File No. 130119 Committee Item No. 5
Board Item No. _____

COMMITTEE/BOARD OF SUPERVISORS

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Completed by: Alisa Miller **Date** March 22, 2013
Completed by: _____ **Date** _____

[Building Code - Mandatory Seismic Retrofit Program - Wood-Frame Buildings; Optional Evaluation Form Fee]

Ordinance amending the Building Code to establish a Mandatory Seismic Retrofit Program for wood-frame buildings of three or more stories or two stories over a basement or underfloor area that has any portion extending above grade, and containing five or more dwelling units where the permit to construct was applied for prior to January 1, 1978, and the building has not been seismically strengthened; establishing a fee for administering the program; adopting environmental findings and findings of local conditions under California Health and Safety Code, Section 17958.7; establishing an operative date; and directing the Clerk of the Board to forward the legislation to specified State agencies.

NOTE: Additions are *single-underline italics Times New Roman*; deletions are *~~strike-through italics Times New Roman~~*. Board amendment additions are double-underlined; Board amendment deletions are ~~strikethrough normal~~.

Be it ordained by the People of the City and County of San Francisco:

Section 1. General Findings.

(a) At a duly noticed public hearing held on February 20, 2013, the Building Inspection Commission considered this ordinance.

(b) The Planning Department has determined that the actions contemplated in this ordinance comply with the California Environmental Quality Act (California Public Resources Code Section 21000 et seq.). Said determination is on file with the Clerk of the Board of Supervisors in File No. 130119 and is incorporated herein by reference.

(c) In Section 19160 of the California Health & Safety Code, the State Legislature declared that because of the generally acknowledged fact that California will experience moderate to severe earthquakes in the foreseeable future, increased efforts to reduce

earthquake hazards should be encouraged and supported. California Health and Safety Code Section 19161 authorizes each city, city and county, or county to assess the earthquake hazard in its jurisdiction and to identify buildings that are potentially hazardous to life in the event of an earthquake. Health and Safety Code Section 19162 authorizes the governing body of any city, city and county, or county to establish by ordinance seismic retrofit standards for these buildings.

(d) Among the potentially hazardous buildings identified in Health and Safety Code Section 19161 are wood-frame, multi-unit residential buildings constructed before January 1, 1978 having soft, weak or open front wall lines (a "soft-story condition"). These conditions generally arise in a building because the first story has perimeter walls that have large openings for garage doors or windows, has few interior partitions, and/or is constructed of materials that have deteriorated over time.

(e) In enacting Health and Safety Code Section 19160 et seq., the State Legislature found that residential buildings with a soft-story condition are particularly vulnerable to severe damage and collapse. Their collapse can ignite fires that threaten trapped occupants and neighboring buildings in the event of an earthquake and could complicate emergency response. In addition, these buildings are an important component of the State's housing stock that are in jeopardy of being lost in the event of a major earthquake. Soft-story residential buildings were responsible for 7,700 of the 16,000 housing units rendered uninhabitable by the Loma Prieta earthquake and over 34,000 of the housing units rendered uninhabitable by the Northridge earthquake. As noted in subsection (j) of Health and Safety Code Section 19160, the Association of Bay Area Governments estimates that soft-story residential buildings will be responsible for 66 percent of the uninhabitable housing following a seismic event on the Hayward fault. In subsections (l) and (n) of Health and Safety Code Section 19160, the Seismic Safety Commission recommended to the State Legislature that

any mandatory mitigation programs adopted significantly reduce unacceptable hazards in buildings by 2020 and the Legislature stated its intent that local jurisdictions be encouraged to address the seismic safety of soft-story residential buildings and to initiate efforts to reduce the seismic risk in these vulnerable buildings.

Section 2. Findings of Local Conditions Under California Health and Safety Code Section 17958.7.

(a) The Applied Technology Council (ATC) is a nonprofit organization that develops and promotes state-of-the-art, user-friendly engineering resources and applications to mitigate the effects of natural and other hazards on the built environment. Beginning in 1998, ATC was contracted to perform a study called the San Francisco Community Action Plan for Seismic Safety (CAPSS), which was initiated by the San Francisco Building Inspection Commission. Under CAPSS, ATC, together with the CAPSS Public Advisory Committee, studied buildings in San Francisco that are vulnerable to collapse or severe damage in an earthquake.

(b) The purpose of the CAPSS study was to develop earthquake safety policy recommendations founded on clear technical bases. "Here Today, Here Tomorrow," ATC's first policy report under CAPSS, was published in February 2009 and focused on the City's wood-frame structures that have five or more residential units, three or more stories, and were built before the adoption of codes regulating earthquake-resistant construction. It was determined that the possible collapse of many of San Francisco's wood-frame, multi-story buildings containing residential units represents one of the most significant earthquake impacts to the City. The final CAPSS report, issued December 31, 2010, also addressed other vulnerable building types that present risks to the people of the City and County of San Francisco.

(c) In 2010, the San Francisco Planning and Urban Research Association (SPUR) published a white paper entitled "The Resilient City – Part I," containing SPUR's recommendations regarding how San Francisco can prepare for and rebound quickly from a major earthquake. As noted in the Preface to "Here Today – Here Tomorrow," there has been significant cooperation and communication between the CAPSS Public Advisory Committee and SPUR's hazard mitigation task force. The CAPSS recommendations were strongly influenced by SPUR's vision of city-wide mitigation actions to be taken to assure San Francisco's speedy recovery after a future earthquake .

(d) At the request of participants in the CAPSS project, in May 2009 the Federal Emergency Management Agency (FEMA) commissioned ATC to prepare guidelines for the seismic retrofit of so-called soft-story wood frame buildings. Technical advisors to the CAPSS project had concluded that existing engineering procedures were not adequate to fully evaluate the complex behavior of these vulnerable buildings, and were not necessarily yielding optimal retrofit designs. Those advisors recommended that new evaluation and design procedures were needed to ensure more reliable, cost-effective engineering practices for evaluation and retrofit and to provide guidance for practical and enforceable retrofit regulations.

(e) In May 2012 FEMA issued a guidelines document entitled FEMA P-807, Seismic Evaluation and Retrofit of Multi-Unit Wood-Frame Buildings with Weak First Stories, which details procedures for the analysis and seismic retrofit of vulnerable wood-frame buildings that are common in Northern and Southern California and the Pacific Northwest. The guidelines are suitable for implementation through model code provisions that ensure uniform application and enforcement. The retrofit requirements contained in this Ordinance allow the use of FEMA P-807 and other approved methodologies. The retrofit provisions of FEMA P-807 focus on projects in which work is limited to the first story and the second floor diaphragm. Such

retrofits can improve performance and reduce risk of collapse but will not necessarily provide a comprehensive building retrofit to a specific performance objective.

(f) In early 2010, then Mayor Newsom convened a Soft-Story Retrofit Task Force with the aim of crafting a mandatory seismic retrofit program for weak-story buildings in San Francisco, including consideration of a phased implementation program and possible financing mechanisms. In 2011, Mayor Lee initiated the Earthquake Safety Implementation Program (ESIP) to implement the recommendations of the CAPSS program, including completing the development of an ordinance for retrofit of weak-story buildings. That work has resulted in the mandatory seismic retrofit program established in this ordinance.

(g) There are approximately 4,300 wood-frame buildings in San Francisco that were built before January 1, 1978, having five or more dwelling units and three or more stories. The CAPSS analysis determined that at least 2,800 of these may have a weak-story condition or similar vulnerability. These vulnerable buildings can be found throughout the City, most notably in the Mission, Western Addition, Richmond, North Beach, and Marina neighborhoods.

(h) California Health and Safety Code Section 19161(a)(2) has set January 1, 1978 as a benchmark date for characterizing wood-frame, multi-unit residential buildings. This January 1, 1978 date supersedes the date of May 21, 1973 found in the San Francisco Building Code that was previously used to distinguish obsolete structural designs from acceptable structures of this building type. Under the California Health and Safety Code, buildings constructed after January 1, 1978 are considered to have been designed to meet a life safety standard in the design-basis earthquake, which has a two percent chance of occurring in any 50-year period. In San Francisco, the design-basis earthquake is similar to a magnitude 7.9 earthquake on a nearby segment of the San Andreas fault.

(i) Buildings located within the City's potential liquefaction zones may not perform as well as buildings outside these mapped areas. These liquefaction zones are identified in the Official Map of the State of California's Seismic Hazard Zones, which was signed by the State Geologist and released on November 17, 2000. Notwithstanding these possible local geological impacts, buildings in these areas will benefit significantly from the seismic retrofit requirements of this ordinance.

(j) The CAPSS study estimates that as they now stand, 43 to 85 percent of the most vulnerable multi-unit, wood-frame buildings would be posted with a red UNSAFE placard ("red-tagged") following a magnitude 7.2 earthquake on a nearby segment of the San Andreas fault, representing 1,200 to 2,400 red-tagged buildings. Red-tagged buildings are uninhabitable and may not be occupied after an earthquake until they are either repaired or replaced. A quarter of the red-tagged buildings, representing 300 to 850 multi-unit buildings, would be expected to collapse. The CAPSS study estimates that with appropriate seismic retrofit the overall rate of collapse in a 7.2 San Andreas fault earthquake drops dramatically.

(k) The CAPSS study found that about 58,000 people live in the subset of 2,800 buildings with the largest perimeter wall openings. These buildings house close to 2,000 businesses that employ an estimated 7,000 people. Without retrofit, the heavy damage that these buildings are likely to sustain and the fires resulting from the earthquake would kill and injure many people and disrupt many neighborhoods for years after an earthquake. This disruption would displace tens of thousands of people from their homes and neighborhoods and thus they could not contribute to bringing communities back to life. Small businesses along neighborhood shopping streets would suffer severe impacts. Many of these buildings contain rent-controlled apartments that might be rebuilt as condominiums rather than apartment buildings or, if rebuilt as apartments, would be exempt from rent control. The

demographics and character of neighborhoods that experience substantial damage could change significantly.

(l) A resilient city is a city that can rebound from a natural disaster and quickly resume normal function. The purpose of this ordinance is to promote the resiliency goals as identified in the Community Safety Element of San Francisco's General Plan, as well as to protect the health, safety, and welfare of San Francisco residents by reducing the possible collapse, major structural damage, loss of housing stock, or risk of fire caused by an earthquake to the most vulnerable wood-frame, residential buildings. This ordinance requires retrofits that will greatly increase the probability of a building being safely occupiable within 24 hours of an expected moderate earthquake, a measure of performance commonly referred to as "shelter-in-place," using criteria that limit retrofit costs. This moderate earthquake has a magnitude of 7.2 on the Peninsula segment of the San Andreas Fault. For most of the City, the shaking associated with this scenario is expected to occur at least once during the useful life of a structure and more than once if the structure is renovated periodically to extend its useful life.

(m) As the CAPSS study showed, the seismic retrofitting of multi-unit, wood-frame buildings as required by this ordinance would dramatically reduce the consequences of earthquakes to San Francisco by substantially reducing the collapse hazard and allowing up to 58,000 San Franciscans to remain in their homes rather than be relocated to temporary or emergency housing. It would retain significant amounts of housing, preserve architectural and cultural attributes, contribute to sustainability through conservation of energy and resources, improve public safety, and shorten the time that the City requires to recover from large earthquakes.

Section 3. The San Francisco Building Code is hereby amended by adding Chapter 34B, to read as follows:

CHAPTER 34B

MANDATORY EARTHQUAKE RETROFIT OF WOOD-FRAME BUILDINGS

Section 3401B. Purpose and Intent. *The purpose of this Chapter is to promote the health, safety, and welfare of San Francisco residents as well as the ability of the City and County of San Francisco to recover from a major earthquake by reducing the possibility of collapse, major structural damage, or risk of fire caused by an earthquake to certain wood-frame buildings.*

In furtherance of this purpose, this Chapter establishes seismic retrofit requirements intended to significantly reduce the collapse risk of residential buildings with critically vulnerable lower stories and to increase the likelihood that these buildings will be structurally safe to occupy shortly after an earthquake. The engineering criteria established by this Chapter generally limit the structural retrofit work to the ground story or to a basement or underfloor area that extends above grade where the most critical vulnerabilities are typically located, thereby improving building performance while limiting retrofit costs and impacts.

Section 3402B. Scope. *This Chapter shall apply to existing buildings, including mixed-occupancy buildings, that are Type V (wood-frame) construction of three or more stories or two stories over a basement or underfloor area that has any portion extending above grade, and containing five or more dwelling units and for which a permit for construction of a new building was applied for before January 1, 1978 or which is determined by the Department to have been originally constructed before January 1, 1978.*

Exceptions:

1. A building that has been seismically strengthened to meet or exceed the standards of Section 1604.11 of this Code or its predecessor provisions within 15 years prior to the operative date of this Chapter is exempt from this Chapter upon the submittal of documentation showing that such work was properly permitted, completed, and maintained as required by this Code, and that the Department has approved such documentation.

2. A building that has completed voluntary seismic strengthening under the provisions of Administrative Bulletin AB-094 is exempt from the requirements of this Chapter.

Section 3403B. Definitions.

In addition to the definitions in Chapter 2 of this Code, the following definitions shall apply for purposes of this Chapter:

DWELLING UNIT. *A dwelling unit shall include any individual residential unit within either an R-1 or an R-2 occupancy building. It shall also include a guestroom, with or without a kitchen, within either a tourist or residential hotel or motel but shall not include a "housekeeping room." A dwelling unit shall include an area that is occupied as a dwelling unit, whether such is approved or unapproved for residential use.*

STORY. *The first story of any building shall be considered a story, whether or not previously exempted from story count under an earlier edition of the San Francisco Building Code.*

Section 3404B. Compliance Requirements.

3404B.1. General. *The owner of each building subject to this Chapter shall comply with the reporting requirements of this section. If the building is not exempt and does not meet the minimum criteria specified in this Chapter, the owner shall cause the building to be retrofitted to conform to such criteria according to the compliance deadlines set forth in Table 34B-A. Notice of the compliance requirements shall be given by the Department pursuant to Section 3405B.4.*

3404B.2. Screening Form. *The owner of a building who has been notified that their building is within the scope of this Chapter as well as all other owners of buildings that may be subject to this Chapter shall engage an architect or engineer to submit to the Department within the time limits set forth in Table 34B-A a properly completed Screening Form.*

Exception: *Buildings exempt based on the exception in Section 3402B, Exception 2 of this Chapter may complete and submit the required Screening Form without engaging an architect or engineer.*

3404B.2.1. Required information. *The Screening Form to be developed by the Department shall be used to determine whether a building is or is not subject to the requirements of this Chapter, and to assign a building to the appropriate Compliance Tier. The Screening Form shall be completed by an architect as defined in Section 5500 of the California Business and Professions Code or by a civil or structural engineer registered pursuant to the provisions of Section 6700 et seq. of the California Business and Professions Code.*

The submitted Screening Form shall include:

1. all information required by the Department to determine compliance requirements, and

2. whether the building is exempt based on Section 3402B, Exception 1 of this Chapter, and

3. a Declaration, based on a review of building information, of:

(a) whether the building is exempt because it is outside the scope of this Chapter based on its date of original permit application or construction, number of dwelling units, or number of stories, or

(b) if not exempt, the appropriate Compliance Tier.

3404B.2.2. Optional Evaluation Form. *The Optional Evaluation Form to be developed by the Department shall be used to determine if an existing building already meets the criteria of Section 3406B.2 of this Chapter. The Optional Evaluation Form shall be completed by an architect as defined in Section 5500 of the California Business and Professions Code or by a civil or structural engineer registered pursuant to the provisions of Section 6700 et seq. of the California Business and Professions Code. The Optional Evaluation Form shall be accompanied by a completed Screening Form and shall include:*

1. dates and scope of any seismic retrofit work, and

2. plans and other information as the Department may require that are sufficient to support the Declaration below, and

3. a Declaration of whether the building satisfies the evaluation criteria given in Section 3406B.2 of this Chapter.

3404B.3. Compliance Tiers. *Each building not exempt from this Chapter shall be assigned to one of the following Compliance Tiers:*

1. Tier I: Buildings that contain a Group A, E, R-2.1, R-3.1 or R-4 occupancy on any story.

2. Tier II: Buildings containing 15 or more dwelling units, except for buildings assigned to Tier I or Tier IV.

3. Tier III: Buildings not falling within the definition of another tier.

4. Tier IV: Buildings that contain a Group B or M occupancy on the first story or in a basement or underfloor area that has any portion extending above grade, and buildings that are in mapped liquefaction zones, except for buildings assigned to Tier I.

3404B.4. Application for a building permit. *For each non-exempt and non-complying building, the owner or the owner's authorized agent shall submit to the Department an application for a building permit accompanied by the necessary permit submittal documents indicating the proposed seismic retrofit. A permit for this seismic retrofit work may include minor ancillary work but shall be separate from any other permits for building alterations or repairs unless such work is triggered by or integral to the seismic retrofit work. No work other than is required under current codes shall be triggered by this seismic retrofit work.*

3404B4.1. Compliance deadlines. *Compliance deadlines for the submission of the Screening Form, Optional Evaluation Form, building permit application, and for completion of seismic retrofit work are given in Table 34B-A. No transfer of title shall alter the time limits for compliance.*

3404B4.2. Certificate of Final Completion and Occupancy. *A Certificate of Final Completion and Occupancy indicating completion of the required seismic retrofit work shall be obtained upon completion of required seismic retrofit work.*

3404B4.3. Damaged Buildings. *Notwithstanding the provisions of the Table 34B-A Compliance Deadlines, if an as-yet unretrofitted building subject to this Chapter suffers damage from an earthquake or subsequent fire caused by the earthquake that renders the building uninhabitable, results in structural damage that triggers retrofit under regulations adopted by the Department of Building Inspection, or results in "disproportionate damage" as defined in this Code, such building shall comply with the requirements of this Chapter and other applicable Sections of this Code within one year of such damage. The Department may grant an extension of this time period for good cause. Compliance with the provisions of this Chapter does not supersede the requirement to comply with Section 3405.3 of this Code when otherwise required by this Code.*

3404B.5. Historic Preservation. *If any portion of the seismic retrofit work will be visible from the exterior of the subject property and the San Francisco Planning Department determines that the building is a historic resource, or if the interior of the building has been given landmark status, the seismic retrofit work shall be conducted in accordance with guidelines developed by the San Francisco Planning Department, taking into account provisions of the California Historical Building Code.*

3405B. Program Implementation and Administration; Fee.

3405B.1. Administrative Bulletin. *The Department shall prepare an Administrative Bulletin detailing the procedural and implementation requirements for this Chapter. Such procedures shall be generally consistent with the requirements set forth in this Chapter. The Administrative Bulletin may require sign-posting and other public information that the Department determines is necessary or appropriate.*

3405B.2. Compliance Deadlines.

TABLE 34B-A

Compliance Deadlines (in years[1]).

Compliance Tier	*Submission of Screening Form and Optional Evaluation Form*	*Submittal of Permit Application with Plans for Seismic Retrofit Work*	*Completion of Work And Issuance of CFC2*
I	*1*	*2*	*4*
II	*1*	*3*	*5*
III	*1*	*4*	*6*
IV	*1*	*5*	*7*

[1]All time periods are in years measured from 90 days after the operative date of this Chapter.

[2]All time limits and extensions of Chapter 1A of this Code are applicable, except that all work is to be completed by December 31, 2020, as recommended in California Health & Safety Code Section 19160(l).

3405B.3. Administrative Fee. *The fee for services provided by the Department under this Chapter shall be the Standard Hourly Rate for Plan Review and Administration set forth in Table 1A-D of this Code. There shall be no fee required for submittal or review of the Screening Form required by Section 3404B.2. A minimum fee corresponding to two hours for plan review and administration is payable upon submittal of a voluntary Optional Evaluation Form. Additional fees may be charged at the Standard Hourly Rate for additional work and will be payable within 30 days of the Department's notice that payment is due.*

3405B.4. Notice.

3405B.4.1. Service of notice on owner. *No later than 90 days after the operative date of this Chapter, the Department shall send a notice in accordance with Section 102A.4.2 of this Code to the owner of each building believed to be within the scope of this Chapter. The notice shall inform the owner of the requirement to comply with the provisions of this Chapter, and shall be accompanied by a Screening Form and an informational letter or brochure. Any person who believes that a building that*

is within the scope of this Chapter has not been so identified by the Department may notify the Department of the address or location of such building. If the Department determines upon review of the building and/or building records that the building may be within the scope of this Chapter, the Department shall provide notice to the owner as provided in this Section.

3405B.4.2. Failure to give or receive notice. *If the owner of a building within the scope of this Chapter has knowledge that they own such a building, then the failure of the Department to issue the notice required by this Section, or the failure of the owner to receive such a notice, shall not relieve the owner of the obligation to comply with the requirements of this Chapter within the time limits set forth in Table 34B-A. For a building not known to the Department to be within the scope of this Chapter and whose owner or owners have no knowledge that the building is within the scope of this Chapter, the time limits set forth in Table 34B-A shall commence upon an owner having actual or constructive notice that the building may be within the scope of this Chapter. In no case, however, shall the final completion date be extended without the approval of the Board of Examiners after hearing an appeal pursuant to Section 3405B.5.*

3405B.4.3. Notice to public on Department's website. *A list of the buildings by street address and by block and lot for which notice has been given under this Section shall be maintained and made public on the Department's website.*

3405B.5. Appeals. *The owner of any building subject to this Chapter may appeal to the Board of Examiners any determination made by the Department with respect to compliance with the technical requirements of this Chapter. Such appeal shall be in accordance with the provisions of Section 105A of this Code. The time limits for compliance established by Table 34B-A shall not be extended during any appeal period unless specifically approved by the Board of Examiners. Any person may appeal a determination of the Director related to this Chapter to the Building Inspection Commission pursuant to Chapter 77 of the San Francisco Administrative Code.*

3405B.6. Enforcement. Whenever any required action has not been completed within the time limits set forth in Table 34B-A, the Department shall abate the violation in accordance with Section 102A of this Code.

3405B.6.1. Posting of notice. An enforcement action shall, in every case, include the Department posting of the building with a standard Department notice stating as follows:

"Earthquake Warning. This building is in violation of the requirements of the San Francisco Building Code regarding earthquake safety."

This notice shall not be removed until the building is in compliance with this Chapter. This notice shall also be recorded against the title of the building. The Building Official shall cause a release of such notice to be filed with the Assessor-Recorder's Office upon conformance with the requirements of this Chapter.

3406B Engineering Criteria for Evaluation and Retrofit.

3406B.1. General. This Chapter requires that evaluation and/or retrofit of buildings within its scope be undertaken using the engineering criteria established in this section.

3406B.2. Engineering Criteria. A proposed seismic evaluation and/or retrofit plan shall demonstrate that the building satisfies one of the following:

1. FEMA P-807, Seismic Evaluation and Retrofit of Multi-Unit Wood-Frame Buildings With Weak First Stories, as detailed in an Administrative Bulletin to be prepared pursuant to 3406B.3 of this ordinance, with the performance objective of 50 percent maximum probability of exceedance of Onset of Strength Loss drift limits with a spectral demand equal to 0.50 SMS, or

2. ASCE 41-13, Seismic Evaluation and Rehabilitation of Existing Buildings, with the performance objective of Structural Life Safety in the BSE-1E earthquake, or

3. ASCE 41-06, Seismic Rehabilitation of Existing Buildings, with the performance objective of Structural Life Safety in the BSE-1 earthquake with earthquake loads multiplied by 75 percent, or

4. for evaluation only, ASCE 31-03, Seismic Evaluation of Existing Buildings, with the performance level of Life Safety, or

5. for retrofit only, 2012 International Existing Building Code (IEBC) Appendix A-4, or

6. any other rational design basis deemed acceptable by the Department that meets or exceeds the intent of this Chapter.

3406B.3. Alternative Retrofit Criteria. *A proposed seismic retrofit plan which fails to meet the criteria of 3406B.2(1) or 3406B.2(5) shall be deemed to comply with this Chapter if, with the approval of the Department, it satisfies the intent of FEMA P-807, Section 6.4.2 with a maximum acceptable Onset of Strength Loss drift limit probability of exceedance of 70 percent.*

Exception: *Alternative retrofit criteria shall not apply to buildings in which the critical stories, basements, or underfloor areas contain other than parking, storage, or utility uses or occupancies.*

3406B.4. Administrative Bulletin for Technical Requirements. *The Department shall develop and publish one or more Administrative Bulletins that detail the technical requirements to be used for the evaluation and retrofitting of buildings required to meet the criteria established in Section 3406B.2.*

3406B.5. Conformance Period. *Any building retrofitted in compliance with this Chapter and properly maintained, shall not, within a period of 15 years after the operative date of this Chapter, be identified as a seismic hazard pursuant to any local building standards adopted after the date of the building seismic retrofit unless the building incurred disproportionate damage, or otherwise has been damaged or altered so that it no longer meets the engineering criteria under which it was retrofitted.*

3406B.6. *Compliance with this Chapter does not supersede the requirements for compliance with Section 3401.B when otherwise under Chapter 34 of this Code. A permit issued solely for compliance with the provisions of this Chapter shall not be considered a "substantial change" or "structural work" as defined in Chapter 34 and compliance with Section 3401.8 will not be requirement by such work.*

Section 4. The City intends to consider the creation of a voluntary special tax financing program to provide financing for the seismic retrofit work required by Chapter 34B. Under this program, the City would issue bonds on behalf of property owners to finance the required seismic retrofit work on participating properties, and each participating property owner would pay special taxes in an amount sufficient to pay its share of the debt service on the bonds. The financing would be voluntary; only those property owners who elect to participate in the program would receive the benefit of the financing and would be obligated to pay special taxes. Such tax financing program does not obligate the City to pay the special taxes.

Section 5. Outreach and Assistance. The Department, with the assistance of other City agencies, intends to implement a comprehensive outreach and assistance program to provide property owners, tenants, design professionals, contractors, and other interested parties with information about the procedures and technical standards necessary to implement the requirements of this Chapter. Information and assistance to be provided would include, but not be limited to, notice of requirements and standards, assistance with preparation of required forms and permit submittal documents, guidance on available finance options, and general assistance in understanding and complying with the requirements of this Chapter.

Section 6. Reporting. The Department shall maintain current information about program implementation, including the number of buildings at each stage of compliance, program administration and budget, and shall annually provide a report to the Mayor and the Board of Supervisors.

Section 7. Undertaking for the General Welfare. In enacting and implementing this ordinance, the City is assuming an undertaking only to promote the general welfare. It is not

assuming, nor is it imposing on its officers and employees, an obligation for breach of which it is liable in money damages to any person who claims that such breach proximately caused injury.

Section 8. Severability. If any section, subsection, sentence, clause, phrase, or word of this ordinance is for any reason held to be invalid or unconstitutional by a decision of any court of competent jurisdiction, such decision shall not affect the validity of the remaining portions of the ordinance. The Board of Supervisors hereby declares that it would have passed this ordinance and each and every section, subsection, sentence, clause, phrase, and word not declared invalid or unconstitutional without regard to whether any other portion of this ordinance would be subsequently declared invalid or unconstitutional.

Section 9. Effective and Operative Date. This ordinance shall become effective 30 days after the date of passage and operative 60 days after the date of passage.

Section 10. This section is uncodified. In enacting this ordinance, the Board intends to amend only those words, phrases, paragraphs, subsections, sections, articles, numbers, punctuation, charts, diagrams, or any other constituent part of the Building Code that are explicitly shown in this legislation as additions, deletions, Board amendment additions, and Board amendment deletions in accordance with the "Note" that appears under the official title of the legislation.

Section 11. Directions to Clerk of the Board. The Clerk of the Board is directed to forward this ordinance to the State Building Standards Commission after final passage, as

required by Health and Safety Code Section 17958.7. The Clerk is further directed to send a copy of the finally-passed ordinance to the California Department of Housing and Community Development for informational purposes, as required by Health and Safety Code Section 19165.

APPROVED AS TO FORM:
DENNIS J. HERRERA, City Attorney

By: _____
JUDITH A. BOYAJIAN
Deputy City Attorney

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FILE NO. 130119

REVISED LEGISLATIVE DIGEST

(3/12/2013, Substituted in Board)

[Building Code - Mandatory Seismic Retrofit Program - Wood-Frame Buildings; Optional Evaluation Form Fee]

Ordinance amending the Building Code to establish a Mandatory Seismic Retrofit Program for wood-frame buildings of three or more stories or two stories over a basement or underfloor area that has any portion extending above grade, and containing five or more dwelling units where the permit to construct was applied for prior to January 1, 1978, and the building has not been seismically strengthened; establishing a fee for administering the program; adopting environmental findings and findings of local conditions under California Health and Safety Code, Section 17958.7; establishing an operative date; and directing the Clerk of the Board to forward the legislation to specified State agencies.

Existing Law

Among other things, the San Francisco Building Code regulates the construction and alteration of buildings and structures in the City and County of San Francisco and establishes the minimum structural, seismic, and other standards necessary to safeguard life and property. Minimum requirements are established by the California Building Code, but a local jurisdiction is authorized to modify the requirements if they are reasonably necessary because of local conditions.

Amendments to Current Law

The proposed legislation adds a new chapter to the San Francisco Building Code that would require mandatory seismic retrofitting of existing wood-frame buildings, including mixed-occupancy buildings that are three or more stories and contain five or more dwelling units for which a construction permit was applied for before January 1, 1978. An exception is made for a building that has been seismically strengthened within fifteen years prior to the legislation's operative date, which is 60 days from the date of passage. An administrative fee is imposed to cover services provided by the Building Department in implementing and enforcing the seismic retrofitting program.

The retrofit requirements allow the use of guidelines issued by the Federal Emergency Management Agency (FEMA) and other approved methodologies. The owner of a building subject to the mandatory retrofit program must engage an architect or engineer to prepare and submit to the Department of Building Inspection a Screening Form and optional Evaluation Form within one year from the operative date of the legislation. Buildings subject to the seismic retrofitting program are organized into four Compliance Tiers and all retrofitting work under the program must be completed within seven years from the legislation's operative date.

Background Information

California Health and Safety Code Sections 19161 and 19162 authorize local jurisdictions to identify buildings that are potentially hazardous to life in the event of an earthquake and to establish by ordinance retrofit standards for these buildings. Among the potentially hazardous buildings identified by the State Legislature are wood-frame, multi-unit residential buildings constructed before January 1, 1978 having soft, weak or open front wall lines (a "soft-story condition"). These conditions generally arise in a building because the first story has perimeter walls that have large openings for garage doors or windows, has few interior partitions, and/or is constructed of materials that have deteriorated over time. The State Legislature expressly found that residential buildings with a soft-story condition are particularly vulnerable to severe damage and collapse and that these buildings are an important component of the State's housing stock in jeopardy of being lost in the event of an earthquake.

In a study commissioned by San Francisco's Building Inspection Commission, Applied Technology Council (ATC) and a Public Advisory Committee looked at buildings in San Francisco that are vulnerable to collapse or severe damage in an earthquake and developed earthquake policy recommendations. The first policy report was published in February 2009 and focused on the City's wood-frame structures that have five or more residential units, three or more stories, and were built before the adoption of codes regulating earthquake-resistant construction. The study determined that the possible collapse of many of these buildings represents one of the most significant earthquake impacts to San Francisco. The final ATC report issued on December 31, 2010 addressed other vulnerable building types.

In 2010, the San Francisco Planning and Urban Research Association (SPUR) published a white paper containing recommendations for how San Francisco can prepare for and rebound quickly from a major earthquake. The recommendations contained in the ATC study were strongly influenced by SPUR's vision of city-wide mitigation actions to be taken to assure San Francisco's speedy recovery after a future earthquake.

In early 2010, then Mayor Newsom convened a Soft-Story Retrofit Task Force with the aim of crafting a mandatory seismic retrofit program for weak-story buildings in San Francisco, including consideration of a phased implementation program and possible financing mechanisms. In 2011, Mayor Lee initiated the Earthquake Safety Implementation Program to implement recommendations and develop an ordinance for the retrofit of weak-story buildings. That work resulted in the mandatory seismic retrofit program established in this legislation.

BOARD of SUPERVISORS

City Hall
Dr. Carlton B. Goodlett Place, Room 244
San Francisco 94102-4689
Tel. No. 554-5184
Fax No. 554-5163
TDD/TTY No. 554-5227

MEMORANDUM

TO: John Rahaim, Director, Planning Department

FROM: Alisa Miller, Clerk, Land Use and Economic Development Committee
Board of Supervisors

DATE: February 6, 2013

SUBJECT: LEGISLATION INTRODUCED

The Board of Supervisors' Land Use and Economic Development Committee has received the following proposed ordinance, introduced by Mayor Lee on February 5, 2013:

File No. 130119

Ordinance amending the Building Code, to establish a Mandatory Seismic Retrofit Program for wood-frame buildings of three or more stories and containing five or more dwelling units where the permit to construct was applied for prior to January 1, 1978, and the building has not been seismically strengthened; establishing a fee for administering the program; adopting environmental findings, and findings of local conditions under California Health and Safety Code, Section 17958.7; establishing an operative date; and directing the Clerk of the Board to forward the legislation to specified State agencies.

This matter is being forwarded to your department for informational purposes. If you have any comments or reports to be included with the file, please forward them to me at the Board of Supervisors, City Hall, Room 244, 1 Dr. Carlton B. Goodlett Place, San Francisco, CA 94102.

c: Scott Sanchez, Zoning Administrator
Bill Wycko, Environmental Review Officer
AnMarie Rodgers, Legislative Affairs Manager
Joy Navarrete, Senior Environmental Planner
Monica Pereira, Environmental Planner

Non-physical exemption
CEQA Section 15060 (c)(2).
2/25/13

BUILDING INSPECTION COMMISSION (BIC)

Department of Building Inspection **Voice (415) 558-6164 - Fax (415) 558-6509**
1660 Mission Street, San Francisco, California 94103-2414

February 21, 2013

Edwin M. Lee
Mayor

COMMISSION

Angus McCarthy
President

Warren Mar
Vice-President

Kevin Clinch
Frank Lee
Dr. James McCray, Jr.
Myrna Melgar
Debra Walker

Sonya Harris
Secretary

Tom Hui
Acting Director

Ms. Angela Calvillo
Clerk of the Board
Board of Supervisors, City Hall
1 Dr. Carlton B. Goodlett Place, Room 244
San Francisco, CA 94102-4694

RE: Proposed Ordinance (File No. 130119) amending the Building Code to establish a Mandatory Seismic Retrofit Program for wood-frame buildings of three or more stories and containing five or more dwelling units where the permit to construct was applied for prior to January 1, 1978, and the building has not been seismically strengthened; establishing a fee for administering the program; adopting environmental findings, and findings of local conditions under California Health and Safety Code, Section 17958.7; establishing an operative date; and directing the Clerk of the Board to forward the legislation to specified State agencies.

Dear Ms. Calvillo:

On February 20, 2013 the Building Inspection Commission held a public hearing on the proposed amendment to the San Francisco Building Code referenced above. The Commissioners voted unanimously to support this proposed amendment.

The Commissioners voted as follows:

President McCarthy	Yes	Vice-President Mar	Yes
Commissioner Clinch	Yes	Commissioner Lee	Yes
Commissioner Melgar	Yes	Commissioner Walker	Yes

Should you have any questions, please do not hesitate to call me at 558-6164.

Sincerely,

Sonya Harris

Sonya Harris
Commission Secretary

cc: Tom Hui, S.E., Acting Director
Mayor Edwin M. Lee
Supervisor David Chiu
Supervisor Scott Wiener
Supervisor Norman Yee
Supervisor Mark Farrell
Supervisor London Breed
Supervisor Eric Mar

File 130119

CITY AND COUNTY OF SAN FRANCISCO
OFFICE OF THE CONTROLLER

Ben Rosenfield
Controller

Monique Zmuda
Deputy Controller

March 15, 2013

The Honorable Board of Supervisors
City and County of San Francisco
Room 244, City Hall

Angela Calvillo
Clerk of the Board of Supervisors
Room 244, City Hall

RECEIVED
BOARD OF SUPERVISORS
SAN FRANCISCO
2013 MAR 15 PM 2:56

Re: Office of Economic Analysis Impact Report for File Number 130119

Dear Madam Clerk and Members of the Board:

The Office of Economic Analysis is pleased to present you with its economic impact report on file numbers 130119, "Mandatory Seismic Retrofit for Wood-Frame Buildings." If you have any questions about this report, please contact me at (415) 554-5268.

Best Regards,

Ted Egan
Chief Economist

cc Alisa Miller, Committee Clerk, Land Use and Economic Development Committee

Miller, Alisa

From: Toy, Debbie
Sent: Friday, March 15, 2013 3:23 PM
To: Calvillo, Angela; BOS-Supervisors; BOS-Legislative Aides; Kawa, Steve; Howard, Kate; Falvey, Christine; Elliott, Jason; Campbell, Severin; Newman, Debra; Rose, Harvey; sfdocs@sfpl.info; gmetcalf@spur.org; Matz, Jennifer; Licavoli, Madeleine; BOS Legislation; CON-EVERYONE
Subject: Controller's Office, Economic Analysis Division: Mandatory Seismic Retrofit for Wood-Frame Buildings: Economic Impact Report

The Controller's Office has issued an economic impact report on the proposed legislation to mandate seismic retrofitting for wood-frame buildings in San Francisco. The report may be downloaded here:

http://co.sfgov.org/webreports/details.aspx?id=1546

Main Conclusions:

Approximately 44,000 San Francisco housing units are in "soft-story" wooden-frame buildings that are particularly susceptible to damage in an earthquake. Seismic retrofitting can significantly reduce the damage these buildings may experience in an earthquake. Retrofitting can reduce post-earthquake costs, reduce building collapse rates, and increase the ability of residents to shelter in place after a disaster.

Relatively few of these buildings have been retrofitted. The proposed legislation would require owners of most wood-frame buildings in San Francisco to retrofit them over a 4-7 year period. The OEA finds that the proposed requirement would have essentially no net economic impact, positive or negative. Under the City's Rent Stabilization Ordinance, 100% of the cost of mandatory capital improvements may be passed through to tenants, at a likely cost of $38-$79 / month. While retrofitting clearly makes buildings safer for tenants, it is not known if the level of additional level of safety is worth the additional cost to tenants.

Other stakeholders, including property owners and the City itself, will also benefit from mandatory retrofitting. After further study of the impact on life safety, the City may wish to consider a different allocation of costs among tenants, property owners, and the City.

CCSF Controller's Office
1 Dr. Carlton B. Goodlett Place
City Hall, Room 316
San Francisco, CA 94102
Tel: 415-554-7500
Fax: 415-554-7466
Email: controller@sfgov.org

City and County of San Francisco

Mandatory Seismic Retrofit for Wood-Frame Buildings: Economic Impact Report

Controller's Office of Economic Analysis

Item #130019

March 15, 2013

Introduction

- Approximately 44,000 San Francisco housing units are in "soft-story" wooden-frame buildings that are particularly susceptible to damage in an earthquake.
- Seismic retrofitting can significantly reduce the damage these buildings may experience in an earthquake. Retrofitting can reduce post-earthquake costs, reduce building collapse rates, and increase the ability of residents to shelter in place after a disaster.
- Relatively few owners of these vulnerable buildings have retrofitted them. In 2010, the City introduced an incentive program to encourage the voluntary retrofitting, but use of the program has been very limited.
- The proposed legislation would require owners of wood-frame buildings with five or more units, that were built before 1978, to retrofit their buildings within 4-7 years to standards set by the Department of Building Inspection.
- Under the City's Rent Stabilization Ordinance, 100% of the costs of mandatory capital improvements to residential properties may be passed through to tenants, up to a 10% increase in annual rent.

Economic Impact Factors

- The policy will require higher near-term spending on retrofitting, which will cause reconstruction spending to be reduced after an earthquake in the future.
- As the higher near-term spending will be passed on to tenants in the form of higher rents, consumer spending in the city will be reduced by a like amount. The reduction in future repair costs will, in turn, increase property owner income by a like amount in the future.
- The costs and benefits to tenants and property owners may marginally affect market rents and property values, but these factors are not considered in this report.
- Other benefits that were discussed, but not quantified, in reports produced by the Community Action Plan for Seismic Safety (CAPSS) committee. These benefits were not considered in this report, and include:
  - Improved life safety.
  - Reduced emergency response costs, related to shelter, medical care, and fire risk.
  - Preservation of historic resources and neighborhood resiliency.
- REMI model analysis of the increased construction spending, reduced consumer spending, and future impacts yields essentially zero net impact on jobs or the local economy.

Costs and Benefits Related to Building Repair

- The CAPSS considered three retrofitting schemes. The table below summarizes their range of costs and benefits. Given current earthquake probabilities, the net present value of the benefits is within the cost range, given reasonable discount rates.
- 18% of the buildings are in potential liquefaction zones. Liquefaction may reduce the benefits of seismic retrofitting for these properties, but the costs of retrofitting are identical for them.

Scheme	Cost per Housing Unit	Repair Savings Benefit per Unit	Net Present Value of Retrofitting*
Scheme 1: Moment frames and limited shear walls	$9,000- $13,000	$24,000	$7,100 - $10,800
Scheme 2: Moment frames and greater shear walls	$15,000 - $20,000	$41,000	$12,100- $18,500
Scheme 3: Cantilevered Columns and greater shear walls	$13,000 - $19,000	$52,000	$15,400 - $23,400

Assuming a 2% annual earthquake probability based on USGS 30-year probabilities of a major earthquake on the San Andreas or Hayward faults, with discount rates ranging from 4 – 7%.

Pass-through Impact on Rents

- The table below indicates how the costs of retrofitting could be passed on to tenants in the form of higher rents.
- All apartment buildings covered by this legislation are also subject to the City's Rent Stabilization Ordinance, as they would be built before 1979.
- In practice, property owners may not be able to pass costs along to tenants already paying close to market rent. However, longer-term tenants paying below-market rents could face the full pass-through.

Scheme	Amortized Monthly Cost at 100% Pass-through	Median Rent	% Monthly Rent Increase due to Legislation
Scheme 1: Moment frames and limited shear walls	$38 - $55	$1,407	2.7–3.8%
Scheme 2: Moment frames and greater shear walls	$63 - $83	$1,407	4.4–5.9%
Scheme 3: Cantilevered Columns and greater shear walls	$55 - $79	$1,407	3.8-5.6%

Conclusions

- Simply from the perspective of preventing future repair expense, the mandatory retrofit appears to be a financially advisable policy, with no overall negative economic impact. Given the limited success of the voluntary program, it may be difficult to design any voluntary program that would be widely used.
- However, the 100% pass-through allowance for mandatory capital improvements does create a potential gap between the costs and benefits for different groups of stakeholders.
- Property owners receive clear benefits, in the form of reduced future repair costs. The CAPSS data suggests these benefits would approach or exceed the costs of retrofitting for many property owners, even without a pass-through.
- Many of the purported benefits – to emergency response costs, and to future neighborhood resiliency – are general city-wide benefits. A case can therefore be the made that the City should contribute to the cost of the retrofitting, but the proposed legislation does not provide for any City funding.
- While tenants clearly benefit from improved life safety in their residences, the CAPSS did not attempt to quantify how much retrofitting improves survivability. It therefore remains unclear if the benefits exceed the costs for tenants.
- The City may wish to further study how residents in affected buildings would benefit before making final decisions about the allocation of costs among tenants, property owners, and the City.

Staff Contacts

Ted Egan, Chief Economist, (415) 554-5268 ted.egan@sfgov.org
Jay Liao, Economist, (415) 554-6159 jay.liao@sfgov.org

City and County of San Francisco
Department of Building Inspection



Edwin M. Lee, Mayor
Tom C. Hui, S.E., Acting Director

February 15, 2013

Building Inspection Commission
1660 Mission Street
San Francisco, CA 94103

RE: Proposed Ordinance File # 130119
Building Code – Mandatory Seismic Retrofit Program for Wood-Frame Buildings

Honorable Members of the Commission:

At the regular meeting of February 13, 2013, the full Code Advisory Committee (CAC) deliberated on a proposed new ordinance (File #130119) amending the San Francisco Building Code to establish a Mandatory Seismic Retrofit Program for wood-frame buildings of three or more stories and containing five or more dwelling units where the permit to construct was applied for prior to January 1, 1978, and the building has not been seismically strengthened; establishing a fee for administering the program; adopting environmental findings, and findings of local conditions under California Health and Safety Code, Section 17958.7; establishing an operative date; and directing the Clerk of the Board to forward the legislation to specified State agencies.

The CAC forwards a unanimous recommendation of support as written to the Building Inspection Commission for their consideration at this time.

Respectfully submitted,

Kirk Means
DBI Technical Services Division
Secretary to the Code Advisory Committee

cc: Tom C. Hui, S.E., Acting Director
Edward Sweeney, Acting Deputy Director
David Leung, Manager
Ned Fennie, Jr., Chair, Code Advisory Committee
William Strawn, Legislative Affairs

Attach: Ord. File #130119

MANDATORY SOFT STORY RETROFIT ORDINANCE

March 18, 2013

Earthquake Safety Implementation Program

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ATC-52-3 Earthquake Safety for Soft-Story Buildings

Section5

ATC-52-3A Earthquake Safety for Soft-Story Buildings Technical Documentation

OFFICE OF THE
CITY ADMINISTRATOR

Edwin M. Lee, Mayor
Naomi M. Kelly, City Administrator

March 11, 2013

Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, Ca. 94102-4689

Dear Ms. Calvillo and Members of the Board of Supervisors,

It is my pleasure to present the enclosed information to the members of the Board of Supervisors in reference to File Number 130119 amending the San Francisco Building Code to introduce a mandatory seismic retrofit program for wood-frame buildings. This program is a critical step forward for San Francisco's safety and resilience.

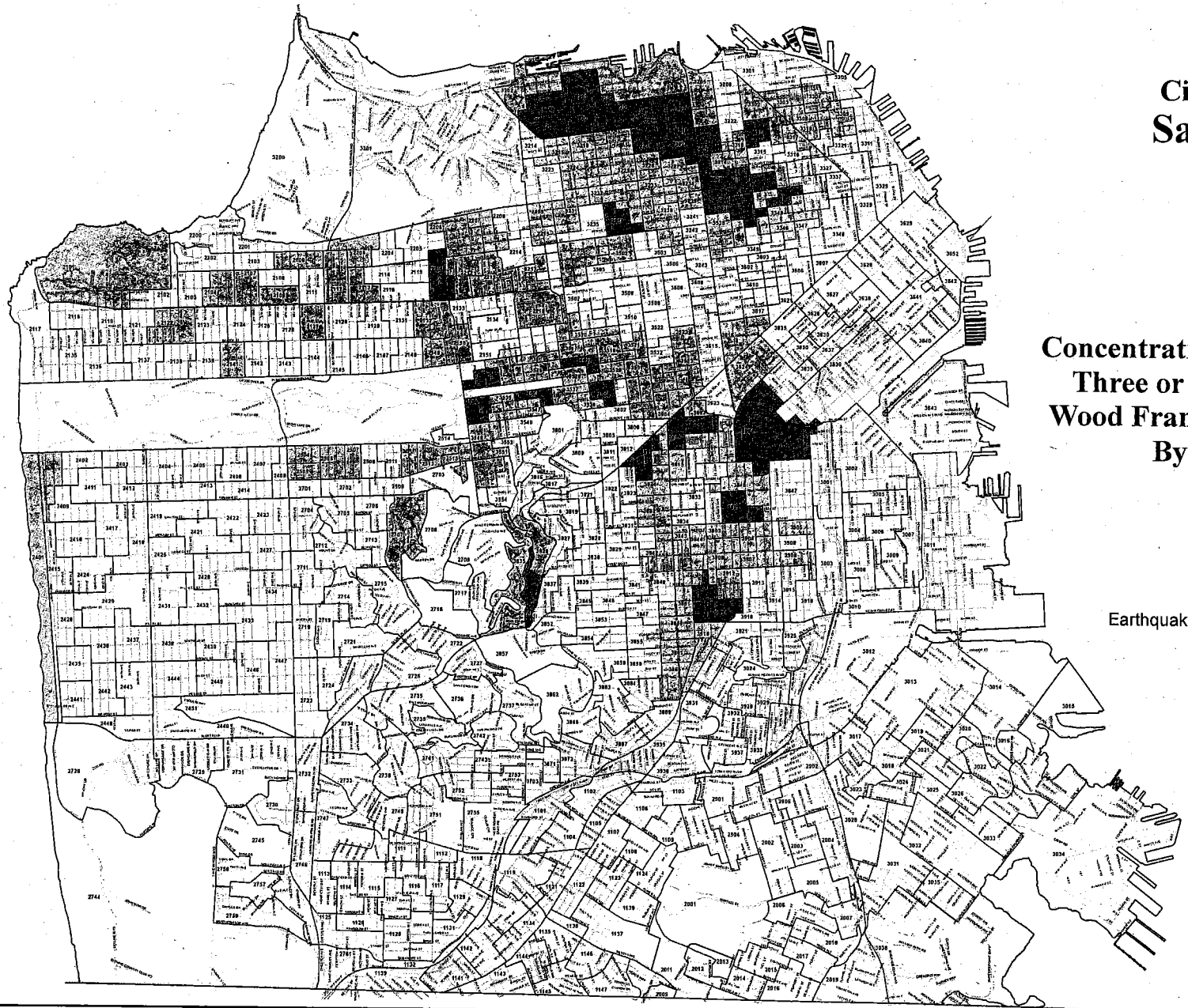
This ordinance requires retrofits of San Francisco's dangerous "soft-story" buildings housing 58,000 San Francisco residents and employing 7000 people working in 2000 small businesses. This program was developed through the Community Action Plan for Seismic Safety (CAPSS) program, a community-based effort to understand the impacts of earthquakes on San Francisco and recommend ways to mitigate those hazards. This effort is also directly in line with the recent amendments made the Community Safety Element of the San Francisco General Plan by the Board of Supervisors in late 2012.

This ordinance requires mandatory retrofits of one of San Francisco's most dangerous building types: wood frame buildings built before 1978 containing five or more residential dwelling units and having three or more stories in height. These retrofits would typically be limited to the ground floor, and the work required will typically allow residents to remain in their homes and business to remain in operation during construction. We anticipate about 4300 buildings will receive a notice requiring a simplified screening. Following this screening process, an estimated 2800 buildings will be placed in one of four compliance tiers requiring the seismic upgrade work be completed from four to seven years from the operative date of this ordinance.

Thank you for your support in ensuring that San Francisco will be prepared for the next major earthquake

Sincerely,

Patrick Otellini
Director of Earthquake Safety
CAPSS Earthquake Safety Implementation Program



Map
of the
City & County of
San Francisco

showing

Concentration of Five or More Unit, Three or More Story, Pre-1978, Wood Frame Residential Buildings By Voting Precinct

January 2013

CAPSS
Earthquake Safety Implementation Program

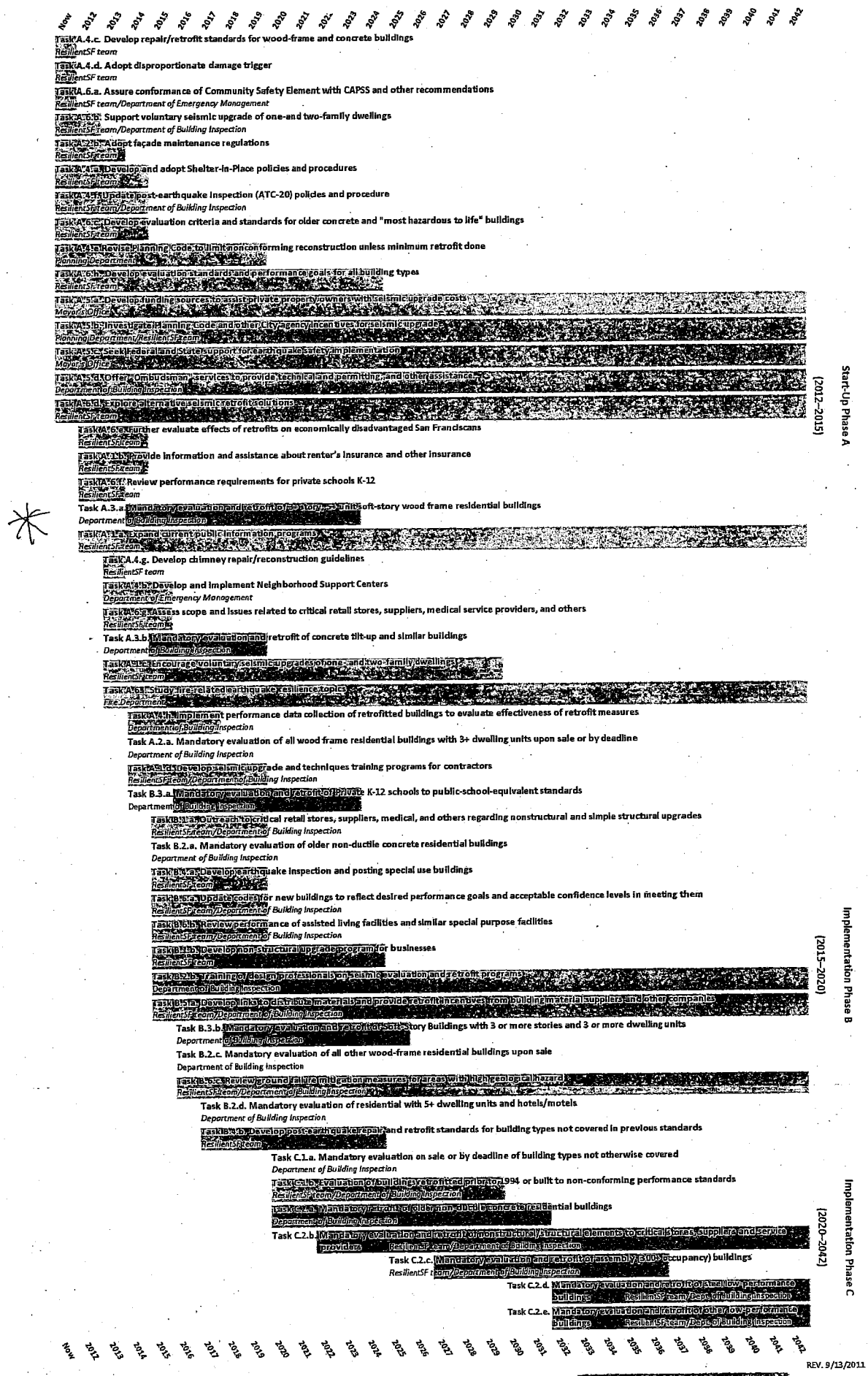
Number of Buildings
- 0
- 1 - 10
- 11 - 25
- 26 - 45

N

0 0.45 0.9 1.8 Miles

Source: CAPSS Analysis, Department of Building Inspection Housing Database, Office of the Assessor Recorde

CAPSS Earthquake Safety Implementation Program – 30 Year Plan



Task A.3.a. Mandatory evaluation and retrofit of 3+ story, 5+ unit soft-story wood frame residential buildings

Schedule

- Begin immediately, complete by 2024, phased in four categories based on geological hazard and use.

General Comments

- Impact study, overall analysis, professional review, and community input have been completed (see CAPSS report ATC 52-3 and 52-3A, Earthquake Safety for Soft-Story Buildings, 2009).
- Detailed implementation program has been developed by Mayor's Soft Story Task Force (see CAPSS report ATC 52-2, A Community Action Plan for Seismic Safety, Chapter 4, Table 3.)
- Legislation based on the recommendation of the Mayor's Soft Story Task Force has been prepared.
- This has been determined to be one of San Francisco's highest resilience priorities. Damage to these larger buildings will cause some of the City's most significant earthquake impacts due to many expected collapses and red-tags.
- The anticipated damage will lead to moderate loss of life, many injuries, and will severely impact the City's supply of affordable housing, small businesses, historic resources, neighborhoods, and many other elements.
- Estimated number of buildings to require retrofit is 2 800 of a total building population of about 4 400.

Costs and Other Impacts

- Retrofit costs expected to range from $10 000 to $20 000 per dwelling unit (see ATC-52A, Appendix 5, Cost Estimates for Retrofits)
- Retrofits limited to the soft-story (typically the ground level).
- Commercial spaces on the soft-story floor typically do not need to be vacated for this work.
- Disability access work in ground floor commercial spaces where retrofit occurs will be required.
- Many building owners will seek financial assistance.

Technical Issues

- Applied Technology Council (ATC), supported by FEMA, is now completing development of a new engineering analysis and retrofit design program, ATC 71-1, for soft-story buildings using San Francisco as a model. This tool is expected to be available for use upon the effective date of this ordinance.
- The new Applied Technology Council program will allow rapid and inexpensive preliminary screening to determine hazardous level of buildings.
- Hardware manufacturers and contractors are now developing reduced-cost solutions.
- New technical concepts allow use of a variety of retrofit solutions, reducing costs.

Necessary Preliminary Work

- Completion of current ATC 71-1 work
- Adjustment of ATC 71-1 to meet San Francisco needs, incorporating building performance goals and target earthquake.

Legislative Action Required

- Adoption of ordinance by the Board Of Supervisors (prepared)
- Preparation and adoption of an Administrative Bulletin by Department of Building Inspection

Lead Agency

- Program development: ResilientSF team
- Program implementation: Department of Building Inspection

Supporting City Agencies

- Planning Department, for approvals
- Mayor's Office of Housing, for financing and other assistance
- Assessor/Recorder's Office, for data and information about incentives
- Rent Stabilization Board

External Involvement

- San Francisco Apartment Owners Association
- Other building owner and management groups
- Contractors and building materials suppliers
- SEAONC (Structural Engineers Association of Northern California)
- ATC (Applied Technology Council), currently developing program technical framework
- FEMA (Federal Emergency Management Agency)
- CAPSS ESIP advisory group

Implementation Cost

- Some minor program development costs and staff costs.
- Most program operating costs will be covered by permit fees and related fees.

MANDATORY SOFT STORY RETROFIT ORDINANCE

FACT SHEET

1. The ordinance will mandate the seismic retrofit of all soft story wood-frame buildings constructed before 1978 of three or more stories containing five or more dwelling units.
2. The projected 2,800 to 3,000 buildings that will be required to retrofit house 58,000 San Franciscans and 2,000 businesses employing 7,000 workers.
3. The mandated retrofits are expected to cost between $60,000 and $130,000 per building, taking between 30 and 90 days to complete and will be limited to the ground floor.
4. Though not contained in the ordinance, the banking community has answered the Mayor's and Board's call for a comprehensive menu of financing options, including low-interest loans for non-profit housing.
5. In almost all cases residents will not be displaced, but their housing will be much safer and more likely to be immediately usable after an earthquake. It is critical that we protect the safety and future of San Francisco's vital rent-controlled housing stock
6. This program does not seek to alter the Rent Ordinance and its existing framework for passing through the costs of Seismic Work and Improvements Required by Law.
7. The expected earthquake is projected to be two to three times larger than the 1989 Loma Prieta earthquake, which impacted this subset of buildings intensely, causing fire, collapse and loss of life.
8. While parking spaces may not be accessible during construction, we have engaged with involved stakeholders to work towards a solution.
9. The ESIP team and City, private, and non-profit partners will be out in the community helping residents and property owners alike to both understand and navigate this process successfully.
10. The ESIP team is working with the Department of Building Inspection, as well as the Building Inspection Commission and other involved City agencies, to create a streamlined permitting process.
11. This ordinance is vital to public safety and the well-being of San Francisco. The ordinance protects both tenants who must be able to remain in their homes after a disaster and building owners who have invested in San Francisco and its prosperous future.

MANDATORY SOFT STORY RETROFIT ORDINANCE

ADDITIONAL FACTS

Passthroughs

The ordinance seeks to protect the safety of tenants and keep them in their homes after a disaster. It does not to change the rent ordinance and its existing framework of protections and passthrough regulations.

The ordinance mandates a comprehensive program of outreach, working directly with tenants, property owners, and design professionals to educate them about the ordinance and ensure that their concerns are addressed as this legislation is implemented.

We believe in the rent ordinance but understand the process can be complex, especially for disadvantaged San Franciscans. The City will provide additional staffing to assist tenants and property owners navigating the rent board process.

This ordinance seeks to address a serious public safety hazard, the known collapse risk of large wood frame soft story residential buildings. While there is some cost to tenants attached to this, the cost of even one life is much, much too high to ignore this problem.

Financing Options

More than a dozen financial institutions, including credit unions and non-profit lenders, answered the Mayor and Board's call for a comprehensive financing package. A menu of financing options has been complied to allow building owners to have many options to finance these retrofits.

The ordinance contains intention language establishing a discontiguous Mello Roos district and public finance program. This would allow property owners to attach the cost of making their building safer onto the property itself while keeping this loan off of their balance sheets.

Cost of Retrofit

Each retrofit is unique to the building and its condition. While the CAPSS study indicated an average cost for these retrofits, at this phase of the program it is important to work with building owners to understand how their building can cost-effectively be made safe for residents.

Leading design professionals have used actual recent soft story retrofits to validate the CAPSS cost estimates.

ADA Compliance

For any privately owned building constructed prior to March 13, 1991 disabled access improvements for the residential portions of the building are exempt per San Francisco Building Code Section 1102A.2.

For any privately owned building with ground-floor commercial spaces, the San Francisco Building Code Section 1134B requires 20% the construction costs be spent on disabled access improvements.

Much of the work associated with this type of seismic retrofit will be limited to small portions of the perimeter at any given time, allowing businesses to remain in operation during construction.

Also hardships can be granted to businesses who are struggling to improve their businesses despite cost constraints, physical constraints and other limitations that prove unnecessarily burdensome.

We are working with the small business community to understand the impact this ordinance will have and how to finance that impact.

The Americans with Disabilities Act seeks to ensure the accessibility of many of our nations buildings to our most vulnerable citizens. This ordinance may trigger accessibility requirements but we believe that is also an important part of making our City's buildings safe and functional.

The List / Buildings Potentially Impacted

The CAPSS study produced a list of approximately 4,500 five or more unit, three or more story, pre-1973 wood frame buildings. From that list nearly 2,800 buildings are believed to contain a soft story.

That list does not indicate a specific building's safety or likely performance in an earthquake.

The ESIP team is currently working with the Department of Building Inspection to develop a comprehensive list of buildings to notice. Those buildings will be required to complete an evaluation form that will either opt them in or out of the program based on an industry professional's assessment.

Miller, Alisa

From: Board of Supervisors
Sent: Tuesday, March 19, 2013 1:32 PM
To: BOS-Supervisors; Miller, Alisa
Subject: File Number 130119 - Mandatory Soft Story Seismic Retrofit Program

---

From: Rose Merryman [mailto:rose.merryman@gmail.com]
Sent: Monday, March 18, 2013 3:40 PM
To: Board of Supervisors
Cc: Rose Merryman; Rose Merryman; Otellini, Patrick
Subject: File Number 130119 - Mandatory Soft Story Seismic Retrofit Program

Dear Angela Calvilla, Clerk of the Board,

I appreciate all the knowledge and thought that has gone into the Soft Story Seismic Retrofit program. I am strongly behind the proposed ordinance for retrofit.

My understanding is that the initiative has two key aspects. The first aspect is that the ordinance puts the force of the law behind getting our buildings retrofit. Without it, retrofitting never makes the cut list for funding priority.My view is that it is always better to "prevent" or mitigate' loss of life and property damage versus suffering the consequences. The risk is simply too large. It's not an "if"; it's a "when". The second key aspect is recognition that funding support needs to be available. Should this become law, my building partners would be interested in funding via property tax.

I am a forty year California resident, that firmly believes that there will be another earthquake in our area and that it may be devastating. The scientific community agrees.

I am a co-owner of a 6-unit residential soft-story wooden structure built in 1924. We are also on a corner and have a bulge on the outside plaster wall. Since I bought in in 2007, I have been trying to get support from the other co-owners to even check to determine if our building is bolted to the foundation and have not been able to get this on any priority list, let alone funded. Only with the force of the law, will we be able to realign priorities to take care of this important safety upgrade.

I am also working with SF SAFE to establish a neighborhood group. Our NorthAshburyNeighbors group has recently expanded to include the former PRO SF neighborhood group that essentially expands the "neighborhood to include all of West NOPA. In walking the neighborhood, it is clear that there are many similar residential and small business buildings in our area. It would never be the same after a significant earthquake.

Finally, I take emergency preparedness very seriously by taking the NERT training. As a NERT co-coordinator for the NOPA neighborhood, I volunteer time and effort in further training, readiness preparation and practice and community outreach.

Your ordinance is a significant step forward in ensuring neighborhood safety and financial stability in the event of a significant earthquake. We need to move beyond the "thinking" that compares what happened in 1989 and what might happened should the epicenter been in a slightly different place or the magniture slightly higher..

I urge you to support this ordinance and help move SF toward earthquake resiliency.

Best regards,
Rose Merryman

Miller, Alisa

From: Board of Supervisors
Sent: Tuesday, March 19, 2013 1:30 PM
To: BOS-Supervisors; Miller, Alisa
Subject: File Number 130119 – Mandatory Soft Story Seismic Retrofit Program
Attachments: image001.jpg; image002.png; image003.png; image006.png; image007.png

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From: John Bozeman [mailto:JohnB@boma.com]
Sent: Monday, March 18, 2013 12:56 PM
Cc: Otellini, Patrick; Ken Cleaveland
Subject: File Number 130119 – Mandatory Soft Story Seismic Retrofit Program

Good Afternoon,

The Building Owners and Managers Association of San Francisco (BOMA) supports the Mandatory Seismic Retrofit Program for Wood Framed Buildings legislation that will be considered at today's Land Use and Economic Development Committee (Item Number 4; File Number 130119). This measure is a step in the right direction for the City and County of San Francisco to improve housing resiliency in the event of a major earthquake in the region.

BOMA is a non-profit trade organization whose members represent commercial real estate in San Francisco and adjacent counties. Our member buildings house a majority of San Francisco's small business tenants and their employees – many of whom live in the City. We are pleased to support this measure, appreciate the sensible phase-in provisions, and urge you to support the current draft of the legislation.

Respectfully,

John M. Bozeman
Manager, Government and Public Affairs
Building Owners and Managers Assoc. of San Francisco
233 Sansome Street, 8th Floor
San Francisco, CA 94104
Cell: (415) 686-9652

Google+

BOMA San Francisco's Blog

Miller, Alisa

From: Board of Supervisors
Sent: Monday, March 18, 2013 12:27 PM
To: BOS-Supervisors; Miller, Alisa
Subject: File 130119: Letter of Support for Soft Story Legislation on Behalf of San Francisco Bay Area NARI

From: Judy Tufo [mailto:judytufo@gmail.com] **On Behalf Of** Judy Tufo
Sent: Friday, March 15, 2013 3:59 PM
To: Board of Supervisors
Subject: Letter of Support for Soft Story Legislation on Behalf of San Francisco Bay Area NARI

NARI®
NATIONAL ASSOCIATION OF THE REMODELING INDUSTRY
SAN FRANCISCO BAY AREA
CHAPTER

March 14, 2013

Angela Calvillo

Clerk, Board of Supervisors

City Hall, Room 244

1 Dr. Carlton B. Goodlett Place

San Francisco, CA 94102

Members of the Board of Supervisors

City Hall

1 Dr. Carlton B. Goodlett Place

San Francisco, CA 94102

Dear Members of the Board of Supervisors:

The San Francisco Bay Area Chapter of the National Association of the Remodeling Industry (NARI) strongly supports the passage of the Mandatory Seismic Retrofit Program for Wood Frame Buildings. Our contractor members have witnessed first hand after the Loma Prieta eqrthquake just how important this type of strengthening is the protection of life and safety but also the housing stock of our city.

In a big seismic event, these type buildings will fail catastrophically, placing the tenant's heath and even their lives in jeopardy. Moreover, the tenant will become a refugee forced to live in a tent in the park, or a FEMA trailer somewhere. He or she will lose all personal possessions and will be unable to continue working and dependent on government for food. If the building is strengthened he/she can shelter in place and continue with normal activities.

For property owners seismic strengthening is an outstanding investment. Every dollar spent preventing damage will save at least ten dollars in damages. NARI members who repaired damage after Loma Prieta can attest to that ratio. Many buildings that did not suffer significant structural damage incurred hundreds of thousands of dollars in repair expenses In "cosmetic" damage, the majority of which, could have been avoided with some simple strengthening strategies.

If these buildings are allowed to fail, they will dump tens of thousands of homeless, hungry citizens onto the care of government. There is little doubt that these numbers of refugees exceed the capacity of our resources to house and feed them. Further, the physical destruction of all these buildings will take a long time to clear and cost enormous sums of money. Thousands of business will be devastated, hampering a restoration of normal economic activity. A giant chunk of the city's rent controlled housing stock will be instantly converted to market rate housing with unimaginable consequences for the diversity of our future population. The loss of the architectural heritage represented by these buildings will transform the culture of this city in ways that cannot be calculated.

To not require this strengthening and to allow these **KNOWN** consequences to come to pass is not just unwise but irresponsible. This ordinance is a critical step forward for San Francisco, making our City safer and more resilient. It is all of our responsibilities to ensure every citizen has equal access to safe housing and that our great City is preserved.

Thank you so much for your consideration. I am looking forward to working together to make San Francisco a safer, stronger, and more resilient City.

Sincerely,

Michael Hamman

Michael Hamman

Chair, Governement Affairs Committee

cc: Honorable Edwin Lee, Mayor

Patrick Otellini, Director of Earthquake Safety

Miller, Alisa

From: Board of Supervisors
Sent: Monday, March 18, 2013 12:27 PM
To: BOS-Supervisors; Miller, Alisa
Subject: File Number 130119 – Mandatory Soft Story Seismic Retrofit Program

---

From: zanturner@aol.com [mailto:zanturner@aol.com]
Sent: Friday, March 15, 2013 8:30 PM
To: Board of Supervisors
Cc: Otellini, Patrick
Subject: File Number 130119 – Mandatory Soft Story Seismic Retrofit Program

March 15, 2013

Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, Ca. 94102-4689

Re: File Number 130119 –
Mandatory Soft Story Seismic Retrofit Program

Dear Supervisors:

As a San Francisco building inspector in 1989, I saw firsthand the damage inflicted by the Loma Prieta earthquake to and by soft-story buildings. Not only did many of these buildings collapse but they also caused damage to neighboring property. I was subsequently disturbed to learn that many people seem to think that such a danger no longer exists, assuming that the local government has corrected this problem in the years since the event. The program for voluntary seismic upgrade of soft-story buildings has resulted in very little improvement of the situation over the last 24 years. It is obvious that regulations requiring such upgrade must be established before the next earthquake. I urge your support of the CAPSS Mandatory Soft Story Seismic Retrofit Program.

Thank for your consideration.

Sincerely,

Zan Turner

Miller, Alisa

From: Board of Supervisors
Sent: Monday, March 18, 2013 10:03 AM
To: Miller, Alisa
Subject: FILE NO. 130119 FW: March 18 Committee Hearing on Mandatory Seismic Retrofit Program for Wood-Frame Buildings

---

From: Frank Noto [mailto:Frank@fnstrategy.com]
Sent: Friday, March 15, 2013 10:38 AM
To: Chiu, David
Cc: Otellini, Patrick; Board of Supervisors; Mar, Eric (BOS); Cohen, Malia; Wiener, Scott; Farrell, Mark; Kim, Jane; Campos, David; Avalos, John; Lee, Mayor; Breed, London; Yee, Norman (BOS); Tang, Katy
Subject: March 18 Committee Hearing on Mandatory Seismic Retrofit Program for Wood-Frame Buildings

President Chiu and Honorable Supervisors,

As a 37-year San Francisco resident, I strongly support the passage of the Mandatory Seismic Retrofit Program for Wood-Frame Buildings. This ordinance is a critical step forward for San Francisco, making our City safer and more resilient.

The legislation could save hundreds or even thousands of lives, and ultimately preserve housing for more than 50,000 citizens. Matters of life and death should not be optional.

It is part of our responsibility to ensure access to safe housing and that our City is preserved in the event of an earthquake.

Thank you for your consideration.

Frank Noto
15 Quintara Street
San Francisco, CA 94116

Office: 415-834-5645
Cell: 415-830-1502

BOS-11, cpage
File 130119

San Francisco Association of REALTORS®

Opening the Door to Your Success

March 14, 2013

RECEIVED
BOARD OF SUPERVISORS
SAN FRANCISCO
2013 MAR 15 PM 4:03

Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102-4689

RE: Soft Story Ordinance/ Mandatory Seismic Retrofit

Dear Ms. Calvillo:

301 Grove Street
San Francisco
CA 94102

P: 415.431.8500
F: 415.553.3968

On March 18, 2013 the Land Use & Economic Committee is scheduled to hear the Soft Story Ordinance/ Mandatory Seismic Retrofit ordinance.

The ordinance proposes to amend the Building Code to establish a comprehensive and needed seismic safety retrofit program for qualifying wood-frame buildings of three or more stories, which have five or more dwelling units that were constructed prior to January 1, 1978.

The proposed ordinance is the result of years of work by the City to properly define the risks and practical solutions for earthquake safety. The ordinance would benefit all San Franciscans by providing needed protection. Earthquake safety must be taken seriously, and the proposed City ordinance is the first in the state to do so.

The San Francisco Association of Realtors supports the proposed legislation, but believes that a modest disclosure component is necessary to ensure that when building subject to the new ordinance are sold, the buyer is notified by the seller if he or she has received a notice from the City that the property is subject to the ordinance. Our proposed revisions are enclosed.

Currently, state law does not impose any disclosure obligation of a seller about seismic bracing, and it does not preclude local governments from doing so. Accordingly, our proposed language expressly codifies a seller's duty to disclose to bona fide purchasers that a notice under this legislation was received.. It is not necessary to obligate the seller in every case. Thus, exemptions are necessary (see paragraph b). e.g. dissolution of marriage. We do not believe that a failure to disclose should affect a right, title or interest or invalidate a sale. There is long standing law for buyers to

seek adequate legal recourse against a seller of property for a failure to disclose. The amendment is comports state laws that obligate a seller to disclose OTHER relevant facts that affect the marketability of the property e.g. if the property is in a seismic safety zone or in a fire hazard zone.

We are greatly appreciative of Patrick Otellini's work.

Sincerely,

Christine Dwiggins
President
San Francisco Association of REALTORS®

cc Patrick Otellini, Director of Earthquake Safety
San Francisco Association of REALTORS® Board of Directors
Janan New, San Francisco Apartment Association
Brook Turner, Coalition for Better Housing

Attachment: Seismic Safety Ordinance Amendment

NORTHERN CALIFORNIA COMMUNITY LOAN FUND
Financial Solutions. Stronger Communities.

File 130119
Land Use Clerk
1 page

RECEIVED
BOARD OF SUPERVISORS
SAN FRANCISCO
2013 MAR 18 PM 3:25
BY

March 14, 2013

Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, Ca. 94102-4689
Email: Board.of.Supervisors@sfgov.org

RE: Support - Building Code - Mandatory Seismic Retrofit Program for Wood-Frame Buildings

To the Land Use Committee of the Board of Supervisors:

I write in **SUPPORT** of the proposed ordinance **Building Code - Mandatory Seismic Retrofit Program for Wood-Frame Buildings.**

The Northern California Community Loan Fund promotes economic justice and alleviates poverty by increasing the financial resilience and sustainability of community-based nonprofits and enterprises. Through flexible financial products and sound advice, we create opportunities to make socially responsible investments that revitalize Northern California communities.

We believe this ordinance is good for the safety of San Francisco's citizens in the event of an earthquake, and we are planning to help work with a number of nonprofit organizations in financing the required retrofits.

Sincerely,

Mary Rogier
President
Northern California Community Loan Fund

cc: Patrick Otellini
Director of Earthquake Safety
City Hall, Room 12A
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102
email: patrick.otellini@sfgov.org

Otellini, Patrick

From:	Frank Noto <Frank@fnstrategy.com>
ent:	Friday, March 15, 2013 10:38 AM
To:	Chiu, David
Cc:	Otellini, Patrick; Board of Supervisors; Mar, Eric (BOS); Cohen, Malia; Wiener, Scott; Farrell, Mark; Kim, Jane; Campos, David; Avalos, John; Lee, Mayor; Breed, London; Yee, Norman (BOS); Tang, Katy
Subject:	March 18 Committee Hearing on Mandatory Seismic Retrofit Program for Wood-Frame Buildings

President Chiu and Honorable Supervisors,

As a 37-year San Francisco resident, I strongly support the passage of the Mandatory Seismic Retrofit Program for Wood-Frame Buildings. This ordinance is a critical step forward for San Francisco, making our City safer and more resilient.

The legislation could save hundreds or even thousands of lives, and ultimately preserve housing for more than 50,000 citizens. Matters of life and death should not be optional.

It is part of our responsibility to ensure access to safe housing and that our City is preserved in the event of an earthquake.

Thank you for your consideration.

Frank Noto
15 Quintara Street
San Francisco, CA 94116

Office: 415-834-5645
Cell: 415-830-1502

NORTHERN CALIFORNIA COMMUNITY LOAN FUND
Financial Solutions. Stronger Communities.

March 14, 2013

Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, Ca. 94102-4689
Email: Board.of.Supervisors@sfgov.org

RE: Support - Building Code - Mandatory Seismic Retrofit Program for Wood-Frame Buildings

To the Land Use Committee of the Board of Supervisors:

I write in **SUPPORT** of the proposed ordinance **Building Code - Mandatory Seismic Retrofit Program for Wood-Frame Buildings.**

The Northern California Community Loan Fund promotes economic justice and alleviates poverty by increasing the financial resilience and sustainability of community-based nonprofits and enterprises. Through flexible financial products and sound advice, we create opportunities to make socially responsible investments that revitalize Northern California communities.

We believe this ordinance is good for the safety of San Francisco's citizens in the event of an earthquake, and we are planning to help work with a number of nonprofit organizations in financing the required retrofits.

Sincerely,

Mary Rogier
President
Northern California Community Loan Fund

cc: Patrick Otellini
Director of Earthquake Safety
City Hall, Room 12A
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102
email: patrick.otellini@sfgov.org

EARTHQUAKE ENGINEERING RESEARCH INSTITUTE

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Executive Director
Jay Berger

March 14, 2013

To: Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Cc: Mayor Edwin Lee
Members of the Board of Supervisors
City Hall
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Cc: Patrick Otellini
City Hall, Room 362
1 Dr. Carlton B. Goodlett Place
San Francisco, 94102

Dear Supervisors,

The Earthquake Engineering Research Institute (EERI) strongly supports the passage of the Mandatory Seismic Retrofit Program for Wood-Frame Buildings. Wood frame soft-story buildings are widely recognized as a significant earthquake risk in San Francisco and many other communities. By mandating that vulnerable wood-frame buildings be seismically retrofitted, San Francisco would reduce its earthquake risk, speed its recovery after future earthquakes, and serve as a model for many communities around the world. Mitigating earthquake risks before an earthquake strikes is both cost-effective and smart long-term planning.

EERI's mission is to reduce earthquake risk by a number of ways, of which one is "advocating comprehensive and realistic measures for reducing the harmful effects of earthquakes." The Mandatory Seismic Retrofit Program for Wood-Frame Buildings is clearly such a measure, and the Institute encourages the City of San Francisco to put this program into action as soon as possible.

The Earthquake Engineering Research Institute is a national, nonprofit, technical society of engineers, geoscientists, architects, planners, public officials, and social scientists based in Oakland, California. EERI's 2800 members include researchers, practicing professionals, educators, government officials, and building code regulators.

Thank you for your consideration.

Sincerely,

J Berger

Jay Berger, Executive Director

499 14TH Street, Suite 220, Oakland, California 94612-1934
☎ (510) 451-0905 FAX (510) 451-5411 eeri@eeri.org http://www.eeri.org
a nonprofit corporation

SF Fire Credit Union

Land Use Committee
San Francisco Board of Supervisors
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102-4689

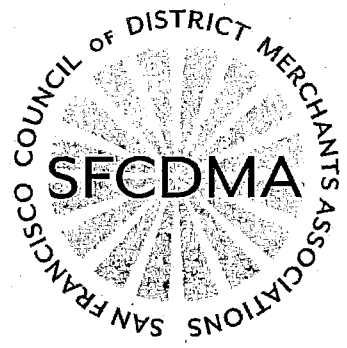
March 14, 2013

Land Use Committee Members,

San Francisco Fire Credit Union supports the proposed Earthquake Safety Implementation Program. We look forward to working with property owners who will need assistance to finance retrofits to comply with the program.

Sincerely,

Glenn Gortney
Vice President
San Francisco Fire Credit Union



SAN FRANCISCO COUNCIL OF DISTRICT MERCHANTS ASSOCIATIONS

March 14, 2013

Mr. Patrick Otellini
Director of Earthquake Safety
Earthquake Safety Implementation Program
Office of the City Administrator
1 Dr. Carlton B. Goodlett Place
City Hall, Room 12A
San Francisco, CA 94102

Dear Mr. Otellini,

I am the president of the SFCDMA (San Francisco Council of District Merchants Associations

I am writing to you regarding the soft story retrofitting legislation.

Although we are concerned about the impact the proposed retrofitting work will have on smal businesses we realize that if nothing is done to retrofit soft stories the result could be that the buildings with soft stories could be damaged, to such a degree that small businesses located in these buildings would not be able to remain open.

We therefore support this legislation.

I am out of town and do not have access to a printer thus this letter does not show my signature however I will submit a letter with my signature on Monday, March 18.

Sincerely,

Henry Karnilowicz
President • SFCDMA

March 14, 2013

To: Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Cc: Mayor Edwin Lee
Members of the Board of Supervisors
City Hall
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Cc: Patrick Otellini
City Hall, Room 362
1 Dr. Carlton B. Goodlett Place
San Francisco, 94102

Dear Supervisors,

Your voting decision for or against the -Mandatory Seismic Retrofit Program- March 18, 2013 may very well be the most important voting decision in your term as district Supervisor. Here's why. You and your colleges will have the power to decide for a significant number of people if they are to survive or die in the coming seismic catastrophe that sooner or later will occur in San Francisco. With the absence of retrofitting a significant number of the 58, 000 residents now living in soft story buildings- including small children- will be buried alive in rubble and likely with pain from injuries slowly die under the most horrible conditions imaginable. Many of them will wonder how this could happen to them and think about their politicians (that's you) and wonder why they didn't act when there was time to prevent or mitigate this tragedy. Parents losing their spouse, child or other family members in this horrific way will start to investigate what their district representative actually did to keep them as safe as possible during their term in City Hall. I urge you, no - I beg you- to carefully think this life and death issue through before you decide how to vote. In 2008 5,000 innocent children where killed in China in the rubble when their schools collapsed due to corrupt and dysfunctional politics. When we read about those hearth breaking events we like to think about ourselves as more advanced and competent. Are we? We will get the answer after March 18, 2013.

Michael Pedersen
400 Hyde street Apt. 201
San Francisco, CA 94109
tel/fax 415-440-3806
email: pedersenm@xemaps.com

√

130119

PACIFIC HEIGHTS RESIDENTS ASSOCIATION

2585 PACIFIC AVENUE
SAN FRANCISCO, CA 94115
TELEPHONE: (415) 922-3572

14 March 2013

RECEIVED
BOARD OF SUPERVISORS
SAN FRANCISCO
2013 MAR 14 AM 11:46

San Francisco Board of Supervisors VIA e-mail
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, Ca. 94102-4689

Subject: File Number 130119 – Mandatory Soft Story Seismic Retrofit Program

Dear Supervisors:

The Pacific Heights Resident's Association (PHRA) represents San Francisco residents within the boundaries of Union to Bush Streets, Presidio to Van Ness Avenues. PHRA was founded over 40 years ago, with the mission of preserving the quality of life and neighborhood characteristics of San Francisco.

Our boundaries include buildings that may be soft story buildings, at risk of collapse in a major earthquake. We are well aware of both the risk to life and the loss of housing should such buildings collapse.

The need for the Mandatory Soft Story Seismic Retrofit Program is clear. This program will save lives and, by preserving existing housing, speed San Francisco's recovery in the event of a major earthquake. The leaders and participants in the CAPSS program have done San Francisco a great service in identifying this need.

PHRA supports the Mandatory Soft Story Seismic Retrofit Program, and urges you to pass the enabling legislation.

Sincerely yours,

Paul H. Wermer
Board Member, Pacific Heights Residents Association

Cc: Angela Calvillo, Clerk of the Board of Supervisors
Patrick Otellini, Director of Earthquake Safety

NARI®
NATIONAL ASSOCIATION OF THE REMODELING INDUSTRY
SAN FRANCISCO BAY AREA
CHAPTER

SERVING ALAMEDA, CONTRA COSTA, SAN FRANCISCO AND SAN MATEO COUNTIES
P.O. BOX 883783, SAN FRANCISCO, CA 94188-3783
Phone: (415) 391-2886 | Fax: (415) 276-8999 | www.sfbanari.org

Michael Hamman, Chair
Government Affairs Committee

March 14, 2013

Angela Calvillo
Clerk, Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Members of the Board of Supervisors
City Hall
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Dear Members of the Board of Supervisors:

The San Francisco Bay Area Chapter of the National Association of the Remodeling Industry (NARI) strongly supports the passage of the Mandatory Seismic Retrofit Program for Wood Frame Buildings. Our contractor members have witnessed first hand after the Loma Prieta eqrthquake just how important this type of strengthening is the protection of life and safety but also the housing stock of our city.

In a big seismic event, these type buildings will fail catastrophically, placing the tenant's heath and even their lives in jeopardy. Moreover, the tenant will become a refugee forced to live in a tent in the park, or a FEMA trailer somewhere. He or she will lose all personal possessions and will be unable to continue working and dependent on government for food. If the building is strengthened he/she can shelter in place and continue with normal activities.

For property owners seismic strengthening is an outstanding investment. Every dollar spent preventing damage will save at least ten dollars in damages. NARI members who repaired damage after Loma Prieta can attest to that ratio. Many buildings that did not suffer significant structural damage incurred hundreds of thousands of dollars in repair expenses In "cosmetic" damage, the majority of which, could have been avoided with some simple strengthening strategies.

NARI®
NATIONAL ASSOCIATION OF THE REMODELING INDUSTRY
SAN FRANCISCO BAY AREA
CHAPTER

SERVING ALAMEDA, CONTRA COSTA, SAN FRANCISCO AND SAN MATEO COUNTIES
P.O. BOX 883783, SAN FRANCISCO, CA 94188-3783
Phone: (415) 391-2886 | Fax: (415) 276-8999 | www.sfbanari.org

If these buildings are allowed to fail, they will dump tens of thousands of homeless, hungry citizens onto the care of government. There is little doubt that these numbers of refugees exceed the capacity of our resources to house and feed them. Further, the physical destruction of all these buildings will take a long time to clear and cost enormous sums of money. Thousands of business will be devastated, hampering a restoration of normal economic activity. A giant chunk of the city's rent controlled housing stock will be instantly converted to market rate housing with unimaginable consequences for the diversity of our future population. The loss of the architectural heritage represented by these buildings will transform the culture of this city in ways that cannot be calculated.

To not require this strengthening and to allow these **KNOWN** consequences to come to pass is not just unwise but irresponsible. This ordinance is a critical step forward for San Francisco, making our City safer and more resilient. It is all of our responsibilities to ensure every citizen has equal access to safe housing and that our great City is preserved.

Thank you so much for your consideration. I am looking forward to working together to make San Francisco a safer, stronger, and more resilient City.

Sincerely,

Michael Hamman

Michael Hamman
Chair, Governement Affairs Committee

cc: Honorable Edwin Lee, Mayor
Patrick Otellini, Director of Earthquake Safety

Joseph P. Grubb
730 2nd Avenue
San Francisco CA
94118-4021

March 14, 2013

Board of Supervisors
Land Use Committee, Room 263
1 Dr. Carlton B. Goodlett Place
City Hall, Room 12A
San Francisco CA 94102

Re: Mandatory Soft Story Retrofit Ordinance

Dear Supervisors Wiener, Kim and Chiu:

This letter is written to urge your support and passage of this vital legislation, long in the making. There is perhaps no finer example of collaborative work in this City than the legislation before you. The years of the CAPSS/Earthquake Safety Implementation Program's efforts towards this goal, the soft story task force convened by Mayor Newsom, and the efforts of city staff are all represented in this comprehensive ordinance that truly reflects the broad coalition of citizens that helped create it.

As former director of the Rent Board during the 1989 earthquake, I saw first hand the devastation of lives, property and the vitality of those neighborhoods most impacted by the event. Soft story buildings were the ones most acutely affected by that earthquake, particularly in the Marina district. This ordinance is meant to reduce that devastation and disruption, save lives and get our City back on its feet more quickly than was possible in 1989.

As chair of Mayor's Newsom's soft story task force, representatives from the tenant, landlord, engineering and other various interest groups worked with one common goal: to bring an ordinance that would result in safer buildings while ensuring the financial feasibility of that effort.

The ordinance before you represents the culmination of those efforts and I would urge each of you to approve it so that San Francisco will be the resilient city it should be after the next earthquake strikes.

Very truly yours,

JOE

Joseph P. Grubb

cc: Patrick Otellini, Director of Earthquake Safety

File 130119

RECEIVED
BOARD OF SUPERVISORS
SAN FRANCISCO
2013 MAR 14 PM 4:09
BY

BOS-11 Alisa-cpage

March 13, 2013

Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Dear Supervisors,

I have been a resident of San Francisco since 1982 and have always put 'seismic safety and awareness' as a high priority. I am NERT trained, and frequently discuss this topic with my neighbors and family. In fact, after attending a neighborhood meeting last year on earthquake safety in the community, I agreed to be on the mayor's task force that was formed to study seismic safety in private schools.

I strongly support the passage of the Mandatory Seismic Retrofit Program for Wood-Frame Buildings. This ordinance is a critical step forward to ensure that San Francisco is safe and resilient and able to handle the eventual large earthquake predicted in the near future. It is all of our responsibilities to ensure that every citizen has access to seismic-safe housing and that our radiant City- by -the -Bay is preserved by strong clear-thinking heads at City Hall and progressive-minded citizens. The more time, effort and resources we expend now, the less tragedy we will experience afterwards.

When this disaster occurs, we want to be remembered for being on guard and ready. Even in an earthquake-prepared city such as Tohoki, Japan, many people died unnecessarily. We all need to think 'outside the box' so that San Francisco avoids such a tragedy!

Please help to bring us together as a community, so this program for wood-frame buildings will pass. In the eyes of the nation and the world, our City stands for so much that is good~~ let's show people that we have what it takes to be proactive, roll up our sleeves, and do the necessary work to keep our City the jewel that she is.

I am grateful that you are working so hard to prepare San Francisco for a destructive earthquake. No one really wants to think about this subject, but hopefully your leadership will provide the necessary collaborative spirit to move people to implement this program.

Sincerely,

Pat McGuire

Pat McGuire
1648 8th Avenue
San Francisco, CA 94122

cc: Mayor Edwin Lee
Patrick Otellini

130119

Miller, Alisa

From: Board of Supervisors
Sent: Wednesday, March 13, 2013 10:12 AM
To: BOS-Supervisors; Miller, Alisa
Subject: File 130119: Soft Story Seismic Retrofit Program

From: Dee Seligman [mailto:deesel91@gmail.com]
Sent: Tuesday, March 12, 2013 6:33 PM
To: Board of Supervisors
Cc: Otellini, Patrick
Subject: Soft Story Seismic Retrofit Program

Dear Bd of Supervisors Land Use Committee Members,
Please support File Number 130119 – Mandatory Soft Story Seismic Retrofit Program. As an active NERT, I understand fully the dangers of soft story construction, and how it will affect all of us as we approach search and rescue after a major earthquake. There is little likelihood that many owners will voluntarily do the retrofitting that is needed, particularly in multi-unit buildings. The City must mandate this retrofitting, and this program is the beginning of that city-wide process that must take place.

Sincerely your,

Dee Seligman
H: 415-668-6308

Seismic
Retrofitters
Consulting
Structural Engineering
Construction
415-822-4200
www.quakeprep.org
LIC# 745230

Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, Ca. 94102-4689
Email: Board.of.Supervisors@sfgov.org

Dear Ms. Angela Calvillo,

March 13, 2013

As third generation San Franciscan and owner of a seismic retrofit company I hope I can offer a unique perspective to the Mandatory Soft Story Retrofit Ordinance (File Number 130119) that the board will be voting on shortly.

Having inspected and retrofitted hundreds of buildings in the San Francisco and greater Bay Area I bear witness to the serious danger posed to thousands of residents and businesses. I also notice a troubling trend with building owners.

Lately, I have encountered an increasing number of San Francisco building owners who desire to retrofit their property but who are hesitant until they understand the requirements (and potential incentives) of the upcoming mandatory retrofit ordinance. In contrast, I have also talked to other owners who, despite the potential danger to their tenants, outright refuse to retrofit their multi-unit apartments or commercial buildings unless the city makes it a requirement.

Of greater concern are the property investors who hire contractors to perform sub-standard retrofits in order to satisfy re-finance or insurance requirements giving false security to tenants and unwitting banks and insurance companies who will be left hanging when the properties become uninhabitable and potentially total financial losses after a major quake.

Based on my experience I hope the San Francisco seismic ordinance will focus on:

- Public Education (how to find qualified contractors and understand consumer rights)
- Qualifying evaluators and standardizing the evaluation process
- Streamlining the construction permit & inspection process
- Defining best practices guidelines for each type of property & location

I would be happy to share my knowledge and recommendations on any or all of these important topics as the ordinance moves forward from definition into implementation. Meanwhile, I hereby voice my support for the San Francisco Mandatory Soft Story Retrofit Ordinance and hope for its approval soon.

Kind regards,

Mark Barbagelata
Seismic Retrofitters
mark@quakeprep.org

File No. 130119 Land Use Clerk BOS-4 page

ASSOCIATION OF BAY AREA GOVERNMENTS

Celebrating 50 Years of Service to the Region

ABAG

RECEIVED
BOARD OF SUPERVISORS
SAN FRANCISCO
2013 MAR 18 PM 3:24
BY

Via email: Board.of.Supervisors@sfgov.org

March 13, 2013

Board of Supervisors
City and County of San Francisco
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102-4689

Subject: Statement of Support San Francisco's Efforts to Retrofit Housing Vulnerable to Damage in Earthquakes

Dear President Chiu and Members of the Board of Supervisors:

The Association of Bay Area Governments (ABAG) is committed to creating a more sustainable, equitable, and prosperous region. To that end, ABAG has long advocated for programs and policies that mitigate the effects of earthquakes and strengthen the resilience of the region so that it can bounce back quickly after an earthquake occurs. One of our greatest concerns is the significant vulnerability of our region's housing stock to earthquakes and the projected lengthy rebuilding process. In 2007 ABAG partnered with San Francisco to assist with the sidewalk survey to identify soft-story buildings in the City.

ABAG strongly supports San Francisco's efforts to retrofit soft-story housing vulnerable to damage in earthquakes. ABAG estimates that 150,000 homes will be severely damaged in a major earthquake and that the majority of those losses will occur in San Francisco. CAPSS has estimated 43 to 85 percent of San Francisco's 2,800 soft-story buildings would be red-tagged after a magnitude 7.2 earthquake on the San Andreas Fault and considered not safe to enter until they are repaired or replaced. Retrofitting these buildings now is much less expensive than repairing them later, will help preserve many architecturally significant buildings for the future, and conserve natural resources and energy.

San Francisco's and the region's ability to quickly recover from an earthquake depend on reducing the number of homes damaged in earthquakes and ensuring that more residents can shelter in place after an earthquake.

Sincerely,

Ezra Rapport
Executive Director

Cc Edwin Lee, Mayor, City and County of San Francisco
Angela Calvillo, Clerk of the Board of Supervisors
Patrick Otellini

March 13, 2013

Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Dear Supervisors,

I have been a resident of San Francisco since 1982 and have always put 'seismic safety and awareness' as a high priority. I am NERT trained, and frequently discuss this topic with my neighbors and family. In fact, after attending a neighborhood meeting last year on earthquake safety in the community, I agreed to be on the mayor's task force that was formed to study seismic safety in private schools.

I strongly support the passage of the Mandatory Seismic Retrofit Program for Wood-Frame Buildings. This ordinance is a critical step forward to ensure that San Francisco is safe and resilient and able to handle the eventual large earthquake predicted in the near future. It is all of our responsibilities to ensure that every citizen has access to seismic-safe housing and that our radiant City- by -the -Bay is preserved by strong clear-thinking heads at City Hall and progressive-minded citizens. The more time, effort and resources we expend now, the less tragedy we will experience afterwards.

When this disaster occurs, we want to be remembered for being on guard and ready. Even in an earthquake-prepared city such as Tohoki, Japan, many people died unnecessarily. We all need to think 'outside the box' so that San Francisco avoids such a tragedy.

Please help to bring us together as a community, so this program for wood-frame buildings will pass. In the eyes of the nation and the world, our City stands for so much that is good~~let's show people that we have what it takes to be proactive, roll up our sleeves, and do the necessary work to keep our City the jewel that she is.

I am grateful that you are working so hard to prepare San Francisco for a destructive earthquake. No one really wants to think about this subject, but hopefully your leadership will provide the necessary collaborative spirit to move people to implement this program.

Sincerely,

Pat McGuire
1648 8th Avenue
San Francisco, CA 94122

cc: Mayor Edwin Lee
Patrick Otellini

130119

L. Thomas Tobin
Tobin & Associates
3451 18th Street
San Francisco, CA 94110
415 380-9141 — lttobin@aol.com

RECEIVED
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2013 MAR 14 AM 11:46
BY

March 13, 2013

The Honorable Members
Land Use Committee
San Francisco Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102-4689
Attn: Angela Calvillo, Clerk of the Board of Supervisors

Dear Members Chiu, Kim and Wiener:

I am writing in support of an ordinance to require evaluation and retrofit, when needed, of all wood frame residential buildings with three or more stories and five or more units.

Weak walls at the ground floor of a few thousand multi unit residential buildings in the City pose a clear threat to public safety, housing availability and affordability, community character, the viability of small businesses and retention of jobs. When earthquakes strike the San Francisco Bay Area the consequences will be severe and long lasting, but avoidable. Fortunately, economically effective and fair measures to strengthen these weaknesses are available. We cannot afford to not fix these obvious deficiencies and protect people and our City.

Your support for this mandatory measure will help San Franciscans prepare for earthquakes, protect the City, tenants and owners, and leave a legacy of leadership.

Sincerely.

L Thomas Tobin

Email: Board.of.Supervisors@sfgov.org

Miller, Alisa

From: Board of Supervisors
Sent: Thursday, March 14, 2013 10:53 AM
To: BOS-Supervisors; Miller, Alisa
Subject: File 130119: Letter of Support for File No. 130119 by EERI Northern California Chapter
Attachments: EERI NC Support File No 130119_FINAL.pdf

From: Heidi Tremayne [mailto:htremayne@berkeley.edu]
Sent: Wednesday, March 13, 2013 4:31 PM
To: Board of Supervisors
Cc: Otellini, Patrick; Hilt, Micah; Schotanus, Marko I.; Laura Dwelley-Samant; Sharyl Rabinovici; MaffeiJ@calquake.com; Mark, Kenneth M; Danielle Hutchings Mieler; Laurence; chuck.real@conservation.ca.gov
Subject: Letter of Support for File No. 130119 by EERI Northern California Chapter

Angela Calvillo, Patrick Otellini, and Micah Hilt,

On behalf of the Earthquake Engineering Research Institute's Northern California Chapter, I am sending our letter of support for the the Ordinance to establish Mandatory Seismic Retrofit Program for Wood-Frame Buildings (File No. 130119). A pdf of the letter is attached.

The EERI Northern California Chapter strongly supports this initiative as we feel that it will help protect the City's inhabitants and make the San Francisco more resilient. The effort builds up on lessons learned from multiple Bay Area policy initiatives to address soft-story housing, utilizes both engineering knowledge and practical experience, and ensures that a higher level of building performance can be achieved for San Francisco residents in a reasonable time frame.

Thank you for sharing our letter with the Board of Supervisors.

Representatives of our Chapter will attend Monday's Board of Supervisors Land Use Committee meeting to support this ordinance.

Regards,

Heidi

--
Heidi Tremayne (Faison)
President
EERI Northern California Chapter
&
Outreach Director
Pacific Earthquake Engineering Research Center
University of California, Berkeley
325 Davis Hall, MC1792
Berkeley, CA 94720
Tel: 510.642.3462
Fax: 510.642.1655
http://peer.berkeley.edu

130119

EARTHQUAKE ENGINEERING RESEARCH INSTITUTE
Northern California Chapter

Board of Directors

Heidi Tremayne, *President*
Janiele Maffei, *Past-President*
Marko Schotanus, *Secretary-Treasurer*
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Chuck Real
Laurence Kornfield
Laura Dwelley-Samant
Ken Mark

March 13, 2013

Via email: Board.of.Supervisors@sfgov.org

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To: Angela Calvillo
Clerk of the Board of Supervisors
1 Dr. Carlton B. Goodlett Place
City Hall, Room 244
San Francisco, 94102-4689

Cc: Mayor Edwin Lee
Members of the Board of Supervisors
City Hall
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102-4689

Cc: Patrick Otellini
City Hall, Room 362
1 Dr. Carlton B. Goodlett Place
San Francisco, 94102-4689

Subject: EERI Northern California Chapter statement of support for Ordinance to establish Mandatory Seismic Retrofit Program for Wood-Frame Buildings (File No. 130119)

Dear Supervisors:

The Northern California Chapter of the Earthquake Engineering Research Institute (EERI-NC) is a regional, member-based organization dedicated to reducing earthquake risk. Our members have long been active in the Community Action Plan for Seismic Safety (CAPSS) study, for example through our help in 2007 to collect data on existing multi-unit residential wood-frame buildings. EERI-NC advocates the development of comprehensive programs for mitigation of the harmful effects of earthquakes. The City and County of San Francisco's (City) Earthquake Safety Implementation Program (ESIP) is such a program, and its measures will help protect the City's inhabitants, and make it a more resilient community.

EERI-NC is strongly in favor of the initiative to create a Mandatory Seismic Retrofit Program for Wood-Frame Buildings in the City of San Francisco. The City's ability to recover quickly from the next major earthquake depends on residents being able to shelter-in-place while their homes are being repaired. However, the vulnerability of the City's housing stock to soft-story earthquake hazards is significant and well-documented (in particular by the CAPSS technical reports). Furthermore, the situation is unlikely to improve without additional public action.

499 14TH STREET, SUITE 220, OAKLAND, CALIFORNIA 94612-1934
PHONE (510) 451-0905 FAX (510) 451-5411 CHAPTERINFO@EERINC.ORG HTTP://WWW.EERINC.ORG

The proposed ordinance builds upon recent momentum and lessons learned from multiple Bay Area policy initiatives to address soft-story housing, including inventories in Santa Clara County, Sebastopol, and Richmond, regional studies by the Association for Bay Area Governments, and a mandatory screening ordinance in Oakland. The mandatory evaluation ordinances in the cities of Berkeley and Alameda, in particular, demonstrate a turning tide of public opinion towards preventative, required seismic upgrading for buildings with documented deficiencies with serious public ramifications. Fremont has had a mandatory retrofit ordinance in place since 2007. Sufficient engineering knowledge and practical experience exists to facilitate mandatory soft-story policymaking. The extensive technical and stakeholder ground work laid by the CAPSS study, combined with insights from the experiences of other cities, can be used to guide the implementation of an administratively efficient and inclusive program in San Francisco.

Most importantly, a mandatory ordinance to retrofit certain weak wood-frame buildings, such as the one introduced by Mayor Lee and Supervisors Chiu, Wiener, Yee, Farrell, Breed and Mar, is a direct way to cost-effectively increase the post-earthquake habitability of the City's housing stock overall. The cost of retrofitting these buildings is much less than the cost of rebuilding them and providing temporary housing for displaced residents during the process. The proposed ordinance allows flexibility in timing for owners to adapt to the new requirements, while still ensuring that a much higher level of building performance is achieved in a reasonable time frame. For all the above reasons, EERI-NC fully supports this ordinance.

Adoption of the ordinance would be an important milestone for implementation of retrofit programs in the City. We look forward to continuing to be a partner of the City and ESIP to achieve our mutual goal of reducing vulnerability to earthquakes.

Sincerely,

Heidi Tremayne

Heidi Tremayne
President

About EERI's Northern California Chapter

The Earthquake Engineering Research Institute's (EERI) Northern California Chapter is a nonprofit technical society dedicated to reducing earthquake risk in Northern California by advancing the science and practice of earthquake engineering, by improving understanding of the impact of earthquakes on the physical, social, economic, political and cultural environment and by advocating comprehensive and realistic measures for reducing the harmful effects of earthquakes. EERI's national office is headquartered in Oakland, California.

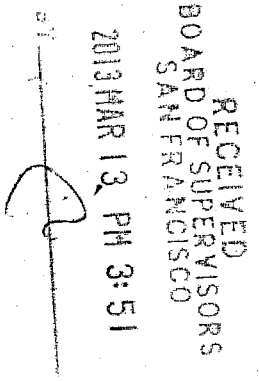
499 14TH STREET, SUITE 220, OAKLAND, CALIFORNIA 94612-1934
PHONE (510) 451-0905 FAX (510) 451-5411 CHAPTERINFO@EERINC.ORG HTTP://EERINC.ORG

130119

San Francisco Apartment Association

March 13, 2013

Re: File Number 130119



Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

To Whom It May Concern,

The San Francisco Apartment Association is in support of Ordinance Number 130119, the Mandatory Soft Story Seismic Retrofit Program, **as it is currently written.** Although mandatory seismic retrofitting could cause a financial burden and hardship on many small residential housing providers, the San Francisco Apartment Association and its members understand that earthquake preparedness and building and resident safety is paramount.

The San Francisco Apartment Association also recognizes that the Mandatory Soft Story Seismic Retrofit Program is a necessary measure to preserve San Francisco's current rent-controlled housing stock and its ability to shelter in place in case of emergency.

Sincerely,

Janan New
Executive Director
San Francisco Apartment Association

Cc: Patrick Otellini
Earthquake Safety Implementation Program

265 Ivy Street, San Francisco, California 94102
Telephone: (415) 255-2288 Fax: (415) 255-1112 www.sfaa.org

1

130119

STANFORD UNIVERSITY

Department of Geophysics
Stanford University
Stanford, CA 94305-2115

Tel.: (650) 723-2782
Fax: (650) 725-7344
e-mail: marylouz@stanford.edu

Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, Ca. 94102-4689

Re File Number 130119 – Mandatory Soft Story Seismic Retrofit Program

Dear Board of Supervisors,

I am writing to lend my strongest support for the Mandatory Soft Story Seismic Retrofit Program. I was involved in the Advisory Committee for the CAPSS (Citizen's Action Plan for Seismic Safety) for 10 years, and had the honor of serving as its co-chair from 2008-2010. The mandatory soft story seismic retrofit ordinance you are considering came directly from CAPSS recommendations which were vetted with technical experts as well as with community members representing building owners, tenants, and neighborhood associations.

The CAPSS program began with detailed (neighborhood scale) assessment of San Francisco's vulnerability to future earthquakes. In the end CAPSS recommended a staged, thirty-year plan to retrofit all seismically vulnerable building types in the city. No other city in the United States has undertaken such a detailed and objective assessment on its seismic vulnerability.

You now have an opportunity to maintain San Francisco's unique national leadership in seismic safety by approving the proposed mandatory soft-story seismic retrofit program. I strong urge you to do this as the first step in a long-term program that will assure that San Francisco is the safest and most resilient community in the United States,

Sincerely,

Mary Lou Zoback

Mary Lou Zoback
Consulting Professor, Dept. of Geophysics
Past Co-Chair, CAPSS Advisory Committee

Cc: Patrick Ottelini, SF Director of Earthquake Safety

130119

March 12, 2012

Supervisors Wiener, Kim, and Chiu
Land Use Committee
SF Board of Supervisors
City and County of San Francisco
City Hall
1 Dr. Carlton Goodlett Place
San Francisco, CA. 94102

RE: March 18th Land Use Committee Meeting; Proposed Soft Story Building Legislation

Dear Supervisors Wiener, Kim, and Chiu:

This is in regard to the subject legislation. I have followed with interest the development of the proposed ordinance. I appreciate all the hard and fine work that has gone into it. The flexibility that is in the "Engineering Criteria for Evaluation and Retrofit" is, I believe, reasonable. I think there should be a little more flexibility in the ordinance.. Suppose a building that is slated for retrofit experiences an earthquake, but the damage that results is significantly less than what had been predicted. Would the owner be allowed to just repair or be required to retrofit to lesser requirements than are in the proposed ordinance or what? In conclusion, it seems that given the gaps of knowledge that still exist regarding the destructiveness of earthquakes that there should be some flexibility in the ordinance to take into account any new information, etc., if only for the fact that it is very costly to retrofit.

The cost of retrofit for most landlords will never be fully recovered given the SF Rent Board regulations. For one thing the passthroughs can only be imposed on those tenants who had lived for a certain period prior to the completion of the retrofit. Also, if rents already were at market rates property owners would be reluctant to use the passthroughs less they lose their tenants. I think retrofits could be very costly for small landlords to comply with as I think we are looking at costs around $100,000. In the year the retrofit is done the cost of it may exceed the total rent from the building. I believe the proposed legislation would put too heavy of a financial burden on landlords and for that reason I must voice opposition to it even though I support the intent.

Sincerely,
Bill Quan

Bill Quan
2526 Van Ness Ave., #10
San Francisco, CA. 94109

SoftStoryLegislation-March2013CommentsToLandUseCommittee

Received Time Mar. 13. 2013 8:38AM No. 0916

130119

Miller, Alisa

From: Board of Supervisors
Sent: Tuesday, March 12, 2013 5:10 PM
To: BOS-Supervisors; Miller, Alisa
Subject: "File Number 130119 – Mandatory Soft Story Seismic Retrofit Program"

-----Original Message-----
From: Diana Arsham [mailto:da@arsham.com]
Sent: Tuesday, March 12, 2013 2:42 PM
To: Board of Supervisors
Subject: "File Number 130119 – Mandatory Soft Story Seismic Retrofit Program"

To Whom it May Concern:

Although I will be unable to attend the meeting on Monday March 18th, I am writing to show support for the Mandatory Soft Story Seismic Retrofit Program.

Thank you for your consideration.

Diana Arsham
PO Box 15608, SF, CA 94115-0608
415-346-4740 (VOICE MAIL)
415-567-3929 (FAX)
DIANA@ARSHAM.COM

Miller, Alisa 130119

From: Board of Supervisors
Sent: Tuesday, March 12, 2013 5:10 PM
To: BOS-Supervisors; Miller, Alisa
Subject: File 130119: the proposed "soft story retrofit" ordinance..."

From: jackbarry99@gmail.com [mailto:jackbarry99@gmail.com] **On Behalf Of** Jack Barry
Sent: Tuesday, March 12, 2013 3:00 PM
To: Board of Supervisors
Subject: the proposed "soft story retrofit" ordinance..."

Dear Board Clerk

Please tell all the Board members that this proposed ordinance must be passsed , ASAP.

SF cannot afford to let such risky conditions go on as they will cause the city to waste big money, in the "damage clean up" after the next big quake.

thanks.

John Barry, Board member, SHARP, the Sunset Hts Assoc. of Responsible People.

(SHARPSF.com)

Real Estate Sales & Management. Full Service. Rates Half the Norm..!
jackbarry99@gmail.com

March 12, 2013

To: Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Cc: Mayor Edwin Lee
Members of the Board of Supervisors
City Hall
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Cc: Patrick Otellini
City Hall, Room 362
1 Dr. Carlton B. Goodlett Place
San Francisco, 94102

Dear Supervisors,

I, John Barry, strongly support the passage of the Mandatory Seismic Retrofit Program for Wood-Frame Buildings. This ordinance is a critical step forward for San Francisco, making our City safer and more resilient. It is all of our responsibilities to ensure every citizen has equal access to safe housing and that our great City is preserved.

I have been on the Board of SHARP, the Sunset Heights Association of Responsible People, for twenty years, and was its President for 10. I am a realtor and was a claim supervisor from 1969 to 1979, for Allstate, et al. I know too well the easily preventable damage that "soft stories" create... Laurence Kornfield has convinced all in attendance at past SHARP meetings...of the great savings in lives and dollars, that will accrue, if this "soft story retrofit" is the law. Some things should not be optional. This retrofit, is like "seatbelt use" is ...in cars.

Thank you so much for your consideration. I am looking forward to working together to make San Francisco a safer, stronger, and more resilient City.

John E.Barry
1627 Tenth Ave, S.F.,ca. 94122 (415 235 7897, cell, to call to confirm that I wrote this.)

SPUR

SPUR URBAN CENTER
654 Mission Street
San Francisco, California
94105
415.781.8726
www.spur.org

SPUR SAN JOSE
38 West Santa Clara Street
San Jose, California
95113
408.510.5688
www.spur.org/sanjose

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Executive Director
Gabriel Metcalf

Urban Center Director
Diane Filippi

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Michael Theriault
Michael Teitz
James Tracy
Will Travis
Jeff Tumlin
Steve Vettel
Cynthia Wilusz-Lovell
Cindy Wu

March 12, 2013

Supervisor Scott Wiener, Chair
Land Use and Economic Development Committee
San Francisco Board of Supervisors
Dr. Carlton B. Goodlett Place
San Francisco, CA 94102-4689

Dear Supervisors,

SPUR strongly supports the Mandatory Seismic Retrofit Program for Wood-Frame Buildings and urges you to move this important piece of legislation forward. The Community Action Plan for Seismic Safety (CAPSS) estimates that at least 2,800 wood-frame buildings constructed in San Francisco prior to 1978 with five or more units and three or more stories have a soft-story condition. Because of large openings for windows or garage openings, the ground floor of the building may be weak ("soft"), leaving it vulnerable to damage or even collapse in an earthquake. The 2,800 multifamily buildings identified by CAPSS are home to roughly 58,000 people and 2,000 businesses employing an estimated 7,000 people.

Currently, the multifamily soft-story buildings identified by CAPSS pose a significant threat to San Francisco's ability to recover from a disaster. CAPSS estimates that 43 to 85 percent of the 2,800 soft-story buildings would be red-tagged after a magnitude 7.2 earthquake on the San Andreas fault. A quarter of the red-tagged buildings would be expected to collapse. However, **if these 2,800 buildings are retrofitted, the 58,000 people who live in these buildings are much more likely to remain in their homes rather than risk injury and/or displacement.**

In our 2009 reports "Defining What San Francisco Needs From Its Seismic Mitigation Policies" and "The Dilemma of Existing Buildings: Private Property, Public Risk" SPUR wrote about the role that the existing housing stock can play in enhancing or undermining the city's resilience. Resilience – the ability to respond to an earthquake emergency and to recover without lasting disruption – can be measured by the speed and completeness with which essential functions, and eventually routine operations, are restored. SPUR has proposed resilience targets for City services, housing, transportation, and other key sectors of the built environment. We identified a goal that 95 percent of San Francisco's housing should be strong enough that people can stay within their homes after a magnitude 7.2 earthquake. **One of our key recommendations to achieve this goal was the development of a mandatory soft-story retrofit program for wood-frame multifamily housing.**

In our 2012 report, "Safe Enough to Stay: What Will It Take For San Franciscans To Live Safely In Their Homes After An Earthquake?" we described how San Francisco has a limited number of emergency-shelter beds, and its capacity to provide interim housing after an earthquake is constrained due to both low vacancy rates and to minimal vacant land. Therefore the city should be taking steps now to ensure that most

San Francisco residents can "shelter-in-place" – i.e. stay in their own homes while they are being repaired – after a major earthquake. Estimates show that only 75 percent of the city's current housing stock will provide adequate shelter for residents after a major earthquake. This means that San Francisco is at risk of losing its most important asset – its people.

The mandatory soft-story retrofit program before you represents an opportunity for San Francisco to dramatically increase the number of units that will be safe enough for residents to stay. We strongly encourage you to support its passage.

Should you have any questions, please do not hesitate to contact me.

Sincerely,

Sarah Karlinsky
Deputy Director

Otellini, Patrick

From: Dee Seligman <deesel91@gmail.com>
Sent: Tuesday, March 12, 2013 6:33 PM
To: Board of Supervisors
Cc: Otellini, Patrick
Subject: Soft Story Seismic Retrofit Program

Dear Bd of Supervisors Land Use Committee Members,
Please support File Number 130119 – Mandatory Soft Story Seismic Retrofit Program. As an active NERT, I understand fully the dangers of soft story construction, and how it will affect all of us as we approach search and rescue after a major earthquake. There is little likelihood that many owners will voluntarily do the retrofitting that is needed, particularly in multi-unit buildings. The City must mandate this retrofitting, and this program is the beginning of that city-wide process that must take place.

Sincerely your,

Dee Seligman
H: 415-668-6308

1

130119

· Laura Dwelley-Samant ·
Supporting Seismic Safety

To: Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

March 12, 2013

Dear Supervisors,

I am writing to express my strong support for the ordinance to mandate retrofit of vulnerable soft-story residential buildings.

Earthquakes are an inevitable part of San Francisco's future and we must plan for them. We know that this type of building, without retrofit, is likely to see heavy damage in future earthquakes. We have seen a preview of this damage before, during the moderate 1989 Loma Prieta earthquake.

After future earthquakes, the proposed ordinance would reduce casualties, preserve housing (notably, rent controlled housing), reduce the number of people that need emergency shelters, and speed the City's economic, social and cultural recovery.

As a San Francisco resident, specialist in earthquake risk issues, and former co-project manager of the San Francisco Community Action Plan for Seismic Safety (CAPSS) project, I have watched a broad group of San Franciscans—building owners, renters, neighborhood representatives, historic building advocates, business leaders, engineers, urban planners, and many others—study these buildings and craft this ordinance from its early stages. This ordinance is the result of years of effort by and discussion among people who truly care about San Francisco's future, and I urge you to support it.

Sincerely,

Laura Dwelley-Samant

Cc: Mayor Edwin Lee
Members of the Board of Supervisors
City Hall
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Cc: Patrick Otellini
City Hall, Room 362
1 Dr. Carlton B. Goodlett Place
San Francisco, 94102

2547 Diamond Street · San Francisco, CA · 94131 · USA
Laura.Samant@gmail.com · office 415-839-9614 · mobile 415-310-3618

March 11, 2013

Mayor Edwin Lee
Members of the Board of Supervisors
City Hall
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Dear Mayor Edwin Lee,

I, Denyse Jones, strongly support the passage of the **Mandatory Seismic Retrofit Program for Wood-Frame Buildings.** This ordinance is a critical step forward for San Francisco, making our City safer and more resilient. It is all of our responsibilities to ensure every citizen has equal access to safe housing and that our great City is preserved.

I have been a volunteer with the SFFD's NERT (Neighborhood Emergency Response Team) for nearly a decade now. I am a Certified Sustainable Building Advisor, who has seen first hand how these City programs are invaluable FREE tools that educate, protect and keep our citizens safe.

Thank you so much for your consideration. I am looking forward to working together to make San Francisco a safer, stronger, and more resilient City.

Denyse Jones, CSBA
March 11, 2013

130119

DAVID BONOWITZ, S.E.
605A BAKER STREET
SAN FRANCISCO, CA 94117
415-771-3227
DBONOWITZ@ATT.NET

March 11, 2013

Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102-4689

BY EMAIL ONLY: Board.of.Supervisors@sfgov.org

SUBJECT Support for Mandatory Seismic Retrofit Program for Wood-Frame Buildings

Supervisors:

I urge you to support the proposed ordinance addressing our collapse-prone wood-frame buildings – buildings just like those that collapsed in the Loma Prieta and Northridge earthquakes.

Our engineering community has been studying these buildings and San Francisco's earthquake risk for years, and we know two things with high confidence:

- The buildings targeted by this ordinance are legitimate collapse risks.
- If you were to rank the seismic vulnerability of every building in the city, these few thousand would be among the very worst.

So if you want to be serious about reducing San Francisco's earthquake risk, approving this ordinance should be your top priority.

Thank you,

DAVID BONOWITZ, S.E.

P.S. For identification purposes only: I am a Fellow Member of the Structural Engineers Association of Northern California, and I chair the Existing Buildings Committee of the National Council of Structural Engineers Associations. For disclosure purposes, please note that I served as a volunteer on the CAPSS Community Advisory Panel and later had a small contracted role on part of the project. I have also provided professional services that helped to develop the proposed ordinance, and I am in the process of being considered for a paid advisory role to the city's Earthquake Safety Implementation Program.

CC: Patrick Otellini, Director of Earthquake Safety, Patrick.Otellini@sfgov.org

1

130119

March 11, 2013

To: Mayor Edwin Lee
Members of the Board of Supervisors
City Hall
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Cc: Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Dear Mayor and Supervisors,

As a native San Franciscan, with a lifetime of experience in real estate ownership and management, I, George Orbelian, strongly support the passage of the Mandatory Seismic Retrofit Program for Wood-Frame Buildings. This ordinance is a critical step forward to making San Francisco a safer and more resilient city. It is all of our responsibilities to ensure every citizen has equal access to safe housing and workspaces and that our great City is preserved.

Preparing for earthquakes by retrofitting our most vulnerable housing and infrastructure will protect and empower the business continuity of the City we love and call home. With this program in place our residential and commercial tenants will continue to have access to homes and businesses ensuring rents to owners. The continuation of rents will make it possible for owners to honor mortgage and tax obligations. This very clear and well thought out policy reflects a consensus of win / win thinking inspired by care for the future of our City. Passage of this program is essential to insuring we avoid foreseeable and preventable earthquake consequences we have witnessed around the world, enabling San Francisco to continue working.

I am proud to live in San Francisco, a city that implements solutions to challenges the rest of the world dreams about solving. I thank you for your efforts and look forward to working with you in furthering our great legacy.

George Orbelian

George Orbelian
Owner, Orbelian Holdings, L.P.
March 11, 2013

130119

March 11, 2013

To: Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Cc: Mayor Edwin Lee
Members of the Board of Supervisors
City Hall
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Cc: Patrick Otellini
City Hall, Room 362
1 Dr. Carlton B. Goodlett Place
San Francisco, 94102

Dear Supervisors,

I, Kenneth Paige, strongly support the passage of the Mandatory Seismic Retrofit Program for Wood-Frame Buildings. This ordinance is a critical step forward for San Francisco, making our City safer and more resilient. It is all of our responsibilities to ensure every citizen has equal access to safe housing and that our great City is preserved.

Because I am on the CAPPS Committee, I feel it is incumbent on me to set a good example of how a good landlord should respond to a potentially dangerous problem without encumbering my tenants with additional obligations or increased rent. I am planning to add a few additional apartment units in the soft story floor and thereby defraying the cost of the seismic upgrade. Although the apartment will be more stable, the future rents not my tenants will pay for the seismic work. With a better constructed building and with more income, First Republic Bank has offered a larger property loan at a much reduced rate. Win, win, win!!

Thank you so much for your consideration. I am looking forward to working together to make San Francisco a safer, stronger, and more resilient City.

Sincerely,

Kenneth J. Paige

130119

JOHN C. PAXTON

155 Montgomery Street, Suite 610
San Francisco, California 94104

Telephone (415) 421-3700
Fax (415) 421-3706

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BOARD OF SUPERVISORS
SAN FRANCISCO
2013 MAR 12 PM 4:13
BY: EHB

March 11, 2013

To the Member of the Land Use Committee,
Supervisors Wiener, Kim and Chiu:

I strongly encourage you to support the Ordinance to mandate the seismic retrofit of vulnerable, soft-story buildings.

I am a residential tenant, and I served as the co-chair of the CAPSS Citizen's Advisory Committee. The diverse participants on the Advisory Committee unanimously concluded that we needed to move forward with programs to retrofit the vulnerable, privately-owned structures in San Francisco. The soft story residential buildings addressed in this ordinance will be the easiest and cheapest to address, and will have the greatest impact on the well being of San Francisco.

The majority of San Francisco's residential buildings were built before WWII, when no design standards existed which recognized seismic forces. The CAPSS report entitled Potential Earthquake Impacts estimated that over 28,000 dwelling units (in wood-frame, soft-story buildings with 5 or more units) would not be "occupyable" following a 7.2 Magnitude earthquake on the San Andreas Fault. To put that in perspective, over the past 20 years, San Francisco has built approximately 31,000 new residential units. In a brief period of time, we could lose nearly as many residential units (mainly rent-controlled, rental units) as have been built since 1993. These losses are largely avoidable if we take the action required by this ordinance.

This ordinance is the first of many steps to make San Francisco safer and more resilient from future earthquakes. Thank you for your support on this important issue.

Very truly yours,

John Paxton

cc: Mr. Patrick Otellini

SAN FRANCISCO
FEDERAL CREDIT UNION

130119

March 8, 2013

San Francisco Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, Ca. 94102-4689

Dear Supervisors,

This letter is to express our support of the Mandatory Soft Story Retrofit Ordinance as well as to express our commitment to working with property owners on financing those needed retrofits. Supporting the financial needs of our San Francisco community is at the heart of our organization.

Sincerely,

Steven Stapp
President & CEO

Cc:

Patrick Otellini
Director of Earthquake Safety
City Hall, Room 12A
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102
email: patrick.otellini@sfgov.org

Angela Calvillo
Clerk of the Board of Supervisors
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, Ca. 94102-4689
Email: Board.of.Supervisors@sfgov.org

SPUR URBAN CENTER
654 Mission Street
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94105

415.781.8726

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SPUR SAN JOSE
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Cindy Wu

February 18, 2013

Angus McCarthy, Chair
Building Inspection Commission
Department of Building Inspection
1660 Mission Street, 6th Floor
San Francisco, CA 94103-2414

Dear Commissioners,

SPUR strongly supports the Mandatory Seismic Retrofit Program for Wood-Frame Buildings and urges you to move this important piece of legislation forward. The Community Action Plan for Seismic Safety (CAPSS) estimates that at least 2,800 wood-frame buildings constructed in San Francisco prior to 1978 with five or more units and three or more stories have a soft-story condition. Because of large openings for windows or garage openings, the ground floor of the building may be weak ("soft"), leaving it vulnerable to damage or even collapse in an earthquake. The 2,800 multifamily buildings identified by CAPSS are home to roughly 58,000 people and 2,000 businesses employing an estimated 7,000 people.

Currently, the multifamily soft-story buildings identified by CAPSS pose a significant threat to San Francisco's ability to recover from a disaster. CAPSS estimates that 43 to 85 percent of the 2,800 soft-story buildings would be red-tagged after a magnitude 7.2 earthquake on the San Andreas fault. A quarter of the red-tagged buildings would be expected to collapse. However, **if these 2,800 buildings are retrofitted, the 58,000 people who live in these buildings are much more likely to remain in their homes rather than risk injury and/or displacement.**

In our 2009 reports "Defining What San Francisco Needs From Its Seismic Mitigation Policies" and "The Dilemma of Existing Buildings: Private Property, Public Risk" SPUR wrote about the role that the existing housing stock can play in enhancing or undermining the city's resilience. Resilience – the ability to respond to an earthquake emergency and to recover without lasting disruption – can be measured by the speed and completeness with which essential functions, and eventually routine operations, are restored. SPUR has proposed resilience targets for City services, housing, transportation, and other key sectors of the built environment. We identified a goal that 95 percent of San Francisco's housing should be strong enough that people can stay within their homes after a magnitude 7.2 earthquake. **One of our key recommendations to achieve this goal was the development of a mandatory soft-story retrofit program for wood-frame multifamily housing.**

In our 2012 report, "Safe Enough to Stay: What Will It Take For San Franciscans To Live Safely In Their Homes After An Earthquake?" we described how San Francisco has a limited number of emergency-shelter beds, and its capacity to provide interim housing after an earthquake is constrained due to both low vacancy rates and to minimal vacant land. Therefore the city should be taking steps now to ensure that most

San Francisco residents can "shelter-in-place" – i.e. stay in their own homes while they are being repaired – after a major earthquake. Estimates show that only 75 percent of the city's current housing stock will provide adequate shelter for residents after a major earthquake. This means that San Francisco is at risk of losing its most important asset – its people.

The mandatory soft-story retrofit program before you represents an opportunity for San Francisco to dramatically increase the number of units that will be safe enough for residents to stay. We strongly encourage you to support its passage.

Should you have any questions, please do not hesitate to contact me.

Sincerely,

Sarah Karlinsky
Deputy Director

130119

STRUCTURAL ENGINEERS ASSOCIATION OF NORTHERN CALIFORNIA

2012-2013

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February 11, 2013

Via email: Board.of.Supervisors@sfgov.org

Angela Calvillo
Clerk of the Board of Supervisors
1 Dr. Carlton B. Goodlett Place
City Hall, Room 244
San Francisco, 94102-4689

Re: SEAONC Statement of Support for Ordinance to establish Mandatory Seismic Retrofit Program for Wood-Frame Buildings (File No. 130119)

Dear Ms. Calvillo:

The Structural Engineers Association of Northern California (SEAONC) enjoys a close working relationship with the City and County of San Francisco and has provided both formal and informal advice on a variety of technical issues related to the field of structural engineering. On September 13, 2011, the City and County of San Francisco published a 30-year workplan as part of the Earthquake Safety Implementation Program (ESIP) which identifies numerous tasks related to improving the overall seismic safety and resilience of the City and County of San Francisco. In support of the ESIP effort, the SEAONC Board set up a formalized process by which both the SEAONC Board and SEAONC members can assist this effort. The main objectives of this process are to engage our members and utilize their technical skills to assist, review, and provide timely and well-coordinated technical feedback to the ESIP.

In this regard, SEAONC has established a working group to participate in ESIP's development of the proposed Soft-Story Wood Frame Retrofit Ordinance which we understand has been introduced to the City and County of San Francisco Board of Supervisors on February 5th. This working group of fifteen Structural Engineers has met numerous times over the last few months to discuss the technical aspects of the proposed ordinance.

As part of these discussions, this working group has developed, and the SEAONC Board endorses, the following seven statements of support for the ESIP and the proposed Soft-Story Wood Frame Retrofit Ordinance:

- SEAONC supports the City and County of San Francisco's ("the City's") efforts to reduce earthquake risks through a comprehensive program such as that envisioned by the Earthquake Safety Implementation Program (ESIP).

- SEAONC supports the City's conclusion that a mandatory ordinance to retrofit certain soft-story buildings can be effective toward its risk-reduction goals, specifically toward a more resilient housing stock better able to provide post-earthquake habitability.

- SEAONC supports both the general objective for the retrofit of these buildings to mitigate the soft story vulnerability, and the use of both existing methodologies and policies (such as those named in AB 094) and new ones (such as FEMA P-807), consistent with the overall risk reduction goal.

- SEAONC finds FEMA P-807 suitable for use in the City's proposed program, subject to SEAONC's concurrence with necessary future modifications as needed for implementation.

- SEAONC will continue to work with the City to develop technical criteria appropriate to the ordinance's purpose and intent. While we expect the retrofit criteria, where applied, will reduce a building's collapse risk and will increase the likelihood that it will be structurally safe to occupy, neither the available engineering tools nor any criteria written into the ordinance or administrative bulletin will explicitly address post-earthquake habitability.

- SEAONC commits to continue working with the City in coordination with ESIP, and commits to working with the Department of Building Inspection and others to develop a mechanism for interpretation and resolution of questions as implementation of the ordinance proceeds.

- SEAONC will continue to support the City's implementation of the ordinance through education and guidance of engineers and other stakeholders.

SEAONC looks forward to continuing to work with the City and County of San Francisco as the language of the ordinance is finalized, and as the Administrative Bulletins used to enforce the

enacted amendments to the San Francisco Building Code are developed. We also look forward to continuing our technical participation in ESIP efforts during the coming years.

Very truly yours,

STRUCTURAL ENGINEERS ASSOCIATION OF NORTHERN CALIFORNIA

Grace S. Kang, SE
President

cc: Mr. Patrick Otellini, Director of Earthquake Safety, City and County of San Francisco

About SEAONC

Founded in 1930, the Structural Engineers Association of Northern California (SEAONC) is committed to the advancement and incorporation of the state-of-the-art in structural engineering standards and practices through applied research, continuing education, and the promotion of professional relations among Civil, Structural, and Geotechnical Engineers.

SEAONC endeavors to enhance the life safety, environmental health, and economic well-being of the public served by Structural Engineers through direct involvement in the development of building codes, through community education and through liaison and consultation with legislative and regulatory agencies that influence the design and construction industry.

The success of SEAONC, in its efforts to serve the public and the profession, stems chiefly from the volunteer commitments of members working on committees, both technical and non-technical, that form the basis of SEAONC operations. The majority of Association members are licensed engineers regularly engaged in the practice of structural engineering. The Association also draws membership from related fields involved in design and construction, including academe (professors and students), contractors, architects, and representatives from industry and government.

575 Market Street, Suite 2125 • San Francisco, California 94105-2870
Phone 415/974-5147 • Fax 415/764-4915 • E-mail: office@seaonc.org • Website: http://www.seaonc.org

130119

Miller, Alisa

From: Board of Supervisors
Sent: Friday, February 08, 2013 5:01 PM
To: Miller, Alisa
Subject: File 130119: NO on Retrofit

From: Mary Robinson [mailto:marycrobinson@yahoo.com]
Sent: Thursday, February 07, 2013 12:00 AM
To: Board of Supervisors
Subject: NO on Retrofit

There is no proof anywhere that demonstrates an older building can be satsifactorily retrofitted without spending hundreds of thousands of dollars on foundation work, etc. I studied this in great detail. It will do nothing unless every window is reinforced requiring a building be taken down to the studs. The unemployed contractors would like this... The East Bay was
required to remove their retrofiting because it caused more problems then it solved. You must be joking or trying to force older owners to sell their rental properties.
This is a complete travesty and unlawful control of property owners. If you vote this in you will be voted out next term. We don't need to spend $100,000 on new shiny metal!

130119

Miller, Alisa

From: Board of Supervisors
Sent: Friday, February 08, 2013 5:00 PM
To: Miller, Alisa
Subject: File 130119: NO on Retrofit

From: Mary Robinson [mailto:marycrobinson@yahoo.com]
Sent: Thursday, February 07, 2013 12:25 AM
To: Board of Supervisors
Subject: Re: NO on Retrofit

Please Forward to All Supervisors

There is no proof anywhere that demonstrates an older building can be successfully retrofitted without spending hundreds of thousands of dollars on foundation work, etc. I studied this in great detail. It will do nothing unless every window is reinforced requiring a building be taken down to the studs. The unemployed contractors would like this... The East Bay was
required to remove their retrofiting because it caused more problems then it solved. You must be joking or trying to force older owners to sell their rental properties.
This is a complete travesty and unlawful control of property owners. If you vote this in you will be voted out next term. We don't need to spend $100,000 on shiny new metal that you can not prove will do anything if the quake moves over one millimeter.

Maybe you should dig under the Marina and remove all of the landfill and fill it with concrete...There was a NOVA documentary that tested a building retrofitted when built and an unretrofitted building under the same earthquake stress - they BOTH fell down equally. This will also displace tenants...

130119

AIA San Francisco

A Chapter of the American Institute of Architects

February 7, 2013

Mayor Ed Lee
Members of the Board of Supervisors
City Hall
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Dear Mayor Ed Lee and Members of the Board of Supervisors:

On behalf of the American Institute of Architects San Francisco chapter, I would like to address seismic risk communications, particularly in respect to the upcoming soft-story ordinance. The ordinance, now under final development, as we understand it, will require a seismic upgrade of wood-frame, soft-story buildings of 3 or more stories and containing 5+ dwelling units. The program is proposed to be over a 7 year period in 4 phases, based upon impacts on occupants and on the City.

AIA San Francisco's Board of Directors would like to express their support of this proposed soft-story ordinance for the following reasons:

- This ordinance will enhance the City of San Francisco's efforts to reduce earthquake risks through a comprehensive program such as that envisioned by the CAPSS/Earthquake Safety Implementation Program.
- It will encourage the City's adoption of a mandatory ordinance to retrofit certain "soft story" buildings to reduce collapse, which will save lives, reduce injuries, and help create a more resilient housing stock that will better provide post-earthquake habitability.
- The ordinance will support the City's objective that certain weak story buildings, as mandated by the ordinance, should be retrofitted to a performance level meeting the City's risk-reduction goal allowing the use of both existing methodologies and codes and new methodologies consistent with the overall risk reduction goal.

By backing the ordinance, AIA San Francisco will continue to support the City's implementations of the ordinance through education and guidance or architects and other stakeholders.

Please utilize these general guidelines as you review the soft-story ordinance and implement legislative actions.

Sincerely yours,

M. O'Driscoll

Margie O'Driscoll
Executive Director

CC: Patrick Otellini

Hallidie Building
130 Sutter Street, Suite 600
San Francisco, CA 94104
Facsimile 415.874.2642
Telephone 415.362.7397
www.aiasf.org

ATC-52-1

Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco

Potential Earthquake Impacts

Prepared for the

DEPARTMENT OF BUILDING INSPECTION (DBI)
CITY AND COUNTY OF SAN FRANCISCO
under the Community Action Plan for Seismic Safety (CAPSS) Project

Prepared by the

APPLIED TECHNOLOGY COUNCIL (ATC)
201 Redwood Shores Parkway, Suite 240
Redwood City, California

PROJECT LEADERSHIP
Vivian L. Day, Chief Building Official, DBI Director
Laurence Kornfield, DBI Project Officer
Christopher Rojahn, ATC Project Principal
L. Thomas Tobin, ATC Co-Project Manager
Laura Samant, ATC Co-Project Manager

PROJECT CONSULTANTS
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Kelly Cobeen
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William Holmes
Tessa Munekiyo
Keith Porter
Tiffany Refuerzo
Sherry Rudnak
Charles Scawthorn
Hope Seligson
Millie Tolleson

PROJECT ENGINEERING PANEL
Roger Borcherdt
Patrick Buscovich*
Richard Eisner
Stephanie King
Jack Moehle
Chris Poland

*ATC Board Representative

2010

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Debra Walker

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Pamela A. Levin, Deputy Director, Administrative Services
William Strawn, Communications Officer
Sylvia Thai, Administrative Support
Hanson Tom, Principal Engineer

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John Paxton, Advisory Committee Co-Chair

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Thomas Anderson
Steve Appiano
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Bruce Bonacker
David Bonowitz
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Sarah Dennis
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Joe Grubb
David Halsing
Craig Hamburg
Michael Hamman
Stephen Harris
Ephraim Hirsch
David Hoska
Danielle Hutchings
Garrett Ingoglia
Jonas Ionin
Carla Johnson
Laurie Johnson
Paul Johnson
Sarah Karlinsky
Jed Lane
Ed Lee
Kent Leung
Reinhard Ludke
Joan MacQuarrie
Mike Mahoney
Dave Massen
David Mar
Jorge Martinez
David McCormick
William Mitchell
Dick Morten
Chris Nance
Janan New
Sherry Niswander
Bob Noelke
Luke O'Brien
Brendan O'Leary
Erevan O'Neill
Shane O'Reilly
George Orbelian
Ken Paige
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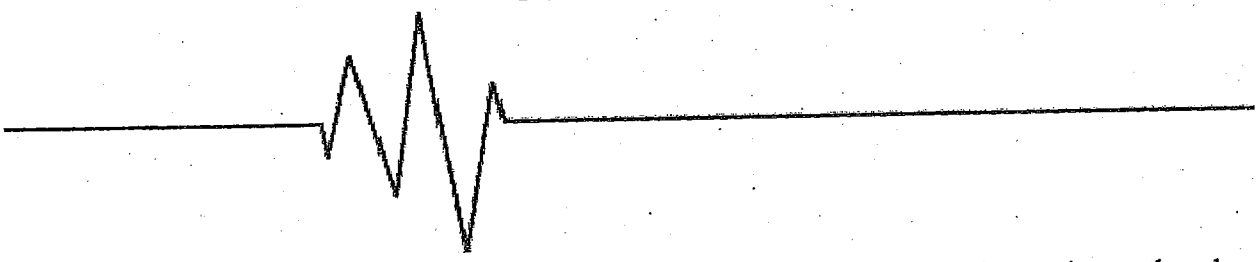
Tom Quan
Evan Reis
Peter Reitz
Badie Rowshandel
Daniel Shapiro
Heidi Sieck
Armand Silva
Skip Soskin
Kate Stillwell
Brian Strong
Fuad Sweiss
Katia Taipale
Michael Theriault
Stephen Tobriner
Dawn Trennert
Brook Turner
Fred Turner
Art VanBeek
Paul VanderMarck
Kay Vasilyeva
Rene Vignos
Kimberly Walsh
Paul Wermer
George Williams

PREFACE



Most San Francisco Bay area residents know that future, devastating earthquakes will occur. Most people have a sense that some buildings (such as brick buildings) in some locations (on top of the Hayward Fault, for example) are bad places to be during the next big earthquake. However, no comprehensive study previously existed to give a clear picture of the risks from the various categories of privately owned buildings, on the people of San Francisco.

The purpose of the Community Action Plan for Seismic Safety (CAPSS) project is to recommend specific, comprehensive mitigation efforts for the privately owned buildings in San Francisco in order to reduce the impacts from future earthquakes. However, to be most effective in targeting our recommendations, we needed to first determine what building types are the most vulnerable.

This vulnerability study and report, *Potential Earthquake Impacts*, is unique. No other city in the nation has undertaken such a comprehensive and detailed analysis of the impacts of a likely natural disaster. The many impacts are explored at the neighborhood level, and include the number and types of damaged buildings, along with the implications the damage will have on affordable housing, vulnerable populations, small businesses, neighborhood's sense of place, and the City's resiliency. This report provides a realistic, state-of-the-art assessment of how the City will likely fare.

But this report is much more than an academic study. It provides a clear picture of the extent of injuries, deaths, and property damage that we can expect if we take no action. It gives policy makers a choice: is it acceptable to have hundreds of people die, thousands injured, and thousands of housing units destroyed – when those impacts are largely preventable?

This is one of several CAPSS reports. Other reports in the CAPSS series, *Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco*, build on the foundation of information contained in this study to formulate recommended programs and an action plan to help San Francisco become a safer, more resilient city if government takes action.

Does San Francisco have the political will to invest in its future, by retrofitting the many known vulnerable building types? We have a clear choice. The effects of future earthquakes, discussed in this report, paint a grim picture if we choose to do nothing.

Mary Lou Zoback
Advisory Committee Co-Chair

John Paxton
Advisory Committee Co-Chair

REPORT SUMMARY

No one knows when the next large earthquake will strike San Francisco, but it is certain that a "big one" will come. When it does, the City's people and economy, its housing and businesses, its culture and character, could suffer heavy consequences. Recovery may take many years and the new, post-earthquake San Francisco that emerges could be different in notable ways.

This report examines four possible earthquakes that could strike the City (Figure A) and estimates the amount of damage and resulting ripple effects that each could cause. It looks only at damage to privately-owned buildings and the impacts that flow from this. Damage to utilities, transportation networks, and public buildings have not been studied but are likely to add substantial consequences to those described here.

The consequences of a large earthquake would be staggering, as summarized below and described in detail in this report. However, it is important to note that San Francisco has already taken great strides to reduce its earthquake risk. If the City continues these efforts in the decades to come (and a major earthquake does not occur in the near future), the damage expected in future earthquakes will decrease. As an example, the City's program requiring retrofit of unreinforced masonry buildings has resulted in a large decrease in the casualties expected to occur in future earthquakes. If the City pursues a program that results in retrofits of large, wood-frame soft-story buildings as recommended in the companion CAPSS report in this series (ATC-52-3 Report, *Earthquake Safety for Soft-Story Buildings*), the number of housing units that cannot be occupied or need to be demolished after an earthquake would be reduced. This report focuses on identifying the consequences of large earthquakes on the City the way it is today. Another report in the CAPSS series (ATC-52-2 Report, *A Community Action Plan for Seismic Safety*), guided by the information presented here, will examine and recommend steps the City can take to reduce these consequences.

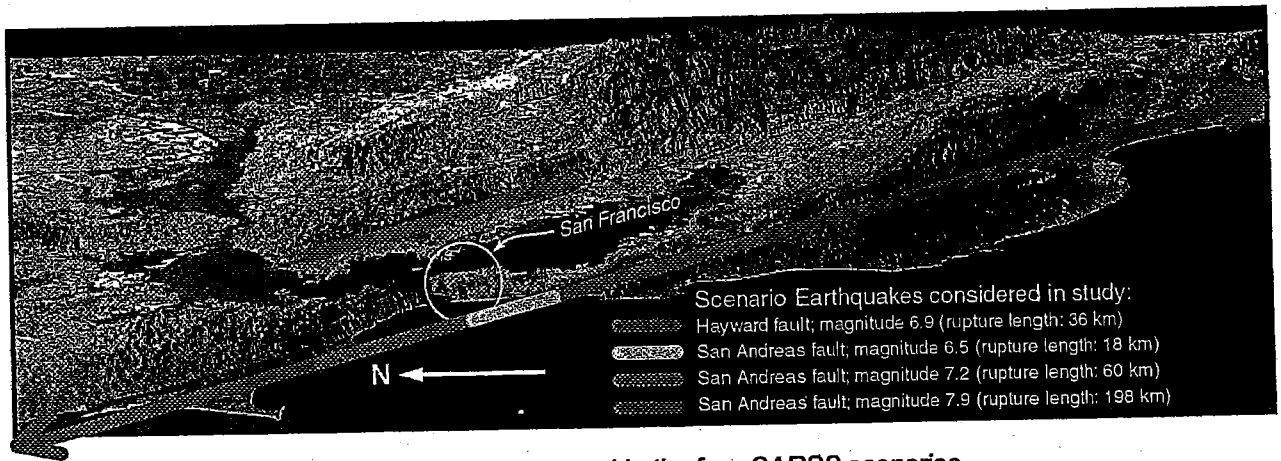


Figure A The location and length of fault ruptured in the four CAPSS scenarios.

Focusing on one possible earthquake, a magnitude 7.2 earthquake on the San Andreas fault directly offshore from San Francisco, illustrates the types of consequences the City can expect following its next large earthquake. Such an earthquake could be considered expected because enough strain to produce an event of this size has built up on the San Andreas fault since 1906. If such an event occurs, the City should expect the following impacts:

- About 27,000 buildings of the 160,000 buildings in San Francisco will not be safe to occupy after the earthquake. About 73,000 more buildings will have moderate damage but will remain usable. Most of the damaged buildings will be wood-frame soft-story buildings, which make up more than half of all buildings in the City. Other structure types, notably concrete buildings built before 1980, will also suffer heavy damage.
- About 3,600 buildings will need to be demolished and rebuilt. Many of these will be older and architecturally valuable buildings; some will be historic resources. The City will permanently lose the character and feel that these buildings contribute. It will also permanently lose any rent-controlled units in these demolished buildings, due to state law.
- Two hundred to three hundred people could be killed, and 7,000 more could have injuries requiring medical care. If the earthquake occurs during the day, older concrete commercial buildings will be responsible for the largest share of casualties. If the earthquake occurs at night, wood-frame soft-story and older concrete residential buildings will cause the most casualties. Casualties could be much higher if even one large, densely occupied building collapses.
- Earthquake shaking sparks fires (Figure B). This scenario is likely to ignite more than 70 fires simultaneously, while impeding the San Francisco Fire Department's ability to respond quickly. This means some fires will burn unchecked for hours. An estimated 2,700 additional buildings could be destroyed by fire, including 5,800 housing units. Damage from fire could be much higher or lower than these estimates, depending on weather, wind, and many other factors.
- 85,000 housing units would not be suitable for occupancy and would take months to years to be repaired or replaced. Rental and low-income housing would be the slowest to come back.
- Economic losses will be huge. The cost for owners to repair or replace their damaged buildings could be $30 billion. Most of this damage will be uninsured. Only 6 to 7 percent of home owners in San Francisco carry earthquake insurance, although coverage is higher for commercial properties. An additional $10 billion could be lost in damage to building contents, loss of inventory, relocation costs, income losses, and wages directly linked to this damage. Post-earthquake fires could add over $4 billion to these losses. Secondary economic losses, stemming from reduced business and household spending, would increase economic hardships.

The next major earthquake that strikes San Francisco will change the City and its people. San Francisco is a world-class city with many special attributes that draw businesses, innovative people who want to live here, and visitors from around the world. In the long-term, San Francisco will recover and thrive, but it will be a different San Francisco. It is possible that a new, post-earthquake San Francisco will have less socio-economic diversity. The loss of many affordable housing options,

exacerbated by a limited number of housing units in the years it will take to rebuild the City, will make it difficult for some middle and low income people to remain in San Francisco. Earthquake damage will stress businesses and the jobs they provide, particularly many small and independent businesses in the City. It will change the way the City looks, with some of the most interesting and beautiful buildings and neighborhoods changed forever. Despite the damage, San Francisco will retain many of the elements that make it an economically successful and socially desirable place – physical beauty, cultural amenities, and proximity to world-class universities, to name a few.

The scenarios described in this report present what is likely to happen if San Francisco makes no changes to its preparations for earthquakes. As discussed in the companion ATC-52-2 Report, *A Community Action Plan for Seismic Safety*, much of this damage is preventable. It is up to San Franciscans to decide how much to invest in steps to reduce the consequences of future major earthquakes.



Figure B *View looking east from California Street during post-earthquake fires in 1906. Photo credit: Courtesy of the National Information Service for Earthquake Engineering, University of California, Berkeley.*

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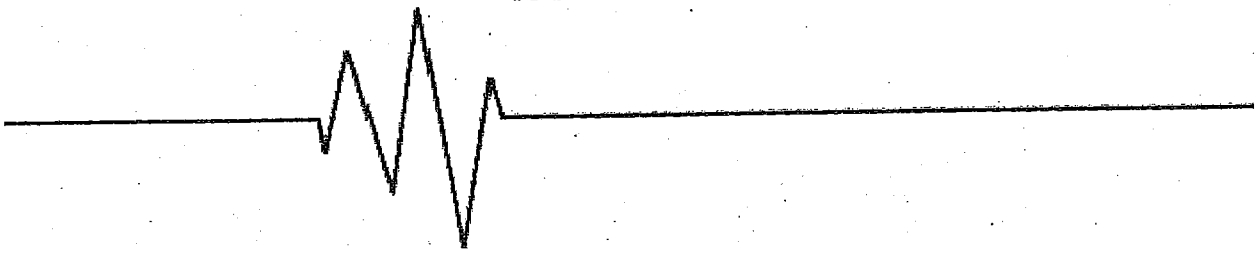

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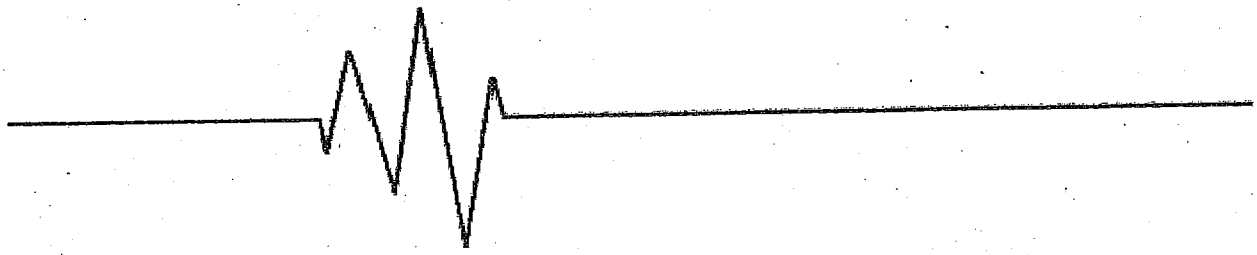

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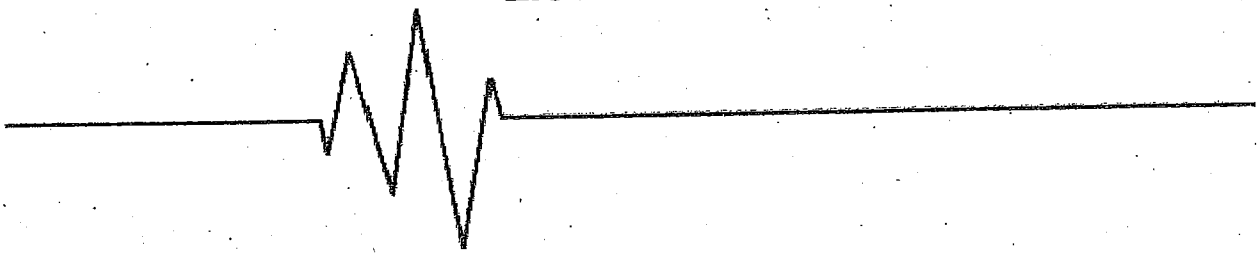

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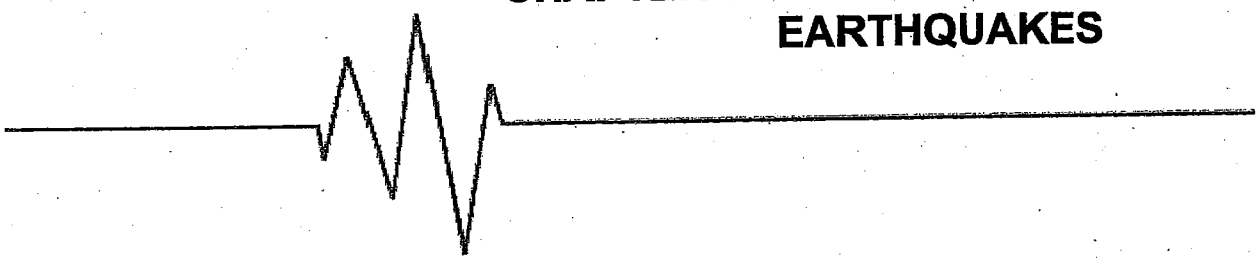
CHAPTER 1: FOUR POSSIBLE EARTHQUAKES



No one knows when the next large earthquake will strike San Francisco, but it is certain that large earthquakes will occur. Scientists estimate that there is a 63 percent chance that a magnitude 6.7 or larger earthquake will occur in the Bay Area within the next thirty years[1]. This report selects four possible earthquakes that could strike the City and estimates the amount of damage and the resulting ripple effects that each could cause. The next large earthquake to strike the City will surely be different – in size, location, and many other characteristics – than the four scenarios examined in this report. The consequences of the next large earthquake, however, are likely to be similar in nature to the consequences estimated in the following chapters. To begin, this chapter describes the four earthquake scenarios studied in this report.

Four scenarios were selected to represent a range of likely seismic events that could strike the City in coming years. The four scenario earthquakes are:

1. A magnitude 6.9[2] earthquake on the Hayward fault in the East Bay. Of the four earthquakes studied, this event has the highest likelihood of occurring in the next 30 years.
2. A magnitude 6.5 earthquake on the portion of the San Andreas fault closest to San Francisco.
3. A magnitude 7.2 earthquake on the peninsula segment of the San Andreas fault closest to San Francisco. This earthquake would produce a level of shaking in many areas of the City that is similar to the level of shaking that the building code requires new structures be designed to resist without major structural failure. For this reason, damage from this scenario is used as an example to explore consequences in detail in many places throughout the report.
4. A magnitude 7.9 earthquake on the San Andreas fault, which is a repeat of the 1906 earthquake. This is the largest known earthquake to have occurred in northern California on the San Andreas fault.

Any of the four earthquake scenarios examined in this study would result in very strong shaking in San Francisco[3]. Figure 1 shows the shaking that would be produced

---

[1] WGCEP, 2008.

[2] All earthquake magnitudes in this report are moment magnitudes. Moment magnitude represents the total amount of energy released in an earthquake and is the preferred scale used by earth scientists. This is similar to Richter magnitude, which is related to the peak displacements caused by an earthquake 100 km from the epicenter.

[3] Information about the technical methods used to estimate this shaking, and all other results in this report, is presented in a companion volume, ATC 52-1A Report, *Potential Earthquake Impacts: Technical Documentation.*

in each of these scenarios, and compares them to the actual shaking experienced during the 1989 Loma Prieta earthquake, the last damaging earthquake experienced in San Francisco. All four of these scenarios would produce shaking throughout the City that is two to four times stronger than the shaking that struck in the Marina—the City's hardest hit neighborhood—during Loma Prieta.

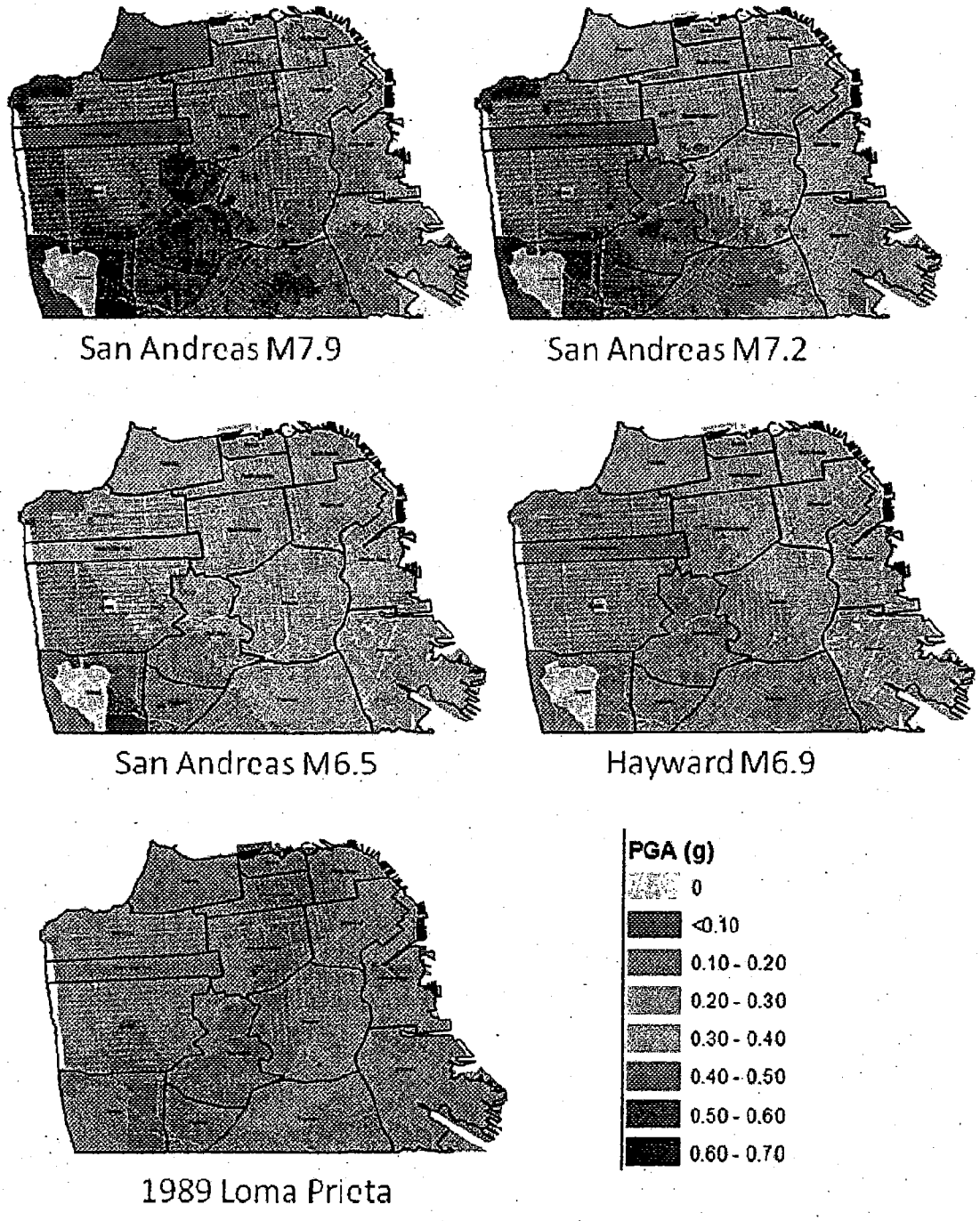


Figure 1 *The estimated shaking for the four scenario earthquakes, and the actual shaking experienced in the 1989 Loma Prieta earthquake. PGA stands for Peak Ground Acceleration, expressed as a percent of the acceleration of gravity.*

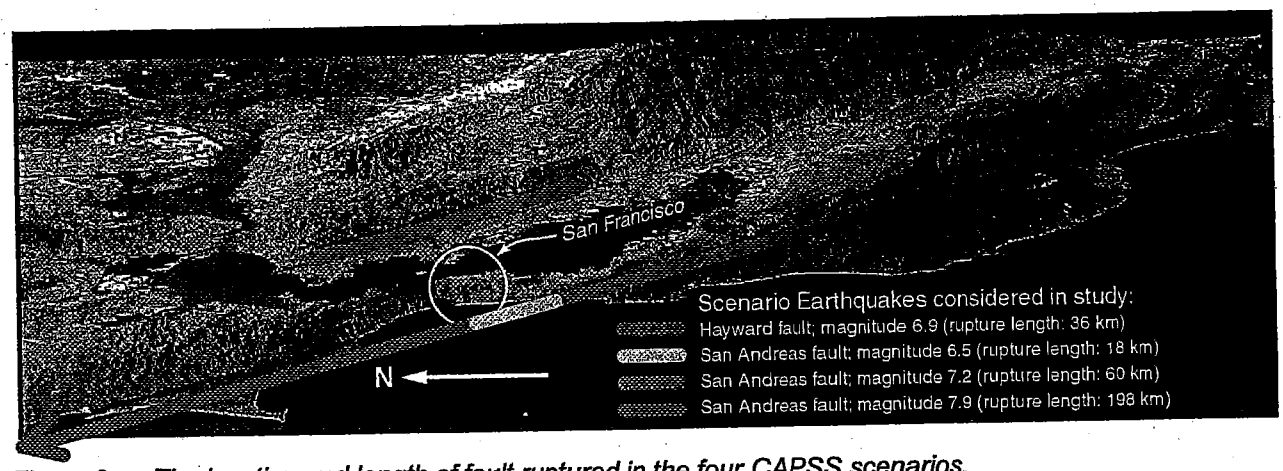


Figure 2 The location and length of fault ruptured in the four CAPSS scenarios.

Figure 2 shows the location of each of the four scenario earthquakes, in relation to San Francisco, and the size of the fault rupture in each event. Larger earthquakes break or rupture a longer length of fault.

The chapters that follow describe what is likely to happen to San Francisco if these four scenario earthquakes occur. While the next significant earthquakes to shake the City will probably be different than those studied here, the same themes will undoubtedly emerge in the damage that follows. The City will lose housing, businesses, people, and historic character. The next chapter discusses the buildings in the City that these events would shake.

CHAPTER 2: SAN FRANCISCO'S BUILDINGS

San Francisco has approximately 160,000 buildings, ranging from gleaming, new downtown high rises to small, single-family homes. This chapter discusses the privately-owned buildings in the City: their numbers and value, how they are used, where they are located, and variations in how they are constructed. This report only covers privately-owned buildings under the jurisdiction of the City's Department of Building Inspection.

Dividing up the City

Earthquakes will affect different parts of the City in different ways due to each location's proximity to faults, underlying soil, and types of buildings. For this reason, some of the findings in this study are presented by district. For the purposes of this project, the City is divided into fourteen districts, shown in Figure 3[4]. There is still

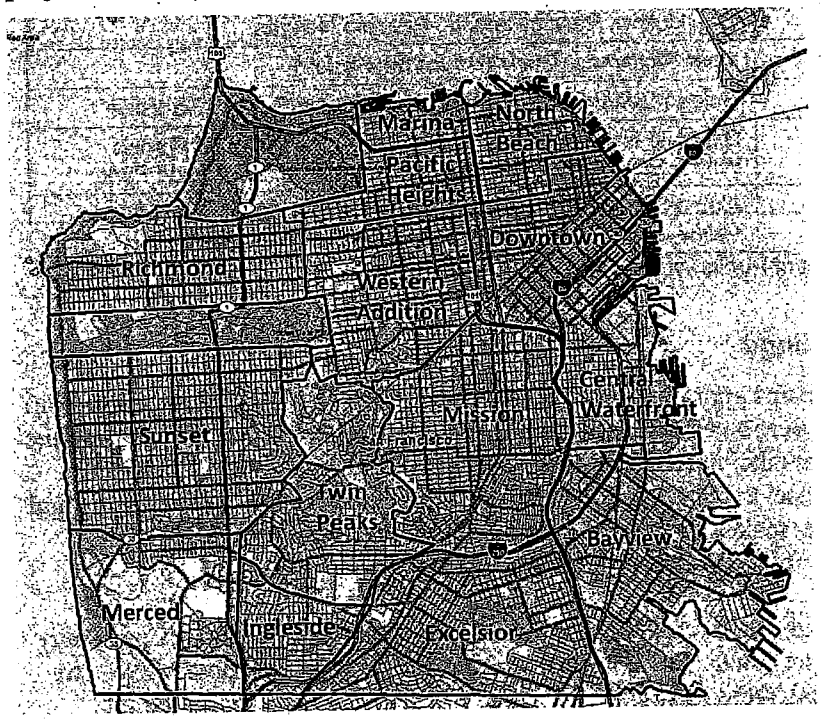


Figure 3 Map of CAPSS district divisions.

[4] These districts are used by the Department of Public Works. The Presidio, Golden Gate Park and Treasure Island (not shown) were not analyzed by the project because no building inventory data were provided to the project team for these locations. Many buildings in those areas are government-owned. This study focuses only on privately-owned buildings.

considerable diversity within any of the relatively large districts used in this study. Further, the district names used by this study may represent a larger area than when those same names are used colloquially by City residents. For example, the CAPSS "Downtown" district encompasses the Financial District, Chinatown, South of Market (SOMA), the Tenderloin, and Nob Hill. Some of the different communities that make up each of the fourteen large districts addressed in this study are presented in Table 1.

Table 1 Communities That Make Up CAPSS District Divisions

CAPSS District Name	Neighborhoods Included in Each District
Bayview	Bayview, Candlestick Point, Hunter's Point, Silver Terrace
Central Waterfront	Dogpatch, Mission Bay, Potrero Hill, South Beach
Downtown	Chinatown, Civic Center, Financial District, Nob Hill, SOMA (South of Market), Tenderloin
Excelsior	Bayshore, Crocker Amazon, Excelsior, Portola, Visitacion Valley
Ingleside	Ingleside, Ingleside Heights, Ingleside Terrace, Oceanview
Marina	Marina
Merced	Lakeshore, Stonestown
Mission	Bernal Heights, Castro, Glen Park, Mission, Noe Valley
North Beach	Fisherman's Wharf, North Beach, Russian Hill, Telegraph Hill
Pacific Heights	Cow Hollow, Pacific Heights, Presidio Heights
Richmond	Inner Richmond, Outer Richmond, Seacliff
Sunset	Golden Gate Heights, Inner Sunset, Outer Sunset, Parkside
Twin Peaks	Diamond Heights, Forest Knolls, Miraloma Park, St. Francis Wood, Sunnyside, Twin Peaks, West Portal, Westwood Park
Western Addition	Alamo Square, Cole Valley, Fillmore, Haight Ashbury, Hayes Valley, JapanTown, Laurel Heights, Western Addition

Source: Department of Public Works.

The City's Buildings

San Francisco contains approximately 160,000 buildings. These buildings range from small homes built over a century ago to newly-constructed high-rises. They house the many activities that take place in the City. They also contribute to San Francisco's unique sense of place: the character, sense of history, and structure for the family and community life that makes this City what it is. Table 2 presents estimates of the number and value of buildings used for various purposes.

The density of buildings and the way they are used varies throughout the City. Many districts—the Sunset, Twin Peaks, Ingleside, and the Excelsior, to name a few—are primarily residential. Other districts have much of their building space used for commercial or other non-residential purposes, such as Downtown and the Central Waterfront. Similarly, the value of the building stock varies by district. More than a quarter of the City's building value is concentrated in the Downtown district. This reflects the large building square footage in this dense and high-rise area. The consequences and costs of earthquake damage depend on which districts are shaken most strongly, and the types and quantity of buildings that are found there. Table 3 shows the estimated number and value of buildings by district.

Table 2 Estimated Number and Value of Buildings Used for Various Purposes in the City

Building Use	Estimated Number of Buildings[a]	Estimated Replacement Value of Buildings[b] ($ Billions)
Single-family Houses	112,000	$53
Two unit Residences	19,000	$22
Three or more unit Residences	23,000	$45
Other Residences[c]	800	$13
Commercial Buildings	5,000	$48
Industrial Buildings	2,100	$7.7
Other[d]	700	$2.6
Total[e]	160,000	$190

a. These numbers are estimates for 2009.
b. These figures represent an estimate of the cost to replace or reconstruct a building in 2009. They do not include the value of the land the building sits on or a building's contents. Replacement values are significantly different than real estate prices or assessed valuation. Building value is based on square footage from San Francisco Assessor's Tax Roll, not the estimated number of buildings.
c. Other Residences includes hotels, motels, nursing homes, and temporary lodging.
d. Other includes religious and educational buildings listed in the Assessor's Tax Roll.
e. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Sources: This study, San Francisco Assessor's Tax Roll, Census data, San Francisco Planning Department, and San Francisco Department of Building Inspection.

The way each of these buildings responds to earthquake shaking depends on many things, including the materials they are constructed from, their size and shape, their engineering design, their quality of construction, and how well they have been maintained. Table 4 shows estimates of the number of buildings of various structural types that exist in San Francisco. The structural types, which reflect a building's materials and the system it uses to carry loads, are used by engineers to differentiate how buildings perform in earthquakes. These numbers are estimates only, based on engineering judgment, City databases, and field surveys[5]. The way that a building's use relates to its structural characteristics can be complex. Buildings used for some purposes tend to be of a predictable structural type; for example, single-family houses in San Francisco are overwhelmingly constructed out of wood. Buildings used for other purposes can be constructed in a wide range of structural types. For example,

[5] There have been sidewalk surveys conducted by engineers for unreinforced masonry buildings and wood-frame buildings with three or more stories and five or more residential units (these are a subset of the wood-frame buildings listed in Table 4). The number of concrete buildings built before 1980 have been estimated by a project called the Concrete Coalition (Kadysiewski, 2009) using street surveys and historical records. CAPSS conducted surveys of a small number of wood-frame buildings in all City neighborhoods to estimate the percent of such buildings with soft-stories and other conditions.

Table 3 Estimated Number and Value of Buildings by District

District	Estimated Number of Buildings[a]	Estimated Replacement Value of Buildings[b] ($ Billions)
Bayview	7,600	$5.8
Central Waterfront	3,600	$9.9
Downtown	5,500	$52
Excelsior	23,000	$11
Ingleside	8,200	$3.5
Marina	2,200	$3.4
Merced	2,600	$1.8
Mission	25,000	$22
North Beach	5,500	$13
Pacific Heights	6,000	$10
Richmond	15,000	$15
Sunset	33,000	$19
Twin Peaks	13,000	$7.4
Western Addition	12,000	$19
Total[c]	160,000	$190

a. These numbers are estimates for 2009.
b. These figures represent an estimate of the cost to replace or reconstruct a building in 2009. They do not include the value of the land the building sits on or a building's contents. Replacement values are significantly different than real estate prices or assessed valuation. Building value is based on square footage from San Francisco Assessor's Tax Roll, not the estimated number of buildings.
c. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Sources: This study, San Francisco Assessor's Tax Roll, Census data, San Francisco Planning Department, and San Francisco Department of Building Inspection.

this study assumes that buildings used for retail could be one of twelve different structural types, with additional variation in their seismic resistance based on the building's age, height and quality of construction.

Seismically Vulnerable Structure Types

Some building types in the City are known to have particular weaknesses in earthquakes, which are briefly described below. In future earthquakes, it is likely that damage will be concentrated in buildings of these types.

Soft-Story Buildings

The first floor in many buildings in San Francisco is significantly weaker or more flexible than the stories above it. The weakness at the ground level usually comes from large openings in perimeter walls, due to garage doors or store windows, and/or few interior partition walls. During strong earthquake shaking, the ground level walls cannot support the stiff and heavy mass of the stories above them as they move back

Table 4 Estimated Number and Value of Buildings of Various Structural Types in the City

Structural Type	Estimated Number of Buildings[a]	Estimated Replacement Value of Buildings[b] ($ Billions)
Wood-frame single-family soft-story	60,000	$29
Wood-frame two unit residential soft-story	10,000	$12
Wood-frame three or more unit residential soft-story[c]	13,000	$26
Wood-frame single-family not soft-story	52,000	$24
Wood-frame two unit residential not soft-story	9,000	$10
Wood-frame three or more unit residential not soft-story[c]	6,000	$12
Concrete built before 1980[d]	3,000	$19
Tilt up concrete	200	$0.8
Modern concrete[e]	600	$4
Steel moment and braced frame	1,500	$21
Unreinforced masonry, retrofitted[f]	1,500	$5
Unreinforced masonry, unretrofitted[g]	400	$1
Other[h]	4,200	$27
Total[i]	160,000	$190

a. The numbers of buildings are estimates for 2009 based on available studies and engineering estimates.
b. These figures represent an estimate of the cost to replace or reconstruct a building in 2009. They do not include the value of the land the building sits on or a building's contents. Replacement values are significantly different than real estate prices or assessed valuation. Building value is based on square footage from San Francisco Assessor's Tax Roll, not the estimated number of buildings.
c. The City is currently discussing a program to require evaluation and possible retrofit of residential wood-frame buildings with 3 or more stories and 5 or more residential units. Some but not all of these buildings have a soft-story. There are an estimated 4,400 of these buildings with an estimated replacement value of $14 billion.
d. Concrete built before 1980 includes concrete shear wall buildings and concrete frames with masonry infill walls. The 1980 date was chosen to be consistent with the survey work of the Concrete Coalition (see footnote, next page, for a description of the Concrete Coalition).
e. Modern concrete buildings include concrete moment frame and shear wall buildings built after 1980.
f. This includes buildings retrofitted under the City's program.
g. This includes buildings in the City's retrofit program that have not yet received their certificate of completion, and buildings not included in the City's retrofit program, such as buildings with fewer than five residential units.
h. Other includes steel frame with cast in place concrete walls or masonry infill walls, reinforced masonry buildings, and non-residential wood-frame buildings.
i. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Sources: This study, Concrete Coalition, and San Francisco Department of Building Inspection.

and forth. The ground level walls could shift sideways until the building collapses, crushing the ground floor.

This type of weakness, called a soft-story, can be found in many types of buildings. It is common in single-family houses, where the dwelling space sits over a garage, and multi-family buildings, which may have parking or large and open commercial space at the ground level. Corner buildings are believed to have the highest risk, because mid-block buildings are often supported by their neighbor buildings. Soft-stories also occur in commercial buildings constructed from concrete or steel, often with retail space at the ground level and offices above. The companion CAPSS report in

this series—*Earthquake Safety for Soft-Story Buildings* (ATC-52-3 Report), released in 2009—took a detailed look at large, wood-frame soft-story buildings, such as the type shown in Figure 4. Many smaller wood-frame soft-story buildings and soft-story buildings constructed from other materials also exist throughout the City.



Figure 4 *A typical multi-family, wood-frame soft-story building in San Francisco. Soft-story buildings can also be smaller buildings, such as single-family homes, or buildings constructed from other materials, such as concrete.*

Concrete Buildings Built Before 1980

Older reinforced concrete buildings can experience dramatic and deadly collapses during earthquakes (Figure 5). Such collapses are responsible for many of the casualties in earthquakes around the world. However, many older concrete buildings might remain standing but suffer a great amount of damage. Inside the columns, beams, walls and floor slabs of reinforced concrete buildings lay steel reinforcing bars. Ideally, these bars allow reinforced concrete buildings to not only carry loads from gravity, but also to withstand the side-to-side shaking caused by earthquakes. Older reinforced concrete buildings may not have enough steel inside them or may not have steel in adequate configurations to survive the level of shaking that will occur in San Francisco earthquakes.

The design and construction of Californian reinforced concrete buildings improved significantly in the mid-to-late 1970's. Engineers learned from dramatic failures of these buildings during the 1971 San Fernando earthquake in Southern California and other earthquakes. It took some years for these lessons to be reflected in building codes and new construction projects. This study assumes that all reinforced concrete buildings constructed before 1980 may have design problems. This date was chosen to be consistent with a focused earthquake hazard reduction program—the Concrete Coalition[6]—that is working to study this type of building.

Many older concrete-frame buildings have unreinforced masonry walls filling the space between columns and floors to form walls for the exterior, elevator shafts, and stairwells. The masonry can help these buildings to remain standing during

[6] A program of the Earthquake Engineering Research Institute, Pacific Earthquake Engineering Research Center at the University of California, Berkeley, the Applied Technology Council, and several other partner organizations (see www.concretecoalition.org)

earthquakes, but the walls, being brittle, can crack and fall into or out of the building, creating significant dangers to those on sidewalks and causing damage that would be expensive and time-consuming to repair. Some of these buildings also have a soft-story at the ground level, and could collapse. It is costly and difficult to reinforce these buildings before an earthquake and to repair them when they are damaged.

There are older reinforced concrete buildings in San Francisco being used as apartment buildings, private schools, office buildings and warehouses. Thousands of people use these buildings daily. What is not known is which specific concrete buildings are most dangerous, and identifying the dangerous ones is challenging. Typically, it requires engineers with specific skills to conduct invasive and costly tests and analyze performance.

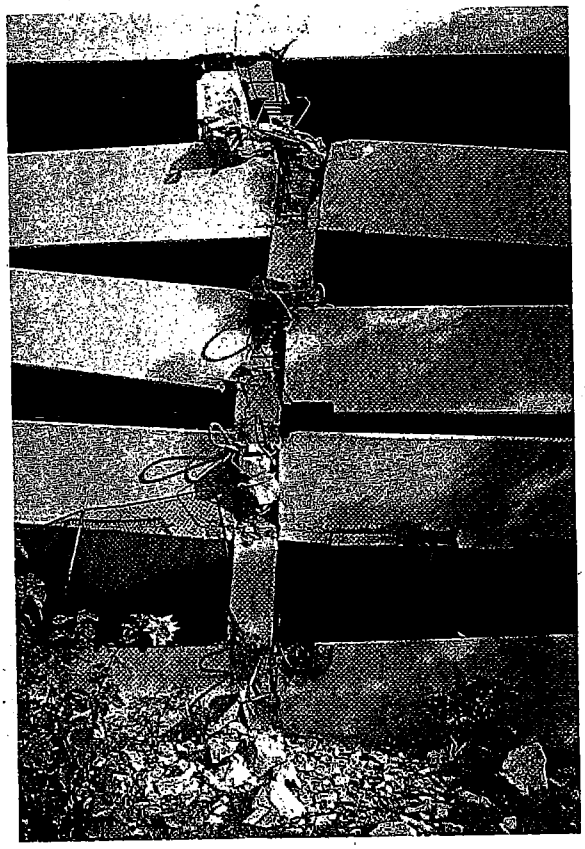


Figure 5 *Damage to a concrete-frame office parking garage in the 1994 Northridge earthquake. Photo credit: Robert K. Reitherman, Courtesy of the National Information Service for Earthquake Engineering, University of California, Berkeley.*

Unreinforced Masonry Bearing Wall Buildings

Unreinforced masonry bearing wall buildings have long been recognized as one of the most dangerous types of buildings in earthquakes. These buildings are constructed with brick walls that bear the weight of the building. They typically have six or fewer stories and were built before the mid-1930's, when building codes were changed to prevent this type of construction. They perform very poorly in earthquakes. Building parapets and sections of walls can fall outward, and some buildings can collapse in even moderate shaking. This building type has been responsible for many deaths in past earthquakes.

San Francisco has been working to improve the safety of its unreinforced masonry bearing wall buildings for decades, first through an ordinance requiring parapets to be anchored, and later through an ordinance requiring most of these buildings to be retrofitted (Figure 6). As of the writing of this report, 90 percent (1,526 out of 1,699) of the buildings on the City's list of unreinforced masonry buildings had been retrofitted or demolished, and a remaining 10 percent (173) were in process of becoming compliant with the ordinance, or were referred to the City Attorney's Office for enforcement[7]. It is important to note that retrofitted unreinforced masonry buildings remain highly vulnerable to earthquakes. When exposed to strong shaking, it is likely that retrofitted buildings would cause significantly fewer casualties than those that have not been retrofitted, but many buildings could be damaged beyond repair, displacing their occupants and requiring demolition. A few hundred masonry buildings were exempted from the City's retrofit ordinance, including buildings used only as residences with four or fewer units. It is likely that many of these remain unretrofitted.

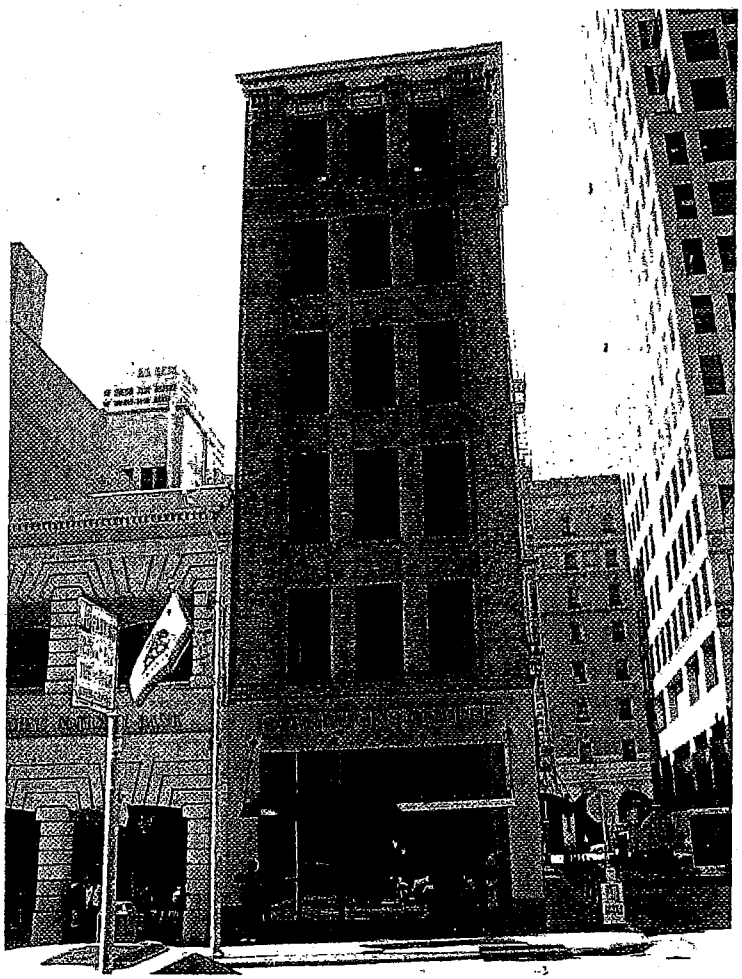


Figure 6 A retrofitted unreinforced masonry building in San Francisco. Photo credit: Courtesy of William T. Holmes.

[7] Kornfield, 2009.

Other Vulnerable Building Types

A number of other building types and characteristics are well-documented as being vulnerable in earthquakes. These include the following:

- *Welded steel moment frame buildings.* The welds connecting columns and beams in steel moment frame buildings built before 1994 can crack in earthquake shaking, leading to a reduction in their capacity to support the building. Before this vulnerability was discovered, this construction type was thought to have excellent seismic performance and, therefore, was popular for large office buildings. The 1994 southern California Northridge earthquake revealed this weakness. A number of San Francisco's downtown high-rises are welded steel moment frames.

- *Concrete tilt-up buildings.* These buildings have precast concrete panels that are raised in place to form the building walls. If the walls are not adequately connected to each other and to the roof, they can separate when shaken by an earthquake, causing the roof to collapse on the occupants and contents of the building. This structure type is often used for industrial purposes, but may also be used for some grocery stores or other commercial purposes. There are an estimated 200 of these buildings in San Francisco.

- *Older steel buildings with masonry infill walls.* San Francisco has many steel-frame buildings from the early part of the last century with masonry walls filling the space between columns and floors to form walls for the exterior, elevator shafts, and stairwells. The steel is often encased in concrete for fireproofing purposes, making the building appear to be a concrete frame to a casual observer. The masonry walls in these buildings can crack up and fall into or out of the building, creating significant dangers to those on sidewalks and causing damage that would be expensive and time-consuming to repair. These buildings are used as residences and offices, and many have beautiful period architectural detailing.

- *Hillside buildings.* San Francisco's characteristic hills have led to many buildings that have more stories on one side than the other. For example, it is common to see buildings with one or two stories of street frontage, but three or four stories when seen from the back. Structurally, buildings with irregular heights can be especially vulnerable to earthquake shaking, particularly if the lower levels have a soft-story or other structurally deficient condition.

- *Cladding, finishes and chimneys.* Buildings of all structural types have elements that can fall off during earthquakes, particularly if their connections have deteriorated due to age or corrosion. These elements can hurt people or affect the functionality of a building. They include cladding (outside finishes of glass, brick, stone, or other materials), and decorative elements. Masonry chimneys are brittle and often lack reinforcing steel. During earthquakes they can snap at the roof or pull away from a building. Falling bricks can crash through roofs or onto the ground below.

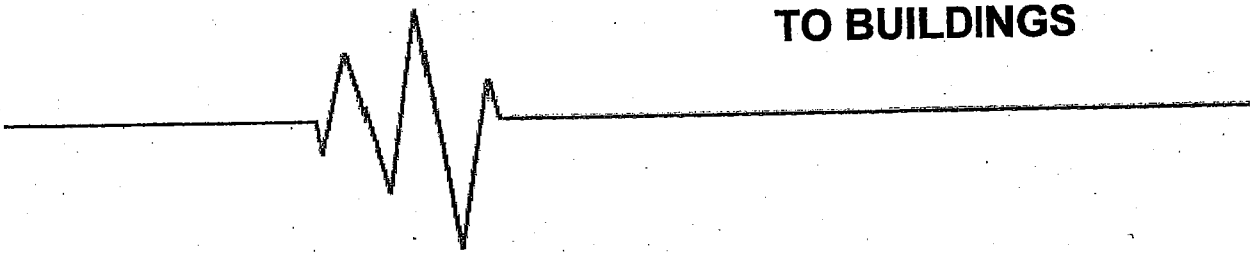
- *Falling hazards and utility failure.* There are a variety of non-structural issues that can lead to deaths and injuries, or make buildings unusable. These include tipping of heavy furniture and equipment and falling light fixtures or objects on shelves. Falling hazards can be serious, even in buildings that are structurally sound. For example, studies following the 1999 Kocaeli earthquake near Istanbul, Turkey found that nearly half of the casualties were caused by non-

structural elements rather than damage to the building structure[8]. A variety of non-structural issues can also make buildings unusable, such as inoperable elevators or destruction of furniture due to water damage.

Future earthquakes will shake all 160,000 privately-owned buildings in the City. The next chapter presents estimates of how much damage these buildings would sustain in the four scenario earthquakes.

[8] Petal, 2009.

CHAPTER 3: EARTHQUAKE DAMAGE TO BUILDINGS



This chapter presents direct estimates of damage to the City's privately-owned buildings in four possible earthquakes, with a focus on a magnitude 7.2 scenario on the San Andreas fault. In that scenario earthquake, nearly 15 percent of the City's buildings—almost 27,000 buildings—would not be fit for occupancy after the earthquake. About 3,600 of these buildings would be damaged beyond repair. It would cost $30 billion to repair and replace damaged buildings. The type of structure that would experience the most damage, both in terms of the number of buildings damaged and the cost of damage, is soft-story wood-frame residences. This is also the most common type of structure in the City, representing slightly more than half of the 160,000 buildings. Other types of structures, such as concrete buildings built before 1980, will also fare poorly. This chapter presents losses due to shaking and ground failure. Additional losses due to fire are discussed in Chapter 4.

Purpose and Proper Use of These Estimates

The damage estimates in this report are intended to guide the City in developing policies and plans that will make San Francisco safer and more resilient during and after future earthquakes. The losses and impacts described in the following pages are reasonable estimates of what could occur in future earthquakes, not accurate predictions of exactly what would happen. Estimating earthquake damage is an inherently uncertain process; if one of the exact events studied in this report should occur, damage could be double or half what is reported here. Some of the many sources of uncertainty include: selecting which scenario earthquakes to study; modeling the way seismic forces travel through the ground; modeling the impact of differing degrees of shaking on structures of various materials and configurations; and estimating exactly which structural types of buildings are in various locations throughout the City. This study looks at earthquake impacts at the citywide and district level. Analysis was not conducted for specific buildings, and this study makes no determination of how any particular building in the City will perform in future earthquakes. It is impossible to know exactly what will happen in the next large earthquake to strike San Francisco. However, the estimates presented in this report rely on internationally accepted techniques to provide reasonable estimates to help guide City decisions.

This report only examines buildings regulated by the Department of Building Inspection that are privately owned. There are many structures, buildings, and facilities in San Francisco that were not included in this study. For example, public buildings (public schools; city, state, and federal buildings; the San Francisco International Airport; and port facilities) and infrastructure (water, sewer, power, gas, transportation, bridges, piers, and tunnels), were not included in the project scope. Only private-sector building damage and repercussions on the people and economy of San Francisco traceable to this damage are addressed in this study. Therefore, the

actual total damage following any of the scenario earthquakes would likely be higher than what is presented in the report. Other City programs, such as the Resilient SF Initiative, are examining risk to public facilities.

Direct Damage to Buildings

This study used the Hazards US (HAZUS®) methodology[9], developed by the Federal Emergency Management Agency (FEMA), to estimate the amount and types of damage that could occur in four possible scenario earthquakes. The analysis using HAZUS® has been extensively customized to represent the unique buildings and conditions in San Francisco. The details of the technical analysis are described in a companion technical volume, *Potential Earthquake Impacts: Technical Documentation* (ATC 52-1A Report). To assure that the application of the HAZUS® methodology and all modifications made for San Francisco were appropriate, an extensive review of the analysis and the results was carried out by an independent CAPSS Project Engineering Panel whose members are intimately familiar with HAZUS®' capabilities and limitations.

The amount of damage that buildings in the City would experience in future earthquakes depends on many things, including the size of the earthquake that occurs, the soil that each building sits on, the proximity of buildings to the earthquake fault, and the structural characteristics and configuration of each building.

Table 5 shows the estimated cost of direct damage that could occur in four possible earthquake scenarios due to shaking and ground failure, expressed in dollar losses by building use. These figures represent the costs to repair or replace buildings damaged in the scenarios and include damage to building structures and integral non-structural elements, such as partition walls, ceilings, and fixtures. The figures combine the costs of minor repairs with the costs incurred by buildings that need to be demolished and replaced from the ground up. The following issues stand out as important findings:

- Residential buildings have the largest losses. Depending on the scenario, 60 to 70 percent of the total citywide estimated cost to repair and replace damaged buildings is due to damage to residences. This finding is not surprising since most of the City's buildings—about 95 percent of all buildings and about 70 percent of all building value—are residential.
- Single-family houses have the largest total losses in the three San Andreas fault scenarios. Many single-family homes are located in the City's western neighborhoods, closest to the San Andreas fault.
- The Hayward Fault scenario would shake the City's eastern neighborhoods more strongly than the western ones. This causes higher losses to multi-family homes and commercial buildings and lower losses to single-family homes, compared to the San Andreas fault scenarios. This difference is due to different building patterns in the City's eastern and western neighborhoods.
- Multi-family residences, including apartments, condominiums, and Tenancy-in-Common buildings, are hit hard in all scenarios. They are responsible for a disproportionate percent of the losses compared to their value. This is because many multi-family dwellings are located in vulnerable structure types, notably soft-story wood-frame buildings and concrete buildings built before 1980.

[9] The study used HAZUS®99 SR2 (FEMA, 2002).

- Industrial buildings also experience heavy damage in all scenarios, particularly in the Hayward fault scenario. Again, this is due to vulnerable structure types—older concrete, concrete tilt-up, and masonry buildings—being common in buildings used for industrial purposes.

Table 5 Estimated Cost to Repair and Replace Buildings Damaged from Shaking and Ground Failure in Four Scenario Earthquakes, by Building Use

Building Use	Cost of Building Damage in Four Scenario Earthquakes ($ billions)[a]			
	Hayward Magnitude 6.9	San Andreas Magnitude 6.5	San Andreas Magnitude 7.2	San Andreas Magnitude 7.9
Single-family Houses	$2.3	$6.0	$8.8	$13
Two unit residences	$1.4	$2.4	$3.6	$5.4
Three or more unit residences	$4.2	$5.2	$7.8	$12
Other Residences[b]	$0.8	$0.7	$1.3	$2.6
Commercial Buildings	$4.5	$4.2	$6.6	$11
Industrial Buildings	$0.9	$1.0	$1.4	$2.2
Other[c]	$0.1	$0.2	$0.3	$0.7
Total[d]	$14	$20	$30	$48

a. Estimates are in 2009 dollars.
b. Other Residences includes hotels, motels, nursing homes, and temporary lodging.
c. Other includes religious and educational buildings listed in San Francisco Assessor's Tax Roll.
d. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Another way to evaluate the damage estimates is to look at the number of buildings that will suffer various degrees of damage in an earthquake. This report expresses damage to buildings in terms of their expected functionality after an earthquake, with the following categorizations[10]:

- *Usable, light damage.* Buildings would experience only minor damage and residents could continue to use them. This report does not assess the likelihood of utilities—water, sewer, power—being functional, which would influence whether occupants choose to remain in these buildings.

10 These functionality states were adapted from San Francisco Planning and Urban Research (SPUR, 2009), and roughly correlate with the states of Safe and Operational, Safe and Usable During Repair, Safe and Usable After Repair, Safe but Not Repairable, and Unsafe, Collapse Risk. The CAPSS state "Not Repairable" combines the SPUR states Safe but Not Repairable and Unsafe, Collapse Risk.

- *Useable, moderate damage (shelter in place).* Occupants of these buildings could continue to use them safely after a major earthquake and during its aftershocks, but there would be damage that may cause inconvenience. The use of these damaged buildings will depend in part on the City's post-earthquake inspection and posting policies and on the willingness of building owners to let tenants occupy moderately damaged buildings.
- *Repairable, cannot be occupied.* Buildings in this state would experience heavy damage and could not be occupied until repaired. Few, if any, buildings in this state would be demolished, thus, repaired rental units would remain under rent control restrictions, and neighborhood character (as defined by style of construction, building scale, and mix of uses) would be maintained.
- *Not Repairable.* These buildings would experience heavy damage and would need to be demolished after the earthquake. They could not be occupied. The City could permanently lose significant amounts of rent-controlled housing, as well as buildings that contribute to the architectural character of the City. Some of these buildings would collapse or experience partial collapse.

Table 6 shows the amount of damage that buildings used for various purposes are estimated to experience in the Magnitude 7.2 San Andreas fault scenario due to shaking and ground failure. Key points that emerge from looking at expected damage in this format include:

- About 27,000 buildings in the City would not be safe to occupy. This includes more than fifteen percent of the City's residential buildings.
- About 1,500 multi-family residential buildings would need to be demolished. When these buildings are reconstructed, the new units would not be covered by rent control due to state law. Owners may choose to rebuild their buildings with condominiums rather than as rental properties.
- Eighteen percent of commercial space—about 900 buildings—would not be safe for occupancy after the scenario earthquake. Nearly 300 of these buildings would need to be demolished and rebuilt.
- Twenty-five percent of industrial buildings—more than 500 buildings—would not be usable after the scenario earthquake. More than 200 of these would need to be demolished and rebuilt.

Damage by District

The neighborhoods close to the fault, those on poor soils, and those with a prevalence of vulnerable building types would experience proportionately more damage than other neighborhoods. It is important to remember that a different scenario earthquake, such as an event on the Hayward Fault in the East Bay, would change the relative damage patterns among districts. Table 7 shows how damage to buildings would be distributed among different districts in the City for a magnitude 7.2 scenario on the San Andreas fault.

Table 6 Estimated Damage States of Buildings Due to Shaking and Ground Failure in a Magnitude 7.2 Earthquake on the San Andreas Fault, by Building Use

Building Occupancy	Number of Buildings in Various States of Damage[a]			
	Usable, Light Damage	Usable, Moderate Damage[b]	Repairable, Cannot be Occupied	Not Repairable[c]
Single-Family Houses	45,000	54,000	11,000	1,700
Two-Unit Residences	8,200	7,400	3,200	290
Three-or-More-Unit Residences[d]	7,200	7,500	7,200	1,100
Other Residences[e]	300	400	80	40
Commercial Buildings	1,600	2,400	630	290
Industrial Buildings	750	820	320	210
Other[f]	330	280	60	30
Total[g]	63,000	73,000	23,000	3,600

a. Building functionality categorizations are derived from HAZUS® damage states. For more information, please see the companion technical volume, *Potential Earthquake Impacts: Technical Documentation* (ATC 52-1A Report).
b. This level of damage can be referred to as "shelter in place".
c. Some of these buildings have collapsed. Others are standing but damaged beyond repair. None can be occupied.
d. The City is currently discussing a program to require evaluation and possible retrofit of residential wood-frame buildings with 3 or more stories and 5 or more units. These buildings are a subset of this category. For more information about the performance of residential buildings, see chapter 6.
e. Other Residences includes hotels, motels, nursing homes, and temporary lodging.
f. Other includes religious and educational buildings listed in the San Francisco Assessor's Tax Roll.
g. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Damage by Structural Type

As discussed previously, some structure types are more vulnerable to earthquake shaking than others. Not surprisingly, these vulnerable structure types are responsible for a disproportionate share of damage to the City's buildings. Table 8 presents expected costs of building damage in four scenario earthquakes by structural type. The following conclusions emerge when looking at damage in this format:

- Residential wood-frame soft-story buildings are responsible for the largest economic losses in all scenarios. This building type, known to be vulnerable in earthquakes, is very common in San Francisco. It has the highest total value of any structure type in the City, and because many of these buildings are small one- or two-unit residences, this type represents by far the largest number of buildings in the City.

Table 7 Estimated Damage States of Buildings Due to Shaking and Ground Failure in a Magnitude 7.2 Earthquake on the San Andreas Fault, by District

District	Number of Buildings in Various States of Damage[a]			
	Usable, Light Damage	Usable, Moderate Damage[b]	Repairable, Cannot be Occupied	Not Repairable[c]
Bayview	3,100	3,200	940	290
Central Waterfront	1,100	1,600	570	200
Downtown	2,000	2,600	660	190
Excelsior	9,900	11,000	2,300	340
Ingleside	3,000	4,400	830	120
Marina	700	740	600	90
Merced	840	1,400	320	60
Mission	10,000	10,000	3,800	560
North Beach	2,500	2,000	820	140
Pacific Heights	2,600	2,300	920	120
Richmond	5,400	6,400	2,700	360
Sunset	12,000	16,000	4,800	660
Twin Peaks	5,400	6,500	1,300	170
Western Addition	4,900	4,900	2,200	310
Total[d]	63,000	73,000	23,000	3,600

a. Building functionality categorizations are derived from HAZUS damage states. For more information please see the companion technical volume, *Potential Earthquake Impacts: Technical Documentation* (ATC 52-1A Report).
b. This level of damage can be referred to as "shelter in place".
c. Some of these buildings have collapsed. Others are standing but damaged beyond repair. None can be occupied.
d. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

- Older concrete buildings also account for significant economic losses in every scenario, particularly when losses are viewed as a percentage of the value of each building type.
- Wood-frame residences *without* a soft-story have relatively high economic losses, but this is due to how common these structures are rather than their vulnerability. In fact, when losses are viewed as a percentage of the value of each structure type, these buildings have the lowest percentage loss of any structure type.

Impacts of Liquefaction

Liquefaction occurs when wet and sandy soils are shaken. It results in a loss of soil strength, and can cause buildings to move sidewise or settle unevenly. As shown in Figure 7, a number of neighborhoods in San Francisco could experience liquefaction,

in particular, pockets of the Marina, Downtown, Central Waterfront, Bayview, and Mission districts. About 12 percent of the estimated dollar losses to buildings citywide can be attributed to liquefaction, and over 20 percent in some districts.



Figure 7 California Geological Survey Hazard Zones Map of San Francisco. Areas susceptible to liquefaction appear in green.

Damage to Buildings with Special Uses

The City has many privately-owned buildings that serve special purposes. These include the following:

- Facilities occupied by vulnerable people (e.g., private schools, daycare centers, assisted living facilities)
- Businesses and organizations that provide important services to people (e.g., pharmacies, medical offices, medical suppliers, dialysis centers, non-profit community service organizations, grocery stores)
- Culturally important buildings (e.g., historic and architecturally important buildings, buildings in historic neighborhoods, museums, universities)

Table 8 Estimated Costs to Repair and Replace Damaged Buildings Due to Shaking and Ground Failure in Four Scenario Earthquakes, by Structure Type

Structure Type	Cost of Building Damage in Four Scenario Earthquakes[a] ($ Billions)				Estimated Replacement Value[b] ($ Billions)
	Hayward Magnitude 6.9	San Andreas Magnitude 6.5	San Andreas Magnitude 7.2	San Andreas Magnitude 7.9	
Wood-frame single-family soft-story	$2.0	$4.4	$6.5	$9.3	$29
Wood-frame two unit residential soft-story	$1.2	$1.9	$2.8	$4.1	$12
Wood-frame three or more unit residential soft-story	$3.5	$4.2	$6.1	$9.2	$26
Wood-frame single-family not soft-story	$0.4	$1.6	$2.4	$3.7	$24
Wood-frame two unit residential not soft-story	$0.3	$0.6	$0.8	$1.3	$10
Wood-frame three or more unit residential not soft-story	$0.4	$0.6	$0.9	$1.6	$12
Concrete built before 1980[c]	$1.9	$2.0	$3.3	$6.5	$19
Tilt up concrete	$0.1	$0.1	$0.1	$0.2	$0.8
Modern concrete[d]	$0.3	$0.3	$0.4	$0.6	$4
Steel moment and braced frame	$1.9	$1.7	$2.6	$3.8	$21
Unreinforced masonry, retrofitted[e]	$0.4	$0.4	$0.6	$1.0	$5
Unreinforced masonry, unretrofitted[f]	$0.1	$0.1	$0.1	$0.2	$1
Other[g]	$2.0	$2.0	$3.2	$6.1	$27
Total[h]	$14	$20	$30	$48	$190

a. Estimates are in 2009 dollars.
b. These figures represent an estimate of the cost to replace or reconstruct a building in 2009. They do not include the value of the land the building sits on or a building's contents. Replacement values are significantly different than real estate prices or assessed valuation. Building value is based on square footage from San Francisco Assessor's Tax Roll, not the estimated number of buildings.
c. This includes concrete shear wall buildings and concrete frames with masonry infill walls. The 1980 date was chosen to be consistent with the Concrete Coalition.
d. Modern concrete buildings include concrete moment frame and shear wall buildings built after 1980.
e. This includes buildings retrofitted under the City's retrofit program.
f. This includes buildings in the City's retrofit program that have not yet received their certificate of completion, and buildings not included in the City's retrofit program.
g. Other includes steel frame with cast-in-place concrete walls or masonry infill walls, reinforced masonry buildings, and non-residential wood-frame buildings.
h. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Sources: This study, San Francisco Assessor's Tax Roll, and the Concrete Coalition.

In general, the City and the Department of Building Inspection know very little about the seismic safety of privately-owned buildings that serve these functions. Many of them may be highly vulnerable to earthquake damage. No specific analyses have been conducted to assess the seismic safety of privately-owned buildings used for these purposes.

Buildings used for these special purposes are probably much like other buildings in the City. In many cases, this means they are old and built to outdated building codes. The average date of construction of buildings in the City is 1937[11]. Only 16 percent of the total building square footage in the City was constructed after the mid-1970's, when significant improvements in seismic safety were made in the building code. It is important to note that a building's age alone does not make it unsafe. Many older buildings were built more solidly and used better quality materials than relatively newer buildings from the 1950's and 1960's.

Buildings built to older codes, including those that may be unsafe in earthquakes, comply with City laws and can continue to be used. Only buildings that have recently changed use or undergone extensive renovations, or were covered by the City's unreinforced masonry building ordinance, have been required to undergo seismic safety upgrades.

Most people assume that school buildings are safe. For public school buildings this is generally true: the state has had stricter building regulations for public schools than other building types since the 1930's and has required retrofit of public schools built before 1933[12]. However, there are no such retrofit requirements for private schools. Newly constructed private schools, especially those built after the mid 1990's when enhanced private school building regulations were enacted, should perform well. However, many of San Francisco's private school buildings were constructed when building standards were much less stringent. Nearly one third of school children—more than 23,000—attend private schools in San Francisco, the highest rate in the entire state[13]. The City knows very little about the seismic safety of its private school buildings.

Many non-profit organizations serve critical roles aiding the City's poorest and most vulnerable residents, such as providing meals and healthcare services. Generally, these organizations operate with tight budgets and may be located in older and poorly maintained buildings, meaning their buildings could face a higher risk of damage in earthquakes than many other buildings. As discussed in Chapter 9, the elderly, poor, disabled, and non-native English speakers—many of whom rely on non-profit agencies for support—are most affected by the dislocation caused by disasters and will be in great need of support services after a large earthquake.

Historic buildings contribute to the unique character and culture of the City and provide a connection with the past. They contribute to the appeal of San Francisco to tourists from around the world. Historic buildings have vulnerabilities similar to other buildings of their era and construction type. The City has about 250 designated

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11 This is the building area weighted average, calculated by this study using the San Francisco Assessor's Tax Roll.

12 Some San Francisco school district buildings that are occupied by administrators, not students, have known seismic vulnerabilities.

13 California Department of Education, 2009.

landmark buildings and 11 historic districts[14]. These numbers of officially designated buildings and areas are increasing as efforts to survey older parts of the City progress; however, it is certain that there are many more buildings that are historic resources in San Francisco. It is difficult to make any uniform statements about the seismic vulnerability of these buildings because they range considerably in construction material, size, and configuration. Some older buildings are very vulnerable to earthquake shaking; others are quite robust. An unknown number have been seismically retrofitted. What is unique about historic buildings is the impact of damage: every historic resource that is destroyed in a future earthquake is irreplaceable.

The impact of future earthquakes on privately-owned buildings that serve special functions in the City can only be understood by learning more about these specific buildings. Until a survey is conducted of these buildings, the City will not know the damage that could occur to these buildings and its consequences to the people of San Francisco.

Building damage due to earthquake shaking is only one piece of the total impact earthquakes can have on a community. The next chapter looks at another critical piece: damage due to fire sparked by the earthquake. Post-earthquake fire is a particularly relevant topic for San Francisco, given the City's experience of a devastating conflagration after the 1906 earthquake.

[14] San Francisco Planning Department, 2010, designated Article 10 Landmarks and Article 10 Historic Districts.

CHAPTER 4: FIRE FOLLOWING EARTHQUAKE

San Francisco will sustain major damage from fires following future earthquakes, in addition to the damage caused by shaking. Most earthquakes occur in parts of the world that do not have large numbers of closely spaced wooden buildings. In San Francisco, over 90 percent of buildings are constructed from wood, many of them directly touching their neighbor buildings. Earthquakes in places with this type of construction have caused the two largest peacetime urban fires in history: in 1906 in San Francisco and in 1923 in Tokyo[15]. San Francisco's experience in 1906 (see Figure 8), in which more than 28,000 buildings were lost, about 90 percent of them due to fire[16], is well-known. The 1906 earthquake and conflagration occurred when the City had less than half the number of people and buildings existing today, and when there was very little development in the western Richmond, Sunset, and Lake Merced neighborhoods closest to the San Andreas fault. After the 1906 fire, San Francisco was rebuilt in much the same way as before, with densely packed, flammable buildings.

More modern events, such as the fires following the 1994 Northridge and 1995 Kobe earthquakes, demonstrate that fires following earthquakes remain a threat today. In both of these moderate-sized earthquakes, more than 100 fires broke out. The Northridge earthquake severely impacted area fire departments, even though it largely affected only the edge of greater Los Angeles. In Kobe, broken water mains left the fire department helpless, and fires destroyed more than 7,000 buildings[17]. Other recent events further demonstrate what could happen following an earthquake: the 1991 East Bay hills fire, which destroyed 3,500 buildings in only a few hours; the 1988 First Interstate Building fire in Los Angeles (the tallest building in the state at the time, requiring more than half of Los Angeles' fire departments); and the San Bruno gas explosion and fire in the Fall of 2010, which required nearly two hours for a ruptured gas line to be shut off.

Fires following earthquakes have a variety of causes, including electricity (electrical shorts, frayed wires, tipped appliances); gas leaks ignited by sparks or open flames; exothermic reactions from spilled chemicals; open flames from stoves, candles, fireplaces, and grills; and arson. In the Northridge earthquake in 1994 in Los Angeles, over half of the ignitions were due to electrical systems and about a quarter were fueled by gas[18].

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[15] Other well-known historical fires, such as Chicago (1871) and London (1666), were not as large as the post-earthquake Tokyo and San Francisco fires.

[16] NOAA, 1972.

[17] Nagano, 1995.

[18] Scawthorn, et al., 1998.

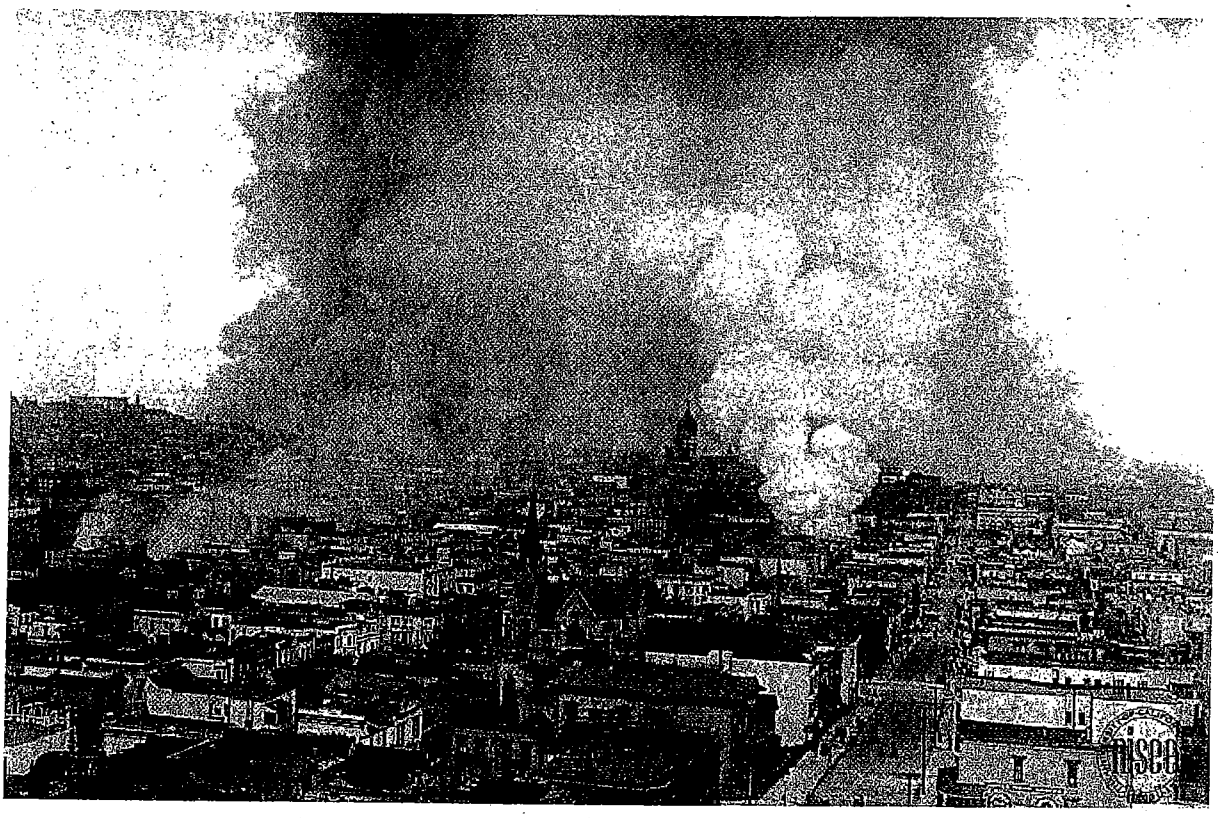

Figure 8 *Fires in San Francisco after the 1906 earthquake. Photo credit: photographer unknown, courtesy of the National Information Service for Earthquake Engineering, University of California, Berkeley.*

The San Francisco Fire Department today is a well-prepared, professional organization that trains for earthquake-caused fires. However, earthquakes simultaneously cause numerous ignitions, degrade the fire resistant features of buildings, drop water pressure due to broken water mains, overwhelm communications systems, and impede transportation routes. After the next large earthquake, there are likely to be more fires than San Francisco's fire fighters can respond to at one time. Out-of-town firefighters will not be able to help the City for many hours, and firefighters in nearby cities will be struggling with their own problems. At least some fires in San Francisco will burn out of control, and may threaten entire neighborhoods.

Following 1906, San Francisco clearly recognized the challenges of suppressing post-earthquake fires and constructed the Auxiliary Water Supply System in the City's eastern and northern neighborhoods. This system is specially designed to survive earthquake shaking and is exclusively used for fighting fires. The City has extended the reach of the Auxiliary Water Supply System with the Portable Water Supply System, which can be deployed wherever needed in the City; this was used to extinguish fires in the Marina district after the 1989 earthquake[19]. The combination of the drinking water system, the Auxiliary Water Supply System, the Portable Water Supply System, cisterns located throughout the City, fireboats that can pump bay

[19] After Loma Prieta, both the drinking water and auxiliary water systems failed to function due to loss of pressure caused by leaks from broken pipes.

water into the auxiliary system, and other special capabilities, makes San Francisco better prepared for suppressing post-earthquake fires than any other city in the world.

This study estimates the number of fires that could occur after four scenario earthquakes and the damage those fires could cause. The analysis considered a wide range of possible situations because the scale of post-earthquake fire can vary dramatically based on conditions after the earthquake. For each earthquake scenario, multiple fire analyses were conducted, varying the number and location of ignitions, the availability of water for fire fighting, the time before professional fire fighters arrive at the scene, weather, wind speed, and many other factors that affect the scope of fire impacts. The analysis is described in detail in the companion volume, *Potential Earthquake Impacts: Technical Documentation* (ATC-52-1A Report).

Table 9 presents estimates of the number of fires requiring fire department response that could occur within hours following the four scenario earthquakes. The table presents the average number of fires estimated after running multiple analyses with varying circumstances, and many more or fewer fires could break out. For example, the average number of fires expected after the magnitude 7.2 San Andreas fault scenario is 73, but there is a 25 percent chance that there could be fewer than 52 fires and a 25 percent chance that there could be more than 89 fires. Table 9 also shows the estimated number of square feet of building floor space that post-earthquake fires could burn. Again, the size of the burned area can vary dramatically based on conditions, so the table shows how this could vary given good, average and bad conditions. For perspective, at any given time the San Francisco Fire Department has about 325 officers and firefighters on duty, and 42 engines and 19 trucks[20].

Table 10 presents estimates of the square footage of building floor space that could be burned by these fires that was not already heavily damaged by earthquake shaking. The figures in this table express destruction caused by fire beyond the damage caused by shaking presented in the previous chapter. Buildings vary greatly in size; therefore, the number of buildings burned will vary significantly depending on the affected neighborhoods. Table 10 also translates the burned square footage into estimates of numbers of buildings of varying sizes.

The additional damage to San Francisco from fire would be expensive. Table 11 provides estimates of the average costs to repair or replace buildings damaged by fire that is in addition to the damage caused by shaking and ground failure. The additional increment of loss, from 12 percent ($5.8 billion) following a magnitude 7.9 earthquake on the San Andreas fault to 22 percent ($3.1 billion) following a magnitude 6.5 on the San Andreas fault, illustrates the economic importance of strategies to reduce fire risks.

Fire damage will add to the City's overall damage, making recovery more difficult and lengthy by increasing the number and severity of damaged buildings, lengthening the time required to repair and replace damaged buildings, displacing residents, and weakening neighborhoods. Buildings that survive the shaking can succumb to fire, including those that have been seismically retrofitted. Conflagration threatens

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[20] In fire service terminology, a fire engine or pumper supplements fire hydrant pressure to provide firefighting water for use by its crew, while a ladder truck, or simply truck, carries numerous ladders and other equipment and additional personnel that provide search and rescue, ventilation, and other needs.

Table 9 Estimated Number of Fires and Size of Burned Area Following Four Scenario Earthquakes

Scenario	Average Number of Fires[a]	Size of Burned Area[b] (Million Square Feet)		
		Good Conditions[c]	Average[d]	Bad Conditions[e]
Hayward Fault, Magnitude 6.9	38	3.6	6.0	11
San Andreas Fault, Magnitude 6.5	57	4.7	7.3	14
San Andreas Fault, Magnitude 7.2	73	7.7	11	19
San Andreas Fault, Magnitude 7.9	95	11	17	28

a. This table shows the average estimated number of fires requiring professional response for the many analyses with varying circumstances. There would be additional small fires extinguished by residents or self-extinguished. Many more or fewer fires could occur.
b. These numbers represent the size of building floor space that is burned. Some of these buildings will also have suffered damage from earthquake shaking.
c. This estimate has a 75 percent chance of being exceeded. Under extremely favorable conditions, the burned area could be smaller.
d. This is the average estimate for the many analyses with varying circumstances.
e. This estimate has a 25 percent chance of being exceeded. Under extremely unfavorable conditions, the burned area could be larger.

Table 10 Average Size of Previously Undamaged Area Burned, with Comparison to Buildings of Various Sizes

Scenario	Average Size of Previously Undamaged Burned Area[a] (Million Square Feet)	This Square Footage Equates to...		
		Number of High Rise Buildings[b]	Number of Average Sized Buildings[c]	Number of Single-family Homes[d]
Hayward Fault, Magnitude 6.9	2.6	6	820	1,500
San Andreas Fault, Magnitude 6.5	6.4	14	2,000	3,500
San Andreas Fault, Magnitude 7.2	8.7	19	2,700	4,900
San Andreas Fault, Magnitude 7.9	11	24	3,500	6,100

a. This is the average area for the many analyses with varying circumstances. Building square footage that experienced heavy damage from shaking has been excluded from these figures, so this table presents the amount of new destruction caused by fire. It excludes burning rubble.
b. This assumes 455,000 square feet per high rise, the size of the Transamerica Pyramid in San Francisco.
c. This assumes 3,200 square feet per building, the average building size in San Francisco considering all buildings of all uses.
d. This assumes 1,800 square feet per single-family home.

Table 11 Average Cost of Damage Caused by Fire Following the Scenario Earthquakes

Scenario	Shaking Damage ($ Billions)[a]	Average Additional Damage Due to Fire[b] ($ Billions)	Shaking Plus Fire Damage[c] ($ Billions)
Hayward Fault, Magnitude 6.9	$14	$2.7	$17
San Andreas Fault, Magnitude 6.5	$20	$3.0	$23
San Andreas Fault, Magnitude 7.2	$30	$4.3	$34
San Andreas Fault, Magnitude 7.9	$48	$5.8	$54

a. These figures include direct damage to buildings from shaking and ground failure, in 2009 dollars.
b. These figures are averages for the many analyses with varying circumstances and do not double count shaking damage (i.e., burning rubble). Results are in 2009 dollars.
c. In 2009 dollars. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

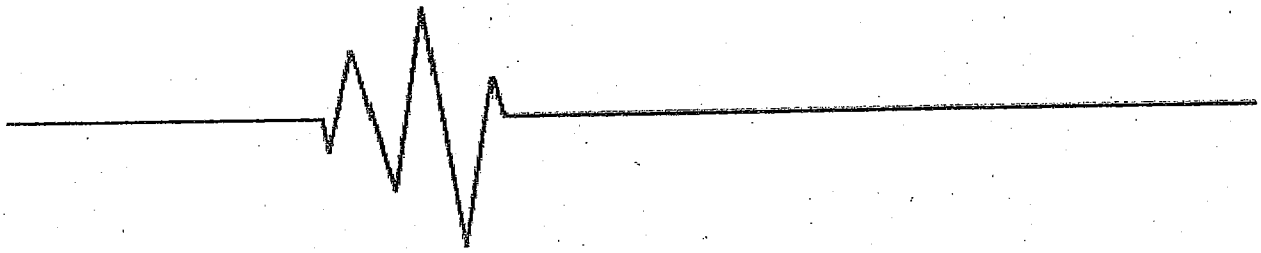
residents with limited mobility, historic neighborhoods, architecturally important buildings, and the character of communities.

Fire damage is usually insured by private insurance policies. Insurance payments, if made quickly, can expedite recovery construction. However, because shaking damage is not covered by normal homeowner or fire insurance policies, fire claims after the next earthquake may be disputed[21]. Disputes could lead to lengthy delays in owners receiving payments to repair or rebuild their properties.

The damage to buildings from shaking and fire can lead to deaths and injuries. The next chapter looks at how many casualties would be expected in the scenario earthquakes, and what might cause those casualties.

[21] In other recent disasters insurers have disputed whether damage after hurricanes was caused by wind, which is generally covered by homeowner's policies, or flood, which is not.

CHAPTER 5: CASUALTIES



Damaged buildings kill and injure people. Table 12 presents estimates of the number of injuries and deaths that could occur in the four scenario earthquakes studied by CAPSS. Depending on the size and time of an earthquake, deaths could range from less than 100 to nearly 1,000. These estimates are based on statistics from casualties in past earthquakes; the collapse of a single, densely packed high-rise building would dramatically increase deaths. These estimates do not include potential casualties due to major fires.

Table 12 Estimated Injuries and Deaths in Four Scenario Earthquakes

Earthquake Scenario	Casualties			
	Severity 1: Injuries Needing First Aid[a]	Severity 2: Injuries Needing Hospitalization[b]	Severity 3: Life Threatening Injuries[c]	Severity 4: Death[d]
Hayward Fault, Magnitude 6.9	1,500 to 2,300	330 to 510	40 to 60	70 to 120
San Andreas Fault, Magnitude 6.5	1,800 to 3,600	390 to 740	40 to 60	80 to 120
San Andreas Fault, Magnitude 7.2	3,200 to 5,600	760 to 1,300	90 to 150	170 to 300
San Andreas Fault, Magnitude 7.9	6,500 to 10,600	1,800 to 3,000	220 to 450	420 to 880

a. Severity 1: Injuries requiring basic medical aid that could be administered by paraprofessionals. These types of injuries would require bandages or observation. Some examples are a sprain, a severe cut requiring stitches, a minor burn (first degree or second degree on a small part of the body), or a bump on the head without loss of consciousness. Injuries of lesser severity that could be self-treated are not estimated by HAZUS® (FEMA, 2002) software.

b. Severity 2: Injuries requiring a greater degree of medical care and use of medical technology such as x-rays or surgery, but not expected to progress to a life threatening status. Some examples are third degree burns or second degree burns over large parts of the body, a bump on the head that causes loss of consciousness, fractured bone, dehydration, or exposure.

c. Severity 3: Injuries that pose an immediate life threatening condition if not treated adequately and expeditiously. Some examples are uncontrolled bleeding, punctured organ, other internal injuries, spinal column injuries, or crush syndrome.

d. Severity 4: Instantaneously killed or mortally injured.

Sources: This study, FEMA (2002).

The deaths and injuries in the next San Francisco earthquake are likely to be on a much smaller scale than those seen in recent international earthquakes, especially those in developing countries. There are many reasons for this. One notable reason is

that San Francisco has been effectively enforcing basic building standards for generations. Fifty years ago, those standards were not as good at producing earthquake-resistant buildings as they are today, but they were far better than no standards. Today, many countries continue to have most of their buildings constructed without meeting any design or construction standards, often due to lax enforcement of their building codes. Another reason for San Francisco's low casualty estimates is that most buildings in the City are constructed from wood. Wood-frame buildings, even when they are severely damaged or collapse, are far less lethal than brick, concrete, and other heavier structure types[22].

Casualty estimates vary by time of day because people are located in different places at different times of day. At night, most people are at home in wood-frame buildings. During the day, commuters significantly increase the City's population and many people are at work or school, in buildings with markedly different structural characteristics than their homes. During commute times, people are traveling from one place to another. The numbers of deaths and injuries that occur in an earthquake can vary significantly depending on circumstances. For example, the World Series baseball game during the 1989 Loma Prieta earthquake, and the consequent decline in traffic, may have prevented more people from being killed by the collapse of the Oakland Cypress Viaduct.

The estimated deaths and injuries shown in Table 12 are only those caused by damage to privately-owned buildings. This study did not estimate possible casualties from other causes, such as damage to infrastructure. In the Loma Prieta earthquake, 41 of the 63 deaths that occurred in the Bay Area were due to the collapses of portions of the Oakland Cyprus Viaduct and the Bay Bridge[23].

A few structure types cause a disproportionate amount of the estimated deaths in the scenarios studied. One of the most lethal structural types is concrete buildings built before 1980. Figure 9 shows the number of deaths[24] caused by each structure type at three times of day in the Magnitude 7.2 San Andreas fault scenario. This figure shows that concrete buildings built before 1980 are expected to be most lethal if an earthquake occurs during the day, but residential wood-frame soft-story buildings will cause the most deaths if an earthquake occurs at night. This difference is due to the different ways these types of structures are used and when they are most densely occupied. However, the collapse of just one multi-story, older concrete residential building would add significantly to the night-time casualty estimate.

Figure 10 presents averages of the estimated casualties for the various times of day and shows the percent of estimated deaths each structure type would be responsible for in a magnitude 7.2 San Andreas fault scenario event. This shows that, on average, concrete buildings built before 1980 are likely to cause about half of the estimated deaths, and residential wood-frame soft-story buildings are estimated to cause about one-third of the estimated deaths. All other building types would be responsible for a relatively small fraction of estimated deaths.

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[22] ATC, 1985.

[23] EERI, 1990.

[24] HAZUS® severity 4 casualties.

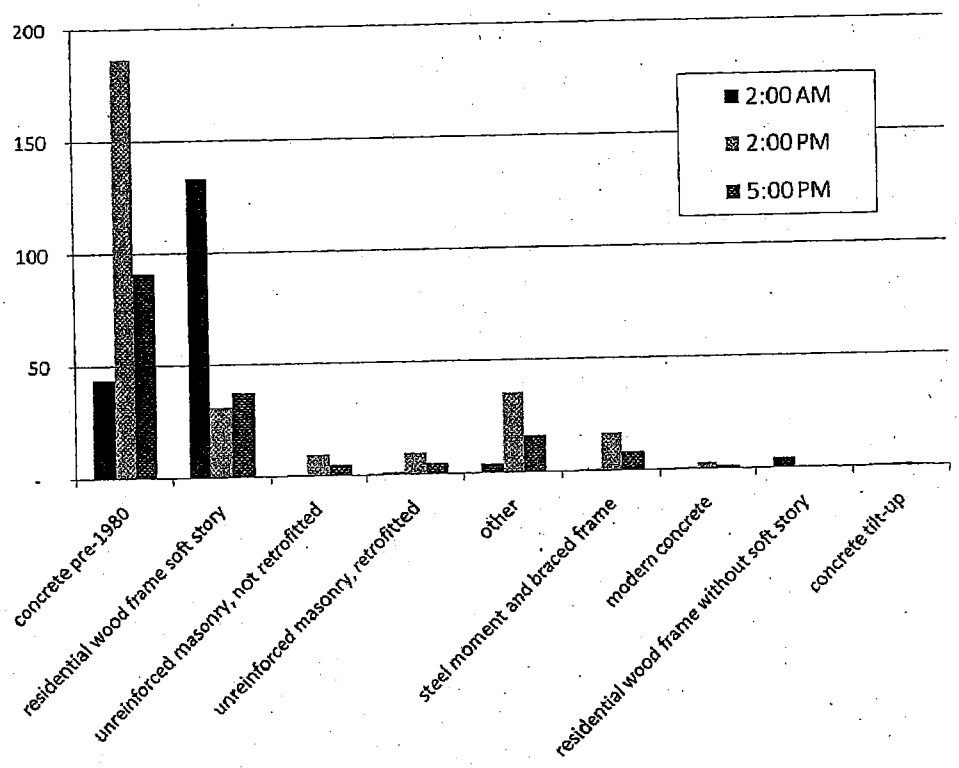


Figure 9 *Estimated deaths caused by each structure type for the magnitude 7.2 San Andreas fault scenario.*

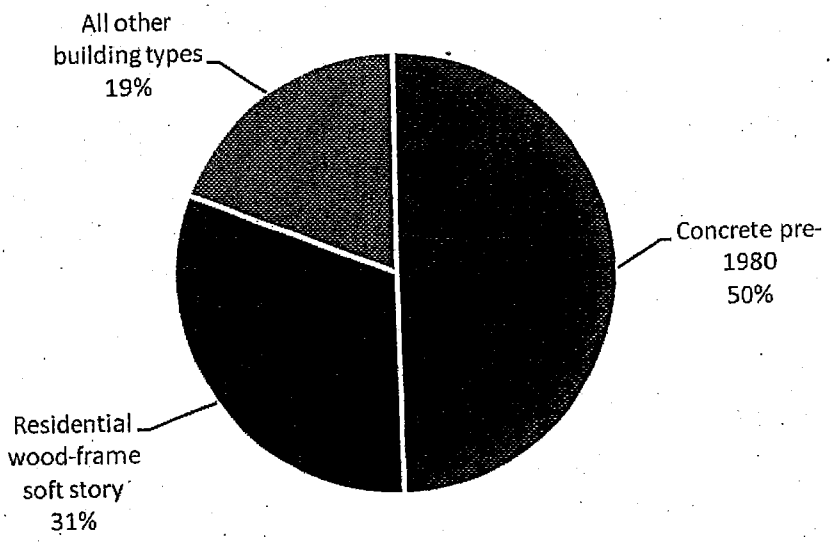
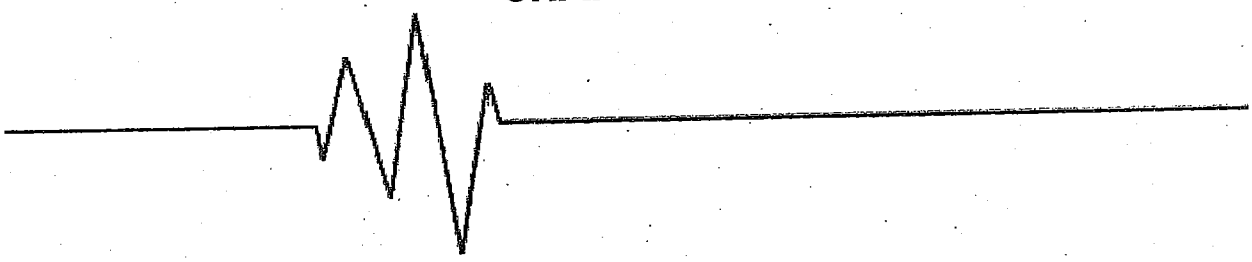


Figure 10 *Percent of HAZUS® severity 4 casualties attributable to various structural types in a magnitude 7.2 San Andreas fault scenario, averaged by time of day.*

Every death and injury the next earthquake causes will be a tragedy. However, there are also other types of losses that will have profound impacts on the entire City for years, perhaps decades, after the earthquake. The next chapter examines one of the most important of these: damage to housing.

CHAPTER 6: IMPACTS ON HOUSING



After an earthquake, many people will not be able to stay in their homes. For some, this displacement will last only a few days. For others, it could last years. This study estimates that after a magnitude 7.2 San Andreas fault earthquake, 85,000 dwelling units will not be safe to occupy. The buildings in which these units are located will require extensive repairs and could take years before they are usable again. Financing these repairs will be challenging, particularly since only about 6 percent of San Francisco residents carry earthquake insurance[25]. Building owners will need to rely primarily on loans and savings to repair and reconstruct their properties. It is the long and slow rebuilding and recovery process that follows the emergency that truly shapes what the post-earthquake San Francisco will be like. The recovery of housing is a critical part of that picture. This chapter looks into damage to the City's housing and identifies issues that will affect how long it takes people to get back into their homes.

The City's Housing

San Francisco's housing stock has unique characteristics that affect its vulnerability to earthquakes. The City's housing is old compared to other cities on the West Coast of the United States. Half of all of San Francisco's residential buildings were built before 1940, and over 80 percent were built before the mid 1970's[26], when building practices improved significantly. It is a City of renters: 65 percent of San Franciscans rent instead of own their homes[27], which affects building maintenance, post-earthquake repair, and how strongly residents are tied to the community. Finally, it is one of the densest large cities in the United States[28]. Many of its houses directly touch neighboring buildings, helping fires spread.

About 95 percent of the City's buildings are residential. These range from single-family homes to high-rise condominium and apartment towers. There are many different ways to look at the City's residential building stock. Figure 11 shows how the City's dwelling units are distributed among buildings of various sizes. The number of units in a building affects building and planning code regulations, condominium conversion, financing, and many other issues. Table 13 shows the number of residential buildings and units used for this study.

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[25] Marshall, 2010.

[26] Bay Area Economics, 2002.

[27] Claritas, 2009.

[28] Bay Area Economics, 2002.

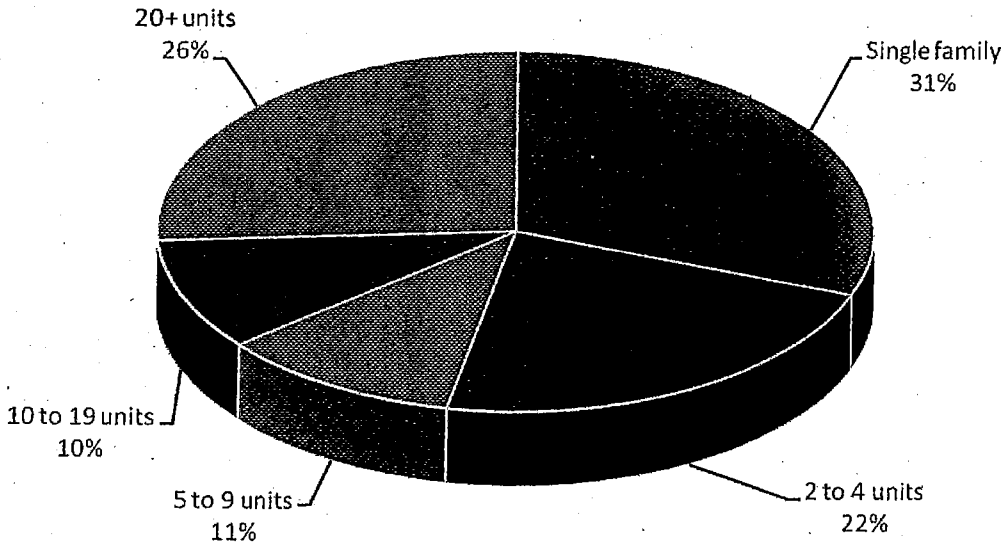

Figure 11 Percent of dwelling units in buildings of various sizes. Source: San Francisco Planning Department (2009)

Table 13 Number of Residential Buildings and Dwelling Units and Building Value Used in CAPSS Analysis

Size of Building	Number of Buildings[a]	Number of Dwelling Units[b]	Value[c] ($ Billions)
Single-Family houses	112,000	112,000	$53
Two unit residences	19,000	38,000	$22
Three or more unit residences[d]	23,000	180,000	$45
Total[e]	150,000	330,000	$120

a. These numbers are estimates for 2009.
b. Note that dwelling unit counts may vary from what is presented in other tables due to different source materials. The counts presented in this table represent a best effort using all available data sources to match building counts with unit counts.
c. These figures represent an estimate of the cost to replace or reconstruct a building in 2009. They do not include the value of the land the building sits on or a building's contents. Replacement values are significantly different than real estate prices or assessed valuation. Building value is based on square footage from the San Francisco Assessor's Tax Roll, not the estimated number of buildings.
d. Note that wood-frame residences with three or more stories and five or more units, discussed in the companion CAPSS report *Earthquake Safety for Soft-Story Buildings* (ATC 52-3 Report), are a subset of these buildings. That report discusses that there are an estimated 4,400 of those buildings built before May 1973, with 45,000 units, valued at about $14 billion. Many, but not all, have a soft-story condition.
e. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

Sources: This study, San Francisco Assessor's Tax Roll, Census data, San Francisco Planning Department, and San Francisco Department of Building Inspection.

Table 14 shows how the City's housing is distributed throughout its districts. This table shows that certain districts have many more housing units than others. Some districts largely consist of single-family homes (e.g., Ingleside, Excelsior and Twin Peaks), while others have mostly multi-family dwellings (Downtown, Marina, and Pacific Heights).

The vast majority of residential buildings in the City are constructed from wood; nearly all one- and two-unit residences are wood frame. This study estimates that 85 percent of dwelling units in buildings with three or more dwelling units are also in wood-frame structures. The remaining 15 percent of multi-family units are spread among buildings of many structural types, old and new.

Many dwelling units are located in structure types that are known to be vulnerable to earthquakes. This study estimates that about 55 percent of single-family houses have a garage or other opening at the ground level, giving them a potential soft-story weakness. Nearly 60 percent of units in buildings with three or more units are estimated to be in wood-frame buildings with an open ground floor and potential soft-story condition. This study estimates that about 10 percent of wood-frame residential buildings have been seismically retrofitted. An additional 8 percent of units are estimated to be in other structure types with known vulnerabilities,

Table 14 Distribution of Dwelling Units by District

District	Number of Dwelling Units[a]	Units in Single-Family Homes (%)	Units in Multi-Family Dwellings[b] (%)
Bayview	9,700	67	32
Central Waterfront	15,000	13	84
Downtown	51,000	2	98
Excelsior	25,000	82	17
Ingleside	7,700	90	9
Marina	8,400	11	89
Merced	7,100	41	59
Mission	53,000	28	72
North Beach	29,000	5	95
Pacific Heights	19,000	15	85
Richmond	29,000	30	70
Sunset	38,000	66	34
Twin Peaks	15,000	72	28
Western Addition	44,000	12	88

a. Note that dwelling unit counts may vary from what is presented in other tables due to different source materials.

b. For this table, multi-family dwellings are buildings with two or more units. Note that this table does not include mobile homes and residences classified as "other", which means that the last two columns do not sum to 100% in all districts.

Source: This study, Claritas (2009).

including concrete buildings built before 1980, retrofitted unreinforced masonry bearing wall buildings, and older steel-frame buildings with masonry infill walls.

Damage to Housing

Residential buildings are expected to suffer significant damage in the four scenario earthquakes studied in this report. Focusing only on one of these scenarios, the magnitude 7.2 event on the San Andreas, illustrates the scope of damage that could occur to the City's housing. Table 15 presents estimates of the amount of damage estimated to residential buildings for the magnitude 7.2 scenario on the San Andreas. These impacts on housing only consider damage from shaking and ground failure, and do not include impacts from fire. Key things to note are:

- About 25,000 residential buildings and 85,000 residential units (out of the City's 330,000 total dwelling units) would not be usable after the scenario earthquake. This means that about 74 percent of the City's dwelling units would be safe to occupy after a magnitude 7.2 San Andreas earthquake, allowing residents to shelter in place.
- Most of the residential buildings that cannot be occupied will be single-family homes, but most of the dwelling units that cannot be occupied will be in multi-family buildings.
- About 3,000 residential buildings with 11,000 dwelling units will need to be demolished. Some of these will be rent-controlled apartments that will no longer be under rent control when rebuilt, due to state law.

Table 15 Estimated Damage to City's Housing After M7.2 San Andreas Fault Scenario From Shaking and Ground Failure

Type of Housing	Usable, Light Damage[a]		Usable, Moderate Damage[a,b]		Repairable, Cannot be Occupied[a]		Not Repairable[a,c]	
	No. of Bldgs	No. of Dwelling Units	No. of Bldgs	No. of Dwelling Units	No. of Bldgs	No. of Dwelling Units	No. of Bldgs	No. of Dwelling Units
Single-Family	45,000	45,000	54,000	54,000	11,000	11,000	1,700	1,700
Two unit residences	8,200	16,000	7,400	15,000	3,200	6,400	290	580
Three or more unit residences	7,200	57,000	7,500	59,000	7,200	56,000	1,100	8,400
Total[d]	60,000	120,000	69,000	130,000	22,000	74,000	3,000	11,000

a. Building functionality categorizations are derived from HAZUS® damage states. For more information, please see the companion technical volume, *Potential Earthquake Impacts: Technical Documentation* (ATC 52-1A Report). Functionality categories are defined in section 3.2.
b. This level of damage can be referred to as "shelter in place".
c. Some of these buildings have collapsed. Others are standing but damaged beyond repair. None can be occupied.
d. Numbers in table have been rounded, which can make totals differ from sum of columns or rows.

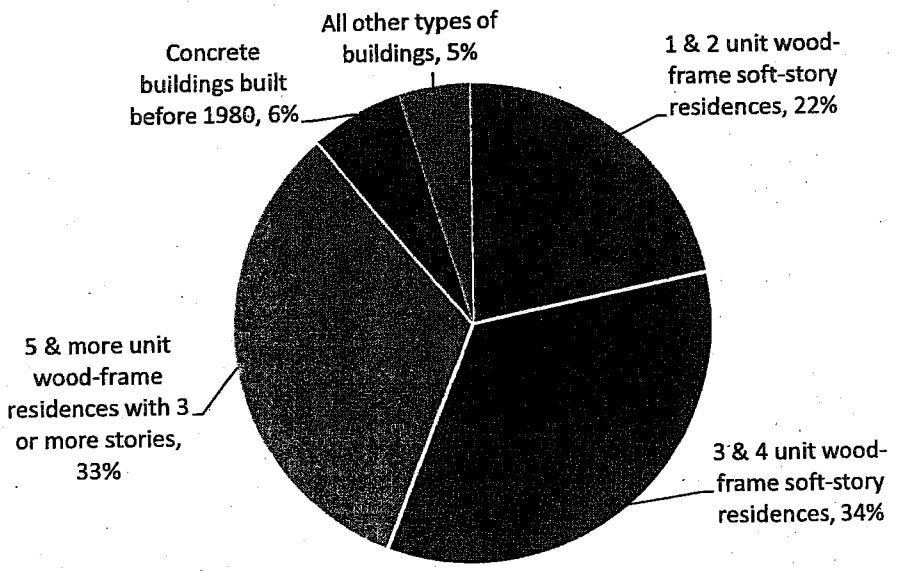

Figure 12 Breakdown of the 85,000 dwelling units that cannot be occupied after the magnitude 7.2 San Andreas fault scenario, by structural type.

Again, certain structural types are responsible for a disproportionate share of the damage to housing. Figure 12 divides the dwelling units that could not be occupied after the magnitude 7.2 San Andreas fault scenario by structural type. This figure clearly shows that approximately two-thirds of all unusable dwelling units would be in multi-family, wood-frame soft-story buildings.

Fire would destroy additional homes. For the magnitude 7.2 San Andreas fault scenario, the average fire scenario would burn an estimated 8.8 million square feet of building floor space that had not already been heavily damaged by earthquake shaking. About two-thirds of all the building square footage in the City is residential buildings. Assuming that about two-thirds of the burned area is in residential buildings would suggest that an additional 5,800 housing units would be lost due to fire[29].

San Francisco Planning and Urban Research (SPUR) has recommended a goal that 95 percent of residential units be available for residents to "shelter in place" after a significant earthquake, such as the magnitude 7.2 San Andreas fault scenario examined in this report[30]. This study estimates that, considering shaking, ground failure, and fire, about 72 percent of residential units could be used to "shelter in place" after a magnitude 7.2 San Andreas earthquake.

Recovery of Housing

The amount of damage that the City's housing stock sustains in future earthquakes is a critical factor in determining how well and how quickly the City rebounds and recovers. If most residents can be back in their homes quickly after an earthquake, it

[29] Assuming 1,000 square feet per residential unit.

[30] See SPUR, 2009. "Shelter in place" means buildings are structurally sound to survive aftershocks, although they may have considerable damage and utilities may not function.

would greatly speed all aspects of the City's recovery. Residents would be able to contribute to helping their neighbors and neighborhoods recover, and would remain close to their jobs, schools, businesses, and services. On the other hand, if many residences cannot be occupied for months or years after an earthquake (Figure 13), neighborhoods would have vacant buildings for extended periods, people may permanently relocate to new areas, perhaps outside the City, and the neighborhood businesses and services that depend on local customers would suffer.

Repairing and rebuilding homes damaged by an earthquake usually takes years, not months. The time for housing to get back in service is influenced by many factors and can vary a lot. Table 16 shows the length of time housing took to recover after two recent California earthquakes: Loma Prieta in 1989 and Northridge in 1994. Housing repair and reconstruction after San Francisco's next major earthquake will happen differently than occurred in either of these two events, but these data provide an interesting snapshot of the range of housing recovery times in localized events with moderate damage. When looking at the San Francisco data from Loma Prieta, it is important to note that all of the four scenarios studied by the CAPSS project would produce much stronger shaking and much more damage than occurred in the 1989 earthquake. The magnitude 7.2 San Andreas fault scenario would damage 25 times as many residences as were damaged in Loma Prieta[31]. San Francisco's recovery from a large earthquake could take up to ten years.

Many steps are required before a damaged building can be reoccupied. Building owners need to make decisions, hire design professionals to analyze damage and design repairs, hire construction professionals, get permits, arrange financing, and



Figure 13 Boarded up San Francisco residences after the 1989 Loma Prieta earthquake. Photo credit: Stephen E. Dickenson, Courtesy of the National Information Service for Earthquake Engineering, University of California, Berkeley

[31] Estimation based on tagging data reported in Comerio and Blecher, 2010.

Table 16 Average Time Required to Repair and Rebuild Housing After 1989 Loma Prieta and 1994 Northridge Earthquakes

Building Damage Level[a]	Loma Prieta Average Time to Reoccupy[b] (Months)	Northridge Average Time to Reoccupy[c] (Months)	San Francisco Average Time to Reoccupy After Loma Prieta[d] (Months)
Needed repair	11	25	7
Needed rebuilding	34	36	46

a. Only includes analysis of buildings with enough damage to be deemed unsafe to occupy.
b. Analyzed data from San Francisco, Hollister, and Watsonville.
c. Analyzed data from Los Angeles, unincorporated Los Angeles County, and Santa Monica.
d. San Francisco Loma Prieta results are based on a small dataset, and detailed timing information was not available for all damaged buildings.

Source: Comerio and Blecher (2010).

conduct cleanup and construction activities. All of this occurs in a time when they may have other personal or professional concerns due to earthquake damage. The many factors that can influence the pace of repair and rebuilding include the following:

- *Amount of building damage.* The amount of damage influences the length of time required for buildings to recover, both from the perspective of an individual building and citywide. Intuitively, a building with more damage takes longer to repair than a building with less. If there is a lot of damage in the City, all construction work takes longer because many of the construction resources in the Bay Area would be overwhelmed. There may not be enough skilled design and construction professionals to do required work without delay. Construction materials and equipment may be in limited supply. Building owners in other Bay Area communities will also have damaged properties and will also be using local resources to make repairs to their buildings.

- *Economy at time of earthquake.* If an earthquake occurs when the City's economy is strong, rebuilding would happen more quickly than if it strikes during a weak economy. There are many reasons for this. Financing for the work would be more readily available. Building owners may also have healthier finances. Landlords would be motivated to repair buildings quickly because they know rent-paying tenants would be eager to occupy the space. During economic downturns, owners are less able and motivated to act quickly. Housing recovered more slowly after the 194 Northridge earthquake than after the 1989 Loma Prieta event, in part because there were high residential vacancy rates in Los Angeles at the time[32].

- *Availability of financing.* Securing construction funds can be difficult as owners need to demonstrate the ability to repay loans and have sufficient equity to serve as collateral. Few owners would be helped by earthquake insurance, as discussed in the next bullet, which means that owners will need to rely primarily on loans and savings to finance repairs. After past disasters, lenders have sometimes been reluctant to finance repairs in heavily damaged

[32] Comerio, 1998.

neighborhoods due to concerns about reduced property values. As discussed below, building ownership can also affect financing. Owners with high debt-to-equity ratios may not qualify for repair loans. Some owners will be forced to default on loans and the damaged buildings would go into a foreclosure process.

- *Insurance.* Payments from insurance companies can help finance repair and rebuilding, but they can also lead to delays. Currently, only 6 to 7 percent of San Francisco residents carry earthquake insurance[33], which means that insurance payments would play a small role in financing San Francisco's reconstruction. Many more carry policies that cover fire damage. After disasters, it is common for insurance payouts to take many months. Often there are disputes about the amount of payment to be made. For example, for properties damaged by post-earthquake fire, insurance companies may want to investigate whether the structure was damaged by earthquake shaking prior to the fire and reduce payments if this is found to be the case. Those homeowners who do carry earthquake insurance may find that not all of their costs to repair or replace their building are covered due to high deductibles and limited coverage of these policies.
- *Building ownership.* Buildings with multiple owners may find it more difficult to arrange financing for repairs and reconstruction than buildings with one owner. Different owners may have varying levels of financial resources. Residential buildings with multiple owners include condominiums, co-ops, and the recently popular ownership model, tenancy-in-common (TIC). Unlike co-op ownership, in which members own shares of the corporation that owns the building, TIC residents actually co-own a parcel of real estate. This form of ownership has been popular in San Francisco in recent years because it offers would-be buyers an alternative to the City's condominium conversion regulations, and typically features a discounted sales price due to the added complication and cost of financing a TIC. The unconventional financing structure of TICs may present additional complexities in the repair process for those buildings. These buildings, however, are generally occupied by their owners, which leads to a high motivation to repair and reoccupy the property quickly after an earthquake.
- *Building use.* Multi-family housing, particularly rental housing, is repaired and replaced significantly slower than single-family housing. A year after Loma Prieta, 90 percent of the multi-family units destroyed or rendered unserviceable in the Bay Area were still out of service. Four years after the earthquake, 50 percent of these units had not been repaired or replaced[34]. For an owner of an apartment building, the incentive to rebuild is connected to his or her ability to enhance cash flow and to service debt. Owners have little incentive to rebuild if construction costs cannot be recovered through rents. For units serving lower-income households, access to construction financing is especially difficult.
- *Availability of construction professionals.* The Bay Area has a limited number of licensed contractors, skilled construction workers, and design

[33] Marshall, 2010.

[34] Camerio, et al., 1994.

professionals who must serve the entire Bay Area. A shortage of skilled workers can cause delays and make construction more expensive, which could lead to additional delays for some owners. Undoubtedly, design and construction professionals from outside the region will come to help rebuild.

- *Regulatory uncertainties.* Recovery occurs quickly if regulations guiding repair and rebuilding are clear. Regulations cover issues such as repair standards, when owners can demolish their buildings, what they are allowed to rebuild, rules particular to historic resources, and many other considerations. The City building and planning codes are complicated, with many steps and requirements for obtaining permits. The sheer quantity of buildings needing repair will pose a challenge to the City in the permitting process.
- *Construction logistics.* San Francisco is a dense city. Most residences have no front yards, small back yards, and little if any access along the sides that could be used to stage construction materials. Streets and sidewalks will probably need to serve this function, but they often are narrow, steep and busy. Construction supplies and equipment may be in short supply, causing further delays.

It is inevitable that the repair and reconstruction of housing after a damaging earthquake will take time. However, many of the problems described above can be mitigated by planning and preparation.

Impacts on Affordable Housing

Affordable housing is particularly slow to recover after natural disasters, as observed after Loma Prieta[35] and, more recently, after Hurricane Katrina[36]. San Francisco's affordable housing stock consists primarily of rent-controlled apartments, single room occupancy hotels (SRO's), and publicly-assisted housing. While all apartments in buildings constructed prior to June 1979 are covered by rent control, it is important to note that many of these units are currently renting at rates that would not be considered affordable to residents with the median City income, as shown in Table 17. Each time a unit is rented to a new tenant, apartment rents can be reset to market rates. This project estimates that 40 to 60 percent of rent-controlled apartments have rents that are at or close to market rates. The City has an estimated 160,000 rental units covered by rent control[37], 19,000 units in SRO's[38], and about 21,000 units of publicly-assisted housing[39].

Building demolitions in multi-family apartments could result in permanent loss of rent controlled apartments. When multi-family properties are demolished after an

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[35] Comerio et al., 1994.

[36] Rose, et al., 2008.

[37] This assumes that 75 percent of rental units are covered by rent control, Bay Area Economics, 2002.

[38] San Francisco Planning Department, 2009.

[39] Mayor's Office of Housing, 2010. Assumes 6,500 units of public housing, 6,000 households subsidized through HUD section 8, and 8,900 units assisted with financing or rent through US Department of Housing and Urban Development.

Table 17 Average Rent and Affordability in San Francisco

Median Annual Household Income, 2009	$70,818
Monthly income available for rent and utilities[a]	$1,770
Monthly utility payment[b]	$170
Affordable rent payment	$1,600
Average rent in San Francisco, June 2009	$2,323

a. Assumes 30 percent of gross household income spent on rent and utilities.
b. Based on San Francisco Housing Authority Utility Allowance chart.
Sources: San Francisco Housing Authority (2009), www.realfacts.com.

earthquake, the market would likely favor those properties being reconstructed as condominiums, rather than apartments. Under current conditions, buildings owners generally find that condominiums generate greater financial returns than do apartments, even in high-priced rental markets such as San Francisco. When demolished apartments are reconstructed, the new construction is not subject to the City's Condominium Conversion Lottery, and the lost rental units may therefore be replaced as ownership units. Similarly, new apartments replacing demolished rental units are not subject to the City's Rent Stabilization Ordinance, commonly known as rent control. Newly constructed buildings would also have a different look and character than the buildings they replace, contributing to a change in San Francisco's character.

Units renting at lower than market rate are often occupied by long-term residents, a significant percentage of whom are elderly. As a result, these residents will be seriously affected as they may have no alternate, affordable places to move. Often these units are older, may have deferred maintenance, and could be more susceptible to damage from an earthquake than typical multi-family residences. For example, more than 90 percent of units in SRO's are located in buildings built before 1920[40], and although the structural characteristics of these buildings are not known, anecdotal evidence suggests that many are highly vulnerable to damage in earthquakes, such as concrete- and steel-frame buildings with masonry infill walls and/or soft-stories.

In the scenario earthquakes studied, it is not known what percentage of housing units lost will be apartments that are currently rented at below-market rents. What is known is that the heavy damage to the City's housing stock is likely to cause the cost of housing of all types to rise as owners invest capitol to carry out repairs and tenants turnover due to loss of jobs and other disruptions. Owners will seek to pass through some costs of repairs to tenants. Vacant apartments may be in short supply, leading to price increases. Low and middle income residents displaced from their homes may no longer be able to afford to live in San Francisco.

After a large earthquake, the City's housing will be severely affected. Housing is a key part of having a functional city, but it is not the only part. People also need the City to have a functioning economy. The next chapter looks at the impact of future earthquakes on the City's businesses.

[40] Analysis of date of construction of SRO's conducted by this study based on data from the San Francisco Department of Building Inspection.

CHAPTER 7: EARTHQUAKE DAMAGE IMPACTS ON BUSINESSES, JOBS AND THE ECONOMY

San Francisco's economy depends on a complex and interdependent mix of many elements. Businesses need to be open to provide services and support the economy. Housing needs to be available to the City's workers and customers. Utility systems and transportation networks need to function. These issues are affected by building and infrastructure damage and the time needed to conduct repairs, as well as how prepared businesses are to cope following earthquakes. This chapter describes how the buildings that house businesses could be affected by future earthquakes, and the impacts that could flow from this damage. One business' loss could be another's gain, and losses experienced in San Francisco may be gains in other jurisdictions as customers or businesses relocate and the mix of residents and workers change.

This study estimates that losses to building contents and losses due to business interruption could increase direct building damage losses by 30 to 40 percent. For the magnitude 7.2 San Andreas fault scenario, this would put direct economic loss at $40 billion. Ripple effects due to damaged businesses would add to these losses, making the economic impact of an earthquake on par with or greater than a recession. Earthquake damage could encourage some companies to relocate all or some of their employees out of San Francisco or the Bay Area. Small businesses would feel particularly heavy impacts.

Damage to Commercial and Industrial Buildings

San Francisco's commercial and industrial buildings take many different forms. Some are modern high-rises. Others are early high-rises that went through the 1906 earthquake. Many are smaller buildings used for a variety of industrial, retail, and office functions. They have considerably more variety in their structural make-up than the City's residential buildings. Many buildings incorporate both residential and commercial functions. A common example of this is the wood-frame apartment building with ground floor retail space, often with a soft-story condition, that is highlighted in the companion CAPSS report, *Earthquake Safety for Soft-Story Buildings* (ATC 52-3 Report).

In general, San Francisco's commercial building stock is more seismically resistant than the City's housing stock. Many commercial buildings have been seismically retrofitted as a requirement of lenders or insurers or as part of a major renovation. Some older commercial buildings have been demolished and replaced with newer buildings that use modern seismic codes. Buyers, sellers, lenders, and renters of commercial properties are generally more sophisticated and better informed than their residential counterparts.

However, as presented previously in this report, commercial buildings are likely to suffer significant damage in the four scenarios studied. The estimates of direct damage to commercial and industrial buildings are:

- $4 to $11 billion to repair or replace damaged commercial buildings, depending on the earthquake scenario. Two-thirds of these losses occur to buildings in the Downtown district.
- $1 to $2 billion to repair or replace damaged industrial buildings, depending on the earthquake scenario. These losses are concentrated in the Bayview, Downtown, Central Waterfront, and Mission districts.
- More than 900 commercial buildings and 500 industrial buildings would not be occupiable after a magnitude 7.2 San Andreas fault scenario.
- Nearly 300 commercial buildings and more than 200 industrial buildings would be damaged beyond repair after a magnitude 7.2 San Andreas fault scenario. These buildings will be rebuilt differently, and could contribute to changing development patterns in some of San Francisco's neighborhoods.

Commercial buildings may get repaired more quickly than residential buildings if owners can finance repairs and are motivated to get rent-paying tenants back in place. However, the pace of rebuilding is highly dependent on market conditions at the time of the earthquake. In a time of high commercial vacancy rates, it could take years before all buildings are fully functional because owners may be loathe to reinvest immediately in repairs for buildings that may be unrented or would rent at low rates. When commercial vacancy rates are low, building owners will be motivated to conduct repairs as quickly as possible, but in the short-term, businesses could find it challenging to locate temporary space while they await repairs to their damaged buildings.

Some retail and office establishments can reopen in a new location before their original building is repaired, which means that many businesses may begin the recovery process long before their pre-earthquake location is fully functional. This might leave some building owners without tenants once repairs are complete. Some businesses will be able to use telecommuting to resume activities before their office space is usable, contingent upon functioning utilities. However, even businesses in buildings that remain functional or those that are easily repaired can be affected if their customers and employees relocate, or if the damage to nearby buildings makes the neighborhood commercially undesirable.

Direct Economic Losses in Addition to Building Damage

The direct physical damage to buildings is only one component of the economic losses due to earthquakes. Many different types of economic losses flow from the building damage and loss of functionality described in previous chapters of this report. The additional types of direct losses estimated by this project include[41]:

- *Contents damage.* This includes furniture, computers, supplies, and equipment that is not integral with the structure. It does not include inventory (counted separately, below) or integral components such as lighting, ceilings, mechanical and electrical equipment, and other fixtures, which are included in building damage.

[41] Adapted from FEMA, 2002.

- *Inventory loss*. The value of inventory varies considerably by type of business. Typically, inventory damage occurs when items fall off shelves or are damaged by water from broken pipes.
- *Relocation loss*. This includes the costs of relocating and the rental of temporary space. Relocation costs are estimated only for some uses; others, such as theatres and parking facilities, are assumed to close until repaired.
- *Output loss*. This includes income associated with business profits, gross receipts, or revenues.
- *Rental income loss*. This includes rents for residential, commercial, and industrial properties.
- *Income and wage loss*. This includes losses to wages and salaries. In some cases, wage losses can be partially recaptured by overtime work once a business resumes.

Table 18 presents estimates of the total direct economic loss resulting from the four scenarios studied. Note that these losses do not include indirect losses in businesses not sustaining direct damage, which are discussed later. Further, these losses are only those attributable to damage to privately-owned buildings, and this project did not put resources into modeling the vulnerability and economic losses associated with the City's infrastructure (roads, bridges, transit systems, water system, sewer system, electrical system, telephone system, gas system, etc.). In the four scenarios studied, the estimated direct economic losses beyond the costs of damage to buildings are about 30 to 40 percent of the costs to repair and replace damaged buildings.

Table 18 Estimated Total Direct Economic Losses in Four Scenario Earthquakes

Scenario	Direct Losses in Four Scenario Earthquakes[a] ($ Billions)			
	Damage to Buildings	Additional Damage Due to Fire[b]	Additional Economic Losses	Total Losses
Hayward Fault, Magnitude 6.9	$14	$2.7	$5.4	$22
San Andreas Fault, Magnitude 6.5	$20	$3.0	$6.8	$30
San Andreas Fault, Magnitude 7.2	$30	$4.3	$10	$44
San Andreas Fault, Magnitude 7.9	$48	$5.8	$15	$69

a. Estimates are in 2009 dollars.
b. These figures do not double count shaking damage (i.e., burning rubble)

Ripple Effects of Business Losses

When businesses shut down, even temporarily, the loss of revenue ripples through the local economy, creating a negative multiplier effect. These closed or suspended businesses do not support other businesses; workers do not spend their incomes on consumer goods. This analysis uses estimates of lost revenues from business

interruption, in conjunction with the IMPLAN[42] input-output model, to estimate the economic impacts of business interruption following a magnitude 7.2 earthquake along the San Andreas fault.

Two additional types of economic losses are estimated, described below:

- *Indirect Impacts.* This refers to the impacts of business closure or slowdown on other businesses. For example, a legal office that needs to close due to earthquake damage no longer purchases office supplies. Thus, the firm that sells those office supplies suffers economic losses due to damage to its customer, even if the office supply company suffered no damage itself.
- *Induced Impacts.* This refers to the impacts of household expenditures. When households earn income, they spend part of that income on goods and services. In the example described above, the induced impacts include the reduced expenditures of employees at the legal firm, as well as the reduced expenditures of people who work in the office supply company that depends on business from the legal firm. Only the disposable incomes from San Francisco workers are analyzed.

The business interruption losses due to a magnitude 7.2 San Andreas fault earthquake would generate a loss of approximately $650 million in indirect activity, or business-to-business lost expenditures within the City of San Francisco. The greatest decreases in output would occur in the real estate, banking, and insurance sectors, as these sectors provide services to the broadest array and largest number of businesses.

In addition to the indirect impacts, the business interruption losses would also generate induced citywide losses (that is, lost household expenditures) of approximately $840 million. Induced impacts represent the impacts of household expenditures of workers in the directly affected and indirectly affected firms. The greatest induced output losses would occur in the payments to housing, wholesale trade, and eating and drinking establishment sectors.

The total losses from business interruptions following an M7.2 San Andreas fault earthquake would represent approximately 2.8 percent of total citywide economic activity. As a measure of comparison, since 1960, recessions in the United States have averaged a 1.7 percent decline in economic output from peak to trough. This suggests that the economic effects of the earthquake would be on par with or greater than a recession. It is also important to note that these impacts would be over and above the damage to buildings and other losses described previously.

This analysis does not account for business interruption losses associated with fire or damage to utilities and transportation systems. These impacts can be significant. Additionally, behavioral responses to the earthquake could also affect the local economy, but that is not factored into this analysis. For example, people's fear about earthquakes could compel them to leave the region or forestall investments in the area.

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[42] The economic model used in this analysis, IMPLAN ("IMpact analysis for PLANning"), is a PC-based computer software package that automates the process of developing input-output models for regions within the United States. The IMPLAN model is well-respected as the industry standard for projecting economic impacts resulting from future "events." Details of this analysis are presented in the companion CAPSS volume, *Potential Earthquake Impacts: Technical Documentation* (ATC 52-1A Report).

Notwithstanding these conclusions, certain industries would conceivably recover more rapidly following the earthquake than others. The construction industry and its suppliers, for example, would likely see a boost in activity, particularly as federal assistance, state aid, and insurance payments are injected into the economy. This kind of response could mitigate some of the negative economic impacts of the earthquake. The economic benefits that come from reconstruction have not been quantified or considered in this analysis.

The City's Economy and Jobs

Businesses in San Francisco employ approximately 570,000 people, with employment well-distributed among a range of sectors (Table 19). This diversity contributes to the City's economic resiliency as the employment base is not

Table 19 San Francisco and Bay Area Employment by Sector[a]

Industry Sector	San Francisco		Bay Area		San Francisco as Share of Bay Area (%)
	Jobs	% Total	Jobs	% Total	
Professional and technical services	130,000	22%	590,000	18%	21%
Government[b]	97,000	17%	450,000	13%	22%
Leisure and hospitality	79,000	14%	340,000	10%	24%
Financial activities	58,000	10%	190,000	6%	30%
Education and health services[c]	56,000	10%	380,000	11%	15%
Retail trade	44,000	8%	330,000	10%	13%
Other services, except public admin.	38,000	7%	160,000	5%	24%
Information	19,000	3%	110,000	3%	17%
Construction	19,000	3%	180,000	5%	11%
Wholesale trade	12,000	2%	120,000	4%	11%
Manufacturing	11,000	2%	340,000	10%	3%
Unclassified	2,000	0.4%	12,000	0.4%	18%
Natural resources and mining	290	0.1%	22,000	0.7%	1%
Utilities	(d)	(d)	5,500	0.2%	(d)
Transportation and warehousing	(d)	(d)	54,000	2%	(d)
Total[e]	570,000	98%	3,300,000	97%	17%

a. Includes all wage and salary employment covered by unemployment insurance.
b. Government employment includes workers in all sectors, not just public administration. It includes public school employees.
c. This does not include public school employees.
d. Indicates that data have been suppressed for confidentiality reasons. The data are suppressed when there are fewer than three establishments in the industry, or if a single employer makes up more than 80 percent of that industry's employment.
e. Numbers in table have been rounded, which can make totals differ from sum of columns or rows. Totals do not sum to 100% due to suppressed data and rounding.

Sources: This study, California Employment Development Department (2009).

dependent on one or two sectors that might be disproportionately affected by an earthquake. Diversity allows the economy to improvise, innovate, and perform resource substitution following a disaster.

In terms of the City's economic role in the Bay Area, San Francisco serves as the regional center for the finance and professional and technical services industries. While San Francisco only has 17 percent of total Bay Area employment, it contains 30 percent of the region's financial activities jobs and 21 percent of the region's professional and technical services jobs. San Francisco has evolved into a regional finance and business hub because it offers companies an internationally recognized address and lifestyle amenities, which appeal to workers in these sectors. In addition, the City's density benefits these firms, which place a high value on face-to-face interaction. San Francisco is also the regional center of the leisure and hospitality industry, containing 24 percent of Bay Area jobs in this sector. This role has evolved thanks to San Francisco's distinct urban amenities, art, culture, entertainment, retail, and dining options, which make it an international tourist destination.

Figure 14 illustrates the long-term historic trends associated with the finance and professional and technical services industries in San Francisco. The number of San Francisco jobs in the finance sector has generally declined since the early 1990's, with a spike in 2001 at the height of the "dot-com" boom. Meanwhile, the professional and technical services industry has been highly volatile, growing and shrinking in tandem with the economic cycle. The dot-com boom and bust led to a peak, followed by a sharp contraction in the early part of this decade. The industry subsequently recovered between 2004 and 2008. In comparison, the leisure and hospitality industry has shown more stability, growing gradually since 1990.

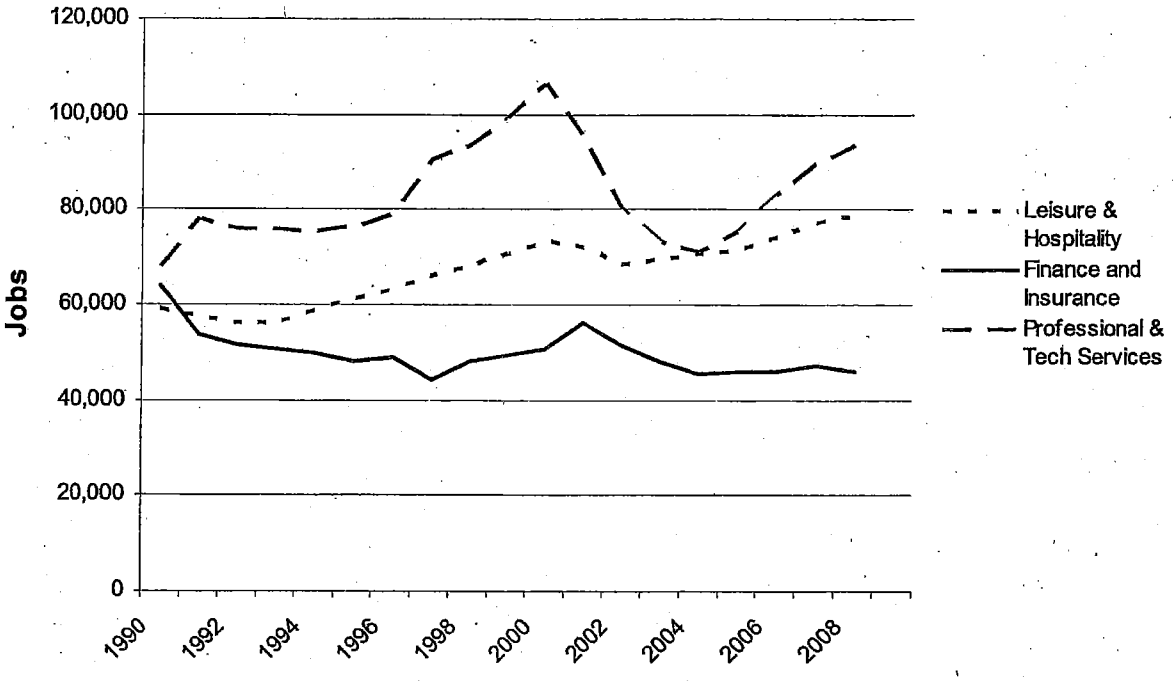


Figure 14 San Francisco jobs in key sectors, 1990-2008.
Source: California Employment Development Department (2009).

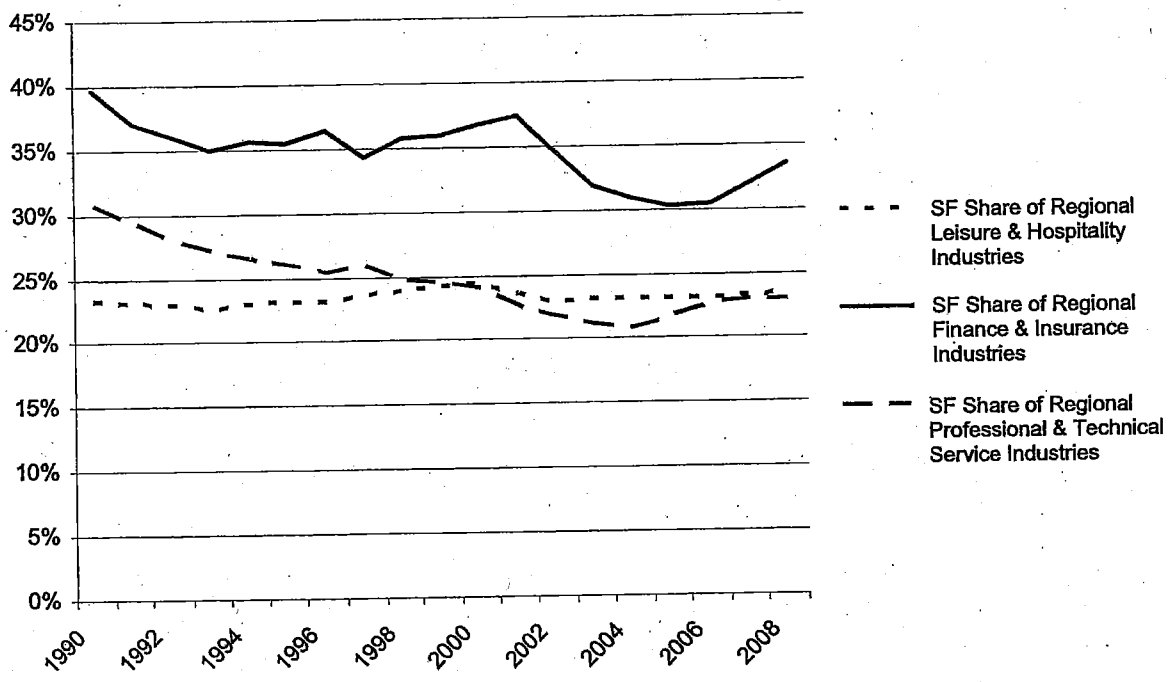


Figure 15 San Francisco jobs as share of Bay Area jobs in key sectors, 1990-2008. Source: This study, California Employment Development Department (2009).

Figure 15 presents San Francisco's regional share of these three key industries over the last two decades. Since 1990, the City's share of the regional jobs in the finance and professional and technical services sectors has generally declined. This trend is a result of the maturation of Silicon Valley and other parts of the Bay Area as viable locations for these industries. As information and technology firms have emerged in San Mateo, Santa Clara, and Alameda counties, finance and professional services firms that interface with these industries have followed their geographic lead.

As discussed previously, commercial space in San Francisco's downtown—the primary location of the City's finance and professional services sectors—would experience significant damage in the scenario earthquakes studied. In a magnitude 7.2 San Andreas fault earthquake, 21 million square feet of commercial space in the City would suffer structural damage that makes it unsafe to occupy. These damage estimates, coupled with the long-term employment trends discussed above, suggest that while the City could retain its status as a regional finance and professional services center over time, a major earthquake does have the potential to accelerate the ongoing dispersal of these industries throughout the Bay Area or even outside the Bay Area following earthquakes. This dispersal may be more pronounced if utilities are not restored rapidly, San Francisco municipal services do not respond effectively and quickly, or if commercial buildings are rendered unsafe for an extended period of time. Under these conditions, companies may opt to maintain a San Francisco presence, but shift the bulk of workers to other parts of the Bay Area. In recent years, a number of large employers have chosen to relocate much of their workforce to less expensive communities. An earthquake could encourage more companies to make this decision. San Francisco has worked hard to attract cutting edge, high-tech businesses, but these businesses are often highly mobile and could relocate easily.

In contrast with the finance and professional service sectors, San Francisco's share of the regional leisure and hospitality industry has remained steady at 23 to 24 percent of total Bay Area jobs in this sector since 1990. This stability is a positive sign of the industry's economic resilience. Certainly, post-disaster studies indicate that the City should expect a decline in visitors and contraction of the tourism industry immediately following an earthquake. A study of the 2008 earthquake in Sichuan, China found significant declines in tourism following the main shock[43]. Analysis of the September 1997 earthquake in Umbria, Italy showed arrival declines up to 50 percent in the city of Assisi, a major tourist destination, in the month after the earthquake, though arrivals did begin to rebound over the following year[44]. In addition, a 2007 analysis of the New Orleans economy following Hurricane Katrina showed a loss of 22,900 tourism jobs in the 10 months following the event[45]. Impacts along these lines would hurt businesses that rely heavily on tourist spending, and financially tenuous businesses may be forced to close, unable to weather the drop in revenues. Despite these impacts, however, in the long run, San Francisco would retain the unique characteristics and attractions that make it an international tourism destination.

San Francisco benefits from being part of an economically vibrant region. Jobs are spread throughout the region, with concentrations in Alameda, San Francisco, and Santa Clara counties. This geographic distribution improves the Bay Area's economic resilience by essentially disseminating the risk of an earthquake across multiple areas. In contrast, if a vast majority of jobs occurred in a single area, a severe disaster at that site would have a much more significant impact on the regional economy.

Small and Neighborhood Serving Businesses

San Francisco's unique features include the many local shopping areas with small, independent businesses that serve their neighborhoods. These establishments help give each neighborhood an individual character, and contribute numerous jobs to the City's economy. Neighborhood businesses provide services, supplies, and conveniences that allow for efficient living and also serve those with language or ethnic preferences. These businesses play an important role in the City's recovery by providing essential local services to residents and contributing to the charm and community character that makes people want to stay in San Francisco. The City has emphasized the importance of these local establishments through recent laws regulating chain stores, and by developing programs such as small loans to establish local businesses.

Small businesses comprise the vast majority of local firms. Almost 89 percent of San Francisco's businesses have 10 or fewer employees, and another 6 percent have 11 to 25 employees. Altogether, firms with 25 or fewer workers contain 38 percent of the City's total jobs, as shown in Table 20.

Small businesses are more vulnerable than large firms to disruption following a natural disaster, as they are less likely to carry insurance and are rarely diversified in

[43] Yang, et al., 2008.

[44] Mazzocchi and Montini, 2001.

[45] Dolfman, Wasser, and Bergman, 2007.

Table 20 San Francisco Firms and Jobs by Number of Employees in Firm

Number of Employees	Firms		Jobs	
	Number	% of Total	Number	% of Total
0 – 4	56,000	76%	100,000	16%
5 – 10	9,300	13%	64,000	10%
11 – 25	4,700	6%	79,000	12%
26 – 50	2,000	3%	73,000	11%
51 – 75	510	1%	32,000	5%
76 – 125	500	1%	48,000	7%
126 +	500	1%	250,000	39%
Total[a]	73,000	100%	660,000	100%

a. Numbers in table have been rounded, which can make totals differ from sum of columns or rows. Total may be inconsistent with other tables due to varying data sources and enumeration methodologies.

Source: Dun and Bradstreet (2008).

terms of products and services. They also often lack the resources to address equipment and inventory damage and interruptions in utility service and transportation networks. Damage to other nearby businesses and residences may also reduce customer traffic, further compounding the economic hardship. In addition, locally-owned businesses face greater difficulty in recovering from disasters compared to their chain competitors, whose operations and profits are not dependent on a single store.

Small retailers appear to be the most vulnerable to major earthquakes. Following the southern California Northridge earthquake, businesses reported that for some time after the earthquake, residents changed their spending patterns, disrupting operations. The highest job loss resulting from the Northridge earthquake was in the retail industry (24 percent of total losses). Some small businesses failed as a result of the Northridge earthquake, as long as two years after the event[46].

A study of the 2001 Nisqually earthquake in the State of Washington also highlighted the vulnerability of small retailers[47]. Of the 13 industries surveyed, retail businesses reported higher rates of both direct physical losses (buildings and equipment) and reduced revenue as a result of lost inventory. This was attributed to the fact that retailers have a higher portion of their assets invested in inventory than most businesses.

Worker Access to Jobs

Following an earthquake, workers' ability to get to their jobs is a key component of a community's recovery. Returning to work allows workers to receive a paycheck,

[46] Petak and Elahi, 2000.

[47] Meszaros and Fiegener, 2002.

provides residents and businesses access to necessary goods and services, and generally restarts the local economic engine.

Table 21 shows commute patterns in San Francisco, as reported by the 2000 Census[48]. Approximately 77 percent of San Francisco's employed residents work in the City, suggesting that the majority of San Francisco residents will be able to reach their jobs following an earthquake. However, 45 percent of San Francisco jobs are held by people who live outside the City. To the extent transportation systems are damaged and inoperable after an earthquake, this could have a significant short- and mid-term impact on the local economy, and could slow recovery. Job access also depends on workers having access to support systems, such as day care and elder care.

Communications technology offers some workers the ability to telecommute, assuming utilities and workplace systems remain operational. Looking at San Francisco's major industries, the financial activities and professional services sectors could operate more effectively though telecommuting than sectors that require

Table 21 San Francisco Commute Patterns

Where San Francisco Residents Work	Number	%	Where San Francisco Workers Live	Number	%
San Francisco	320,000	77%	San Francisco	320,000	55%
Oakland	8,900	2%	Oakland	30,000	5%
South San Francisco	8,800	2%	Daly City	25,000	4%
Redwood City	5,200	1%	Berkeley	9,800	2%
San Mateo	4,600	1%	South San Francisco	8,500	1%
Palo Alto	3,700	0.9%	Pacifica	7,125	1%
Burlingame	3,600	0.9%	Richmond	6,900	1%
San Jose	3,400	0.8%	Alameda	6,900	1%
Berkeley	3,200	0.8%	San Mateo	5,800	1%
Other Bay Area[a]	43,000	10%	Other Bay Area[a]	130,000	23%
Other places in CA	11,000	3%	Other places in CA	28,000	5%
Out-of-state[b]	1,600	0.4%	Out of state[b]	4,000	0.7%
Total[c]	420,000	100%	Total[c]	590,000	100%
San Francisco residents Out-commuting	95,000	23%	San Francisco workers In-commuting	270,000	45%

a. Other Bay Area includes other areas in Alameda, Contra Costa, Marin, Napa, San Mateo, Santa Clara, Solano, and Sonoma counties that are not specifically listed.
b. Out-of-State includes Census Designated Places (CDP's) that cannot be broken down into localities.
c. Figures may not match other tables due to different source materials.
Sources: U.S. Census (2000), Census Transportation Planning Package (CTPP).

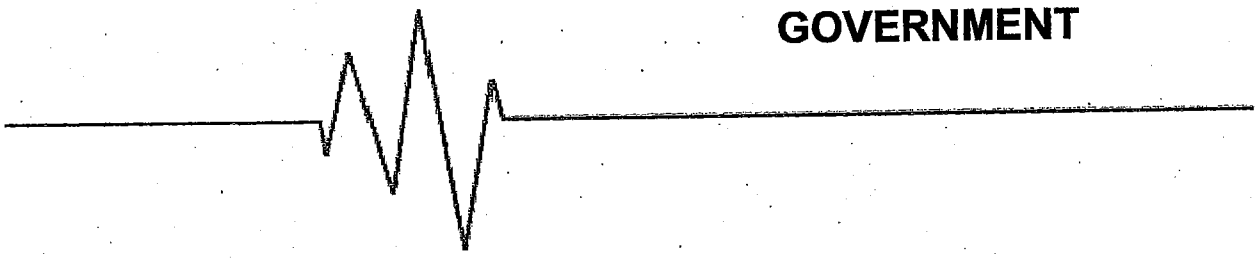
[48] Latest available data.

employees to be present for direct contact with customers or physical activities. Workers in the government, leisure and hospitality, education, and health services industries would be less able to function remotely.

Damaged areas benefit economically from increased employment in the construction trades and an influx of workers and government and private recovery funds from outside the area. Recovery will require trained workers and contractors from outside the region. Temporary workers, insurance adjustors, and state and federal recovery workers will need nearby housing and transportation. Some of these people may relocate permanently, but most will send much of the money they earn to homes outside of San Francisco and may purchase and transport some construction supplies, furnishings, and other materials from outside the region.

City government plays a big role in getting damaged privately-owned buildings repaired or replaced quickly, making the community function again. However, damage to privately-owned buildings also affects how well the City government functions. The next chapter looks at how the damage estimated in this report might affect the City government.

CHAPTER 8: IMPACTS ON CITY GOVERNMENT



San Francisco will need strong leaders and capable city institutions to help the City respond to, rebuild after, and recover from future earthquakes. A large earthquake will affect the ability of the City government to function effectively, just as it affects housing, businesses, and other elements of the City. This report focuses only on damage to privately-owned buildings, which means that facilities owned by the City are not addressed[49]. Damage to private buildings, however, will significantly impact City government.

After an earthquake, the City will see a decline in key revenue sources. This decline will occur at a time when many residents are most in need of assistance from the City, and the City's costs to provide social services and help reconstruction would dramatically rise. San Francisco City government receives revenues from a variety of sources, including taxes on property, sales, payroll, hotels, and parking. Table 22 shows the major sources of City revenue for the fiscal year ending in June 2009. The income from a number of these sources could go down after a damaging earthquake.

Table 22 Sources of Revenue for San Francisco General Fund in Fiscal Year 2008/2009

Revenue Source	Amount ($ Millions)	Percent of Total
Property taxes	$1,000	37%
Intergovernmental	$650	24%
Business taxes	$390	14%
Hotel room tax	$160	6%
Charges for services	$140	5%
Other local taxes	$130	5%
Sales and use tax	$100	4%
Utility users tax	$90	3%
Licenses, permits and franchises	$25	0.9%
Rents and concessions	$19	0.7%
Other	$11	0.4%
Interest and investment income	$9.2	0.3%
Fines, forfeitures and penalties	$5.6	0.2%
TOTAL	$2,700	100%

Source: San Francisco Controller's Office (2009).

[49] In recent years, San Francisco has invested significant resources into improving the seismic safety of key City buildings and infrastructure, particularly facilities needed for emergency response, but known vulnerabilities remain.

Property tax revenues are generated from taxes levied on the assessed value of buildings and land. After an earthquake, the assessed value for land may remain unchanged for most properties. However, if a building was significantly damaged, the property owner could file an appeal seeking a reduction in property taxes due to the decline in the value of the building from this damage. Once reconstruction was complete, the property would be reassessed, but there would be a short-term loss in property taxes. Some people may default on tax payments. This study does not estimate how quickly property tax revenues might recover in the City, and property tax revenue restoration will depend on factors such as the number and type of buildings that are repaired and reconstructed, the speed of the City's reconstruction effort, and how quickly and on what basis properties will be re-assessed once they are rebuilt.

Similarly, other sources of City revenue can be expected to decline in the short and medium term after an earthquake. Many retail establishments would be forced to close due to earthquake and fire damage to the building. While some of these establishments could be relocated or could re-open once their buildings are repaired, there will likely be both short- and long-term losses in retail sales tax. Impacts on businesses could result in reductions in payroll taxes. It is likely that the City will see fewer visitors for some years after a large earthquake, resulting in lower revenues from hotel taxes. Parking revenues would decrease. Other revenue sources could be affected, as well.

The City will receive some funds from the federal government. The Stafford Act provides funds, with some limitations, for the repair of state and local government and certain non-profit facilities on a matching basis, and for other emergency response expenses. However, these funds are likely to cover only a fraction of the City's increased expenses due to an earthquake. Very little federal funding is available for owners suffering losses to the privately-owned buildings studied in this report.

It is important to note that during the current economic downturn, both the state and the City had to lay off and/or furlough workers to reduce their budgets. Reduced staffing or financial capacity may affect their ability to respond to an emergency such as a significant earthquake. While municipal and State finances will eventually recover in tandem with the economic cycle, the current fiscal concerns would lead to a slower recovery if damaging earthquakes occurred during this period.

The City's pace of recovery depends on how quickly buildings—homes, offices, stores, etc.—get repaired or rebuilt and back in service. The speed with which this happens is directly linked to the ability of City departments—Building Inspection, Planning, and others—to review plans and issue permits for the many thousands of buildings that will need work. After a magnitude 7.2 earthquake on the San Andreas, it is reasonable to assume that up to two-thirds of all buildings in the City will require permits for repair or demolition and reconstruction work, although some building owners with moderately-damaged buildings will choose to do the work without permits or cover up damage rather than repair it. The City will need to rely on an interim permit process to allow work to proceed quickly, but with adequate oversight and inspection.

In addition to financial impacts, a large earthquake will reduce the City's ability to focus on other important policy goals. Programs on homelessness, health, environment, and other issues important to San Francisco's people will likely suffer

setbacks or delays. Possible environmental impacts of an earthquake can be used to illustrate this. Currently, the City has nearly met its goal of diverting 75 percent of its waste stream from landfills by 2010. A magnitude 7.2 San Andreas fault scenario earthquake is estimated to result in 6.8 million tons of debris from damaged buildings. Although much of this debris may be recyclable, it is probable that the need to clear debris quickly so rebuilding can start will mean that a large share of it is sent to landfills. A magnitude 7.2 earthquake would produce waste equating to nearly 14 years of trash generation[50]. Rebuilding damaged buildings will require resources, as well, in the form of newly harvested lumber and other construction materials. Newly constructed buildings will probably be very energy efficient, complying with San Francisco's stringent green building requirements. However, specialists estimate that 15 to 20 percent of a building's energy consumption during its lifespan occurs during the extraction, processing, and assembling of raw materials into the finished building[51]. This means that, typically, saving an existing building is more energy efficient than constructing a very energy efficient new building. A final example of an environmental impact from an earthquake could be the release of hazardous materials. There were numerous hazardous materials releases in San Francisco due to the moderate shaking in Loma Prieta, including spills of chemicals, paints, pesticides, and mercury[52]. A larger earthquake could cause much more significant releases that harm the people, land, water, flora, and fauna of the City and region.

Future earthquakes will damage the City's buildings and affect its housing supply, businesses, and government functions. Can San Francisco rebound from this damage? The next chapter puts all of the pieces together to examine how San Francisco's people would recover from future damaging earthquakes.

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[50] Calculation based on figures from 2007 and 2008, from SF Environment website (sfenvironment.org) and Upton, 2009.

[51] Hays and Cocke, 2009.

[52] Perkins and Wyatt, 1994.

CHAPTER 9: THE RESILIENCE OF SAN FRANCISCO AND ITS PEOPLE

The analysis presented in this report makes it clear that future large earthquakes would damage thousands of San Francisco's buildings and have significant repercussions on the activities that occur inside them. This chapter looks at what this damage means for San Francisco. How will the people of San Francisco cope? Will the City be able to rebound and thrive after such an event? This analysis suggests that, yes, in the long-term, the City will continue to thrive after a large earthquake. San Francisco is a strong and robust City situated in a strong and robust region. It will, however, take time for the City to recover, and not all of the City's residents will recover to the same degree. After a large earthquake, the City will change. Some people will lose their assets, with ramifications on their lifestyle, such as the inability to afford college or loss of homeownership. Others will thrive and help shape the new City.

Factors that Affect San Francisco's Long-Term Recovery

Many issues contribute to what San Francisco will be like after it recovers from future damaging earthquakes. Some key components of this—housing and business activity—were explored in previous chapters. Another important factor is the ability of San Francisco's people and organizations, governmental and non-governmental, to adapt to changing conditions after a disaster and mobilize resources to address problems. San Francisco has a large number of highly-educated and innovative residents. These characteristics are often paired with post-disaster resilience. The City also has a large number of residents with modest and fixed incomes, first generation immigrants, and people with disabilities—people who may have a limited ability to respond and adapt to the demands imposed on them by an earthquake. This section of the report discusses a few factors that influence whether businesses and people will want and be able to remain in San Francisco after an earthquake.

Quality of Life

San Francisco is a vibrant city—economically, culturally, and socially—largely because many people find it an attractive place to be. Urban theorists have postulated that economic development in a post-industrial economy requires a strong "Creative Class" of workers[53]. The Creative Class includes scientists, academics, designers, artists, and others whose economic function is to create new ideas, technology and creative content; they are the drivers of today's information economy. Analysts emphasize that quality-of-life factors such as the arts, recreational opportunities, educational institutions, cultural diversity, and attractive urban environments play a crucial role in attracting, cultivating, and maintaining a Creative Class.

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[53] Florida, 2002.

San Francisco and the Bay Area benefit from a rich array of quality-of-life features that have helped it become an international center for the Creative Class. These include outdoor amenities (e.g., The Golden Gate National Recreation Area; City, regional and state parks; the Lake Tahoe Basin), a world-class food and wine culture, a strong network of cultural and arts organizations, a wide range of housing types, and cultural diversity. These characteristics enrich the life of all San Francisco residents. The Bay Area would largely retain these amenities in the event of an earthquake, keeping it a location of choice for many.

Educational Institutions

The San Francisco Bay Area is home to a strong network of public and private educational institutions. Historically, these institutions have played a vital role in establishing the region as a global hub of economic activity and technological development. They act as economic engines and draw employers by creating a highly-educated populace, spawning businesses, and conducting groundbreaking research.

The region's world-class research universities include the University of California campuses in San Francisco and Berkeley, and Stanford University. In addition, the California State University system has campuses in San Francisco and elsewhere in the Bay Area. There are dozens of smaller private institutions in San Francisco such as the Academy of Art, the University of San Francisco, the San Francisco Art Institute, and many others located throughout the region.

Universities will suffer significant damage in a large Bay Area earthquake that could affect their ability to educate students and conduct research. This study has not evaluated the vulnerability of these critical institutions. The University of California and Stanford University have invested heavily in upgrading their buildings and developing plans to prepare for future earthquakes, and other institutions may have made similar investments. The recently constructed University of California San Francisco (UCSF) Mission Bay complex meets modern seismically resistant construction standards. However, these institutions rely on the private sector, and on local businesses and suppliers, for housing and neighborhood support. After a major earthquake, these institutions will continue to attract and produce intellectual and monetary capital, contributing to San Francisco's economy and community. However, it may take time before these "economic engines" restart after an earthquake.

Household Incomes

San Francisco's resilience is affected by the resilience of the region. The Bay Area's strong economy has supported a relatively affluent region. In 2009, the regional median household income was $76,900[54], 28 percent higher than the statewide figure, and 50 percent higher than the national figure. With these higher incomes comes greater social resilience, as households are able to withstand temporary downturns in the economy following an earthquake and may be able to draw upon sufficient financial resources to repair physical damage to their homes. Many San Francisco residents may be able to afford to repair or rebuild their homes, replace their possessions, and rent temporary space while construction is underway.

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[54] The Bay Area region is defined as the counties of Alameda, Contra Costa, Solano, Sonoma, Napa, Marin, San Francisco, San Mateo, and Santa Clara.

However, many San Francisco residents have limited or fixed incomes that would not easily accommodate the expenses associated with disruption after an earthquake. Lower-income households will have more difficulty weathering a loss in employment following a disaster, and are less able to rebuild damaged property, particularly with high construction costs in the Bay Area. Moreover, lower-income households are more likely to be renters than homeowners. As discussed previously, rental properties are rebuilt at a slower rate than owner-occupied properties. Demolished rental units may be replaced by condominiums that are unlikely to be affordable to the previous occupants. An earthquake could lead to increased gentrification in San Francisco: households with ample resources could afford to pick up the pieces and stay, and households with fewer resources may need to move somewhere less expensive, perhaps permanently.

Cost-of-Living

The region's overall affluence has led to a relatively high cost-of-living in the Bay Area. As of September 2009, San Francisco's median home price was $675,000, compared to the statewide median home price of $251,000. Looking at the Consumer Price Index (CPI) shows that, on average, between 1975 and 2008, inflation rose faster in the Bay Area than the nation 57 percent of the time, or 20 out of 35 years. The CPI measures the change in prices on a general basket of consumer goods over time, and serves as an indicator of the cost-of-living. Higher rates of inflation suggest that the cost-of-living in the Bay Area increases faster than the nation as a whole, depending on the rate of annual wage increases relative to prices.

As another measure of the cost-of-living, Sperling's BestPlaces.net web site uses data from the Council for Community and Economic Research to compare the cost of living between US cities. According to Sperling, the cost of living in San Francisco is 87 percent higher than the national average – mostly because of housing costs.

This high cost-of-living may prove a negative factor for San Francisco's recovery following an earthquake. For example, higher construction costs may slow the rebuilding process. Again, the City's high housing costs may also compel households to leave San Francisco altogether if their residences are severely damaged.

Resilience of San Francisco's Neighborhoods

Although San Francisco is a generally affluent city, not all residents are affluent and some neighborhoods are less disaster resilient than others due to their socioeconomic characteristics. Displacement after an earthquake is most difficult for those City residents who are elderly, disabled, or poor. These residents often have limited resources to rebound when they lose their home and possessions, even temporarily. It can be a hardship for them to be separated from services and community members they rely on. Nearly eight percent of residents (over 60,000 people) are physically disabled[55]. These people could be significantly impacted if they need to vacate their homes. Even elderly and disabled residents who can remain in their homes could suffer severe consequences after an earthquake if utilities, such as electricity, gas, water, and sewer, do not function, or if neighborhood services, such as pharmacies and grocery stores, are not open.

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[55] Claritas, 2009.

The percentage of households living below the federal poverty threshold serves as one indicator of a neighborhood's socioeconomic resiliency[56]. As shown in Figure 16, approximately eight percent of San Francisco households live below the poverty threshold[57]. In comparison, Bayview, Downtown, Central Waterfront, Western Addition, and North Beach, all have at least 10 percent of households below the federal poverty threshold.

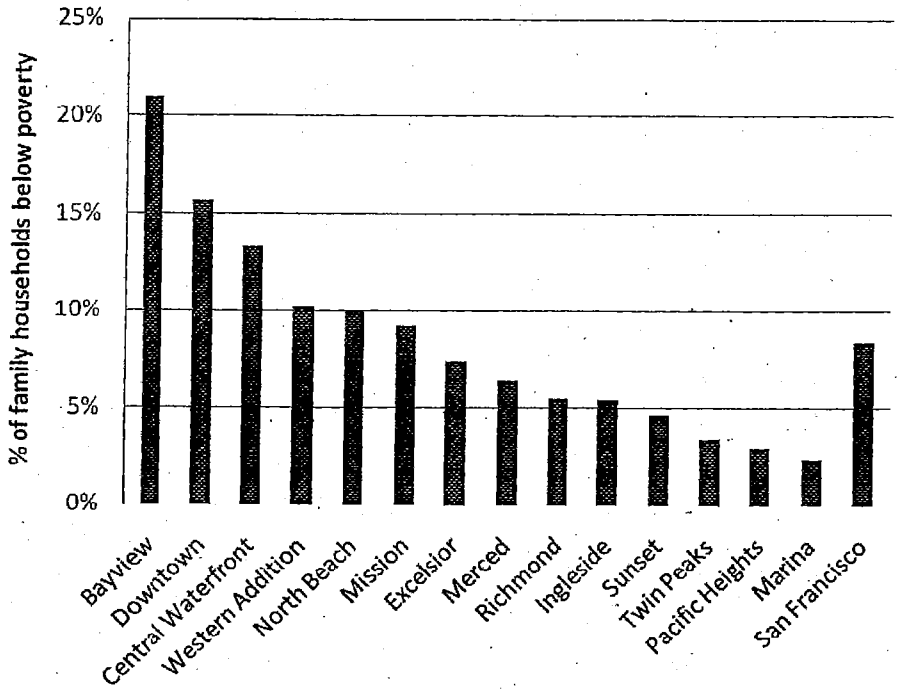

Figure 16 Percent of households living below federal poverty threshold in 2009 by district (only includes family households). Source: Claritas (2009).

Homeownership is another factor that affects how quickly recovery occurs. As noted earlier, homes occupied by their owners tend to be rebuilt at a faster rate than multi-family rental housing following an earthquake. Table 23 presents homeownership rates and housing types by district in San Francisco. As shown, nearly two-thirds of residents in the City are renters. Homeownership rates are lowest in Downtown, North Beach, and the Western Addition, all districts with a heavy concentration of multi-family housing. Conversely, the Sunset, Excelsior, Twin Peaks, and Ingleside have relatively high homeownership rates and a greater incidence of single-family homes.

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[56] The federal poverty threshold was originally developed in 1963-1964 by the Social Security Administration based on the U.S. Department of Agriculture's economy food plan, and is updated each year by the Census Bureau. Although it presents methodological problems, particularly in a high cost region such as the Bay Area, it remains the official federal definition of "poverty" and serves as a useful benchmark for comparing neighborhood profiles for this study. The 2009/2010 poverty threshold for a four person household is $22,050 (USDHHS, 2009).

[57] Only includes family households.

Table 23 San Francisco Unit Types and Homeownership Rates

District	Unit Type		Unit Occupancy	
	Single-Family (%)	Multi-Family (%)	Owner Occupied (%)	Renter Occupied (%)
Downtown	2	98	8	92
North Beach	5	95	19	81
Western Addition	12	88	21	79
Marina	11	89	21	79
Pacific Heights	14	85	28	72
Merced	41	59	28	72
Mission	28	72	33	67
Central Waterfront	13	84	35	65
Richmond	30	70	36	64
Bayview	67	32	52	48
Sunset	66	34	56	44
Excelsior	82	17	68	32
Twin Peaks	72	28	68	32
Ingleside	90	9	74	26
Citywide	31%	69%	35%	65%

Sources: This study; Claritas (2009).

Socio-economic resilience varies significantly by district. In general, districts with higher-income households, greater homeownership rates, and more single-family homes will likely recover and rebuild faster than lower-income areas with more renters and multi-family units. Table 24 provides a perspective on how these factors compare across districts, based on the data presented above. The analysis assigns a "resilience score" to each district according to its poverty rates, homeownership rate, and the percent of units in multi-family buildings. Neighborhoods with greater rates of poverty, renters, and multi-family housing receive lower resilience scores. The findings suggest that the City's most socio-economically resilient districts include Ingleside, the Excelsior, and the Sunset. Its least socio-economically resilient districts include Downtown, North Beach, and the Western Addition.

The next major earthquake that strikes San Francisco will change the City and its people. San Francisco is a world-class city with many special attributes that draw businesses, innovative people who want to live here, and visitors from around the world. In the long-term, San Francisco will recover and thrive, but it will be a different San Francisco. It is likely that the new, post-earthquake San Francisco will have less socio-economic diversity. The destruction of many affordable housing options, exacerbated by a reduced number of housing units available in the years it will take to rebuild the City, will make it difficult for middle- and low-income residents to remain in San Francisco. Earthquake damage will stress businesses and the jobs they provide, particularly the many small and independent businesses in the

Table 24 Socio-Economic Resilience Index, San Francisco Districts

District	Poverty[a]	Home Ownership[b]	Multi-Family Housing[c]	Average Resilience Score
Ingleside	3	3	3	3.00
Excelsior	2	3	3	2.67
Sunset	3	3	2	2.67
Twin Peaks	3	3	2	2.67
Bayview	1	3	2	2.00
Merced	2	2	2	2.00
Mission	2	2	2	2.00
Pacific Heights	3	2	1	2.00
Richmond	2	2	2	2.00
Marina	3	1	1	1.67
Central Waterfront	1	2	1	1.33
Downtown	1	1	1	1.00
North Beach	1	1	1	1.00
Western Addition	1	1	1	1.00

a. Poverty rate, 2009 — Resilience score
0-5% — 3
6%-10% — 2
>10% — 1

b. Homeownership rate, 2009 — Resilience score
>50% — 3
26%-50% — 2
0%-25% — 1

c. % multi-family, 2009 — Resilience score
0-25% — 3
26%-75% — 2
>75% — 1

Sources: This study, Claritas (2009).

City. It will change the way the City looks, with some of the most interesting and beautiful buildings and neighborhoods changed forever. Despite the damage, San Francisco will retain many of the elements that make it an economically successful and socially desirable place – physical beauty, cultural amenities, and proximity to world-class universities, to name a few.

The scenarios described in this report present what is likely to happen if San Francisco makes no changes to its preparations for earthquakes. Much of this damage may be preventable. It is up to San Franciscans to decide how much to invest in steps to reduce the consequences of the next major earthquake. As discussed in the companion ATC-52-2 Report, *A Community Action Plan for Seismic Safety*, there are many steps the City can take to reduce damage and become more resilient.

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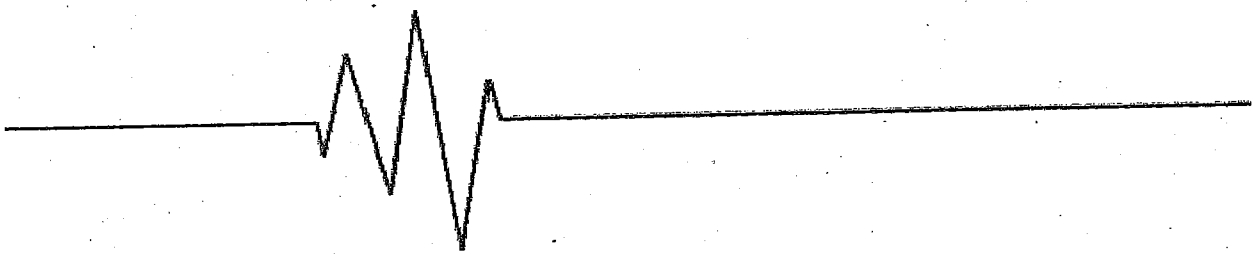

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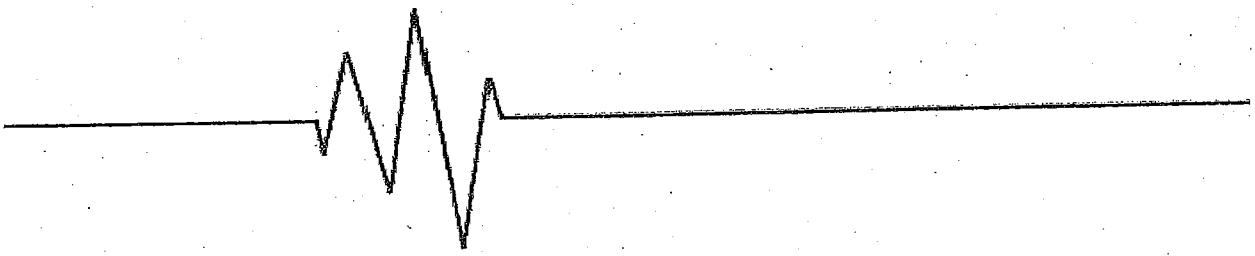

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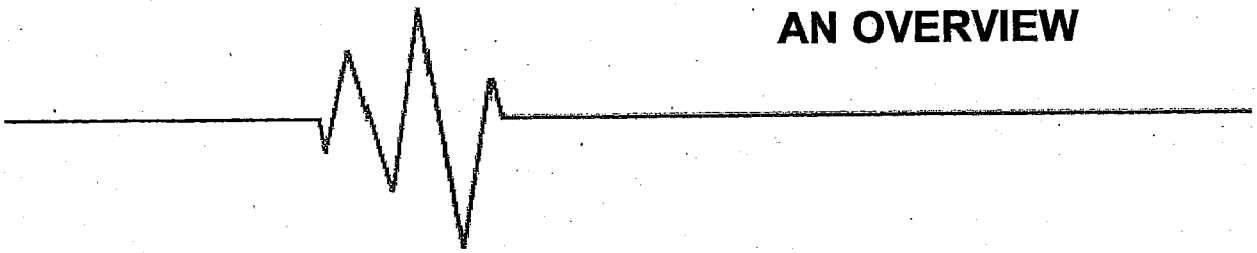

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Since its inception in the early 1970s, the Applied Technology Council has developed numerous, highly respected, award-winning, technical reports that have dramatically influenced structural engineering practice. Of the more than 100 major publications offered by ATC and its Joint Venture partners, the following have had exceptional influence on earthquake engineering practice:

ATC-3-06, *Tentative Provisions for the Development of Seismic Regulations for Buildings*, funded by the National Science Foundation (NSF) and the National Bureau of Standards and completed in 1978, provides the technical basis for seismic provisions in the current *International Building Code* and other model U. S. seismic codes.

ATC-14, *Evaluating the Seismic Resistance of Existing Buildings*, funded by NSF and completed in 1987, provides the technical basis for the current American Society of Civil Engineers (ASCE) Standard 31, *Seismic Evaluation of Existing Buildings* (the national standard for seismic evaluation of buildings).

ATC-20, *Procedures for Postearthquake Safety Evaluation of Buildings*, funded by the California Office of Emergency Services and the California Office of Statewide Health Planning and Development, is the *de facto* national standard for determining if buildings can be safely occupied after damaging earthquakes. The document has been used to evaluate tens of thousands of buildings since its introduction two weeks before the 1989 Loma Prieta earthquake in Northern California.

ATC-40, *Seismic Evaluation and Retrofit of Concrete Buildings*, funded by the California Seismic Safety Commission and completed in 1996, won the Western States Seismic Policy Council' s "Overall Excellence and New Technology Award" in 1997.

FEMA 273, *NEHRP Guidelines for the Seismic Rehabilitation of Existing Buildings,* funded by the Federal Emergency Management Agency (FEMA) and completed in 1997 under the ATC-33 Project, provides the technical basis for the current American Society of Civil Engineers (ASCE) Standard 41, *Seismic Rehabilitation of Existing Buildings* (the national standard for seismic rehabilitation of buildings).

FEMA 306, *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Basic Procedures Manual,* **FEMA 307,** *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Technical Resources,* and **FEMA 308,** *The Repair of Earthquake Damaged Concrete and Masonry Wall Buildings,* funded by FEMA and completed in 1998 under the ATC-43 Project, provide nationally applicable consensus guidelines for the evaluation and repair of concrete and masonry wall buildings damaged by earthquakes.

FEMA 352, *Recommended Post-earthquake Evaluation and Repair Criteria for Welded Steel Moment-Frame Buildings,* funded by FEMA and developed by the SAC Joint Venture, a partnership of the Structural Engineers Association of California, the Applied Technology Council, and California Universities for Research in Earthquake Engineering, provides nationally applicable consensus guidelines for the evaluation and repair of welded steel moment frame buildings damaged by earthquakes.

FEMA P646, *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis,* funded by FEMA and completed in 2008 under the ATC-64 Project, provides state-of-the-art guidance for designing, locating and sizing structures to resist the effects of tsunamis and thereby provide safe evacuation refuge in affected coastal areas.

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ATC-52-3

Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco

Earthquake Safety for Soft-Story Buildings

Prepared for the

DEPARTMENT OF BUILDING INSPECTION (DBI)
CITY AND COUNTY OF SAN FRANCISCO
under the Community Action Plan for Seismic Safety (CAPSS) Project

Prepared by the

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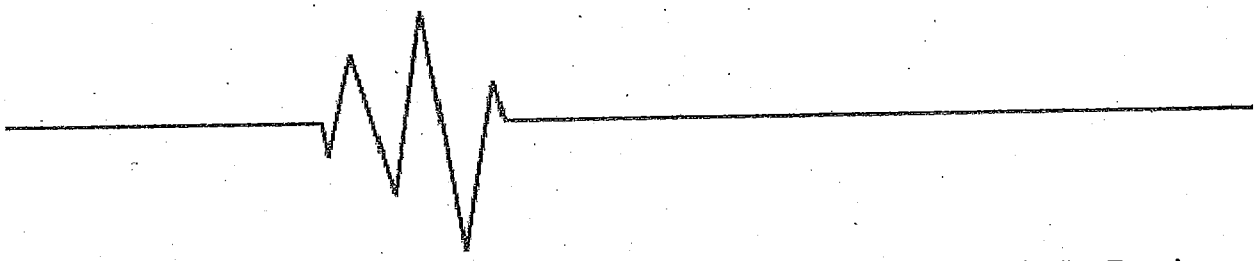
PREFACE



The leaders of the volunteer Public Advisory Committee for the San Francisco Community Action Plan for Seismic Safety (CAPSS) are excited to present this report containing significant recommendations for action. CAPSS was conceived more than 10 years ago by the Department of Building Inspection, with the objective of mitigating the effects of future earthquakes on the people of San Francisco. Nothing will have a greater impact on the City's future than large earthquakes – which we know will occur.

The CAPSS Public Advisory Committee comprises a group of diverse, community-minded volunteers who are dedicated to the collective goal of reducing the risks of future earthquakes. It is made up of many constituents, including renters, building owners, small business owners, planners, contractors, scientists and engineers. What follows is the culmination of their efforts, and represents a package of compromise recommendations for the betterment of the city's seismic safety.

Many building types are susceptible to damage from earthquakes. Mayor Newsom directed CAPSS to first address soft-story residential structures, which are known to be amongst the most vulnerable. To meet the short time frame available to prepare this study and report, the scope was further reduced, and the recommendations are focused on a more narrow category we refer to as "multi-unit soft-story buildings," which is defined as follows:

> **Wood-frame structures, 3 stories or more, with 5 or more residential units, built before May 1973, and having a "soft-story" condition on the ground floor.**

The recommendations are near-revolutionary in their approach, since they were vetted and shaped by citizen policy makers who recognize that all people who occupy buildings expect them to perform to certain minimum levels of performance. Based on that premise, the Public Advisory Committee worked with the CAPSS Project team to craft policy recommendations which focus on performance objectives instead of traditional engineering design standards. The results of this focused study received unanimous support from the highly diverse Public Advisory Committee, and will serve as the foundation for future study and recommendations as CAPSS continues.

The recommendations represent an important first step in addressing the seismic risk we all face. It is essential to emphasize that as the CAPSS project continues over the next two years, it will address other vulnerable building types that present risks to the people of San Francisco.

Significantly, the timing of the release of these recommendations coincides with the release of San Francisco Planning and Urban Research's (SPUR)'s policy white paper, *The Resilient City*. There has been significant cooperation and communication between the CAPSS Public Advisory Committee and SPUR's hazard mitigation task

force. Our CAPSS recommendations are independent from SPUR's but were strongly influenced by their vision of city-wide mitigation actions to be taken to assure San Francisco's speedy recovery after a future disaster. Both documents represent the community's desire to effect action which will reduce our vulnerability to future earthquakes.

All of us on the Public Advisory Committee wish the Mayor and the Department of Building Inspection good luck in shepherding the program forward, which, when implemented, will save lives and reduce loss from earthquakes which are certain to strike our City.

We also offer our sincere thanks to all of the volunteer participants in the CAPSS Advisory Committee meetings, other project meetings, and the project workshop. The names and affiliations of these individuals are provided in the list of Project Participants section at the end of this report.

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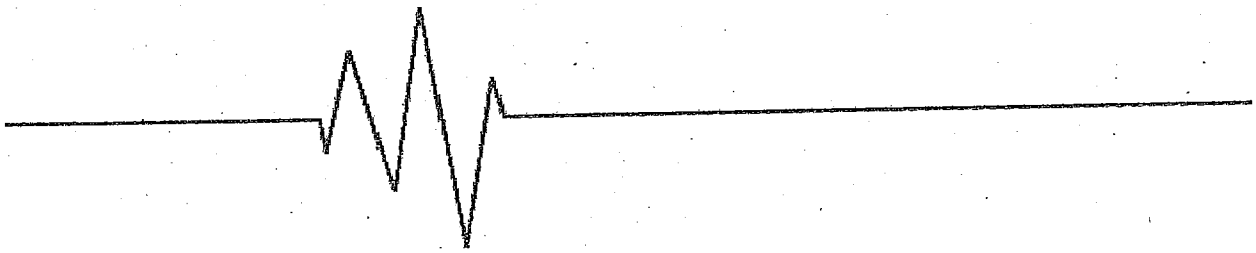
REPORT SUMMARY



Many of San Francisco's wood-frame buildings built before May 21, 1973 that contain three or more stories and five or more residential units would be seriously damaged in future earthquakes. A significant number could collapse. The scope of this damage could set back the City's post-earthquake recovery, could irrevocably change the character and affordability of the City, and could cause many casualties. Therefore, the Community Action Plan for Seismic Safety (CAPSS), a project of the Department of Building Inspection, recommends that owners of these buildings be required to seismically retrofit "soft-story" buildings whose capacity to resist earthquake forces is found to be inadequate. The recommendations detailed in this report are based on technical analysis and on discussions held in public meetings. This work has been guided and reviewed by a dedicated Advisory Committee composed of community members. The CAPSS project believes that establishing this earthquake safety policy is a critical step toward making San Francisco a resilient city that will be able to resume normal life quickly after the next major earthquake strikes.

Retrofitting benefits the entire City, its neighborhoods, building owners, and residential and business tenants. However, sharing the costs of retrofits among the beneficiaries—financial costs and inconveniences—raises policy issues of fundamental importance to the City. The ability to pay for retrofitting or endure disruption is not universal. Retrofitting costs would cause great hardship for some tenants and owners, especially those with limited income. The recommendations in this report recognize this issue, provide insight into the costs and the beneficiaries, and outline a flexible program with financial incentives to facilitate retrofit and protect those with hardships. Finding an equitable balance between those who benefit and those who pay will challenge San Francisco's decision makers. Ultimately, the cost of earthquakes is greater than the cost of preparing.

Retrofitting buildings advances San Francisco's commitment to reducing its carbon footprint. The investment of energy and materials to retrofit a building is a fraction of the investment needed to repair or replace damaged buildings. Retrofitting conserves resources.

Key Recommendations

This report recommends that:

- **The Department of Building Inspection should establish a program that requires owners of wood-frame buildings built before May 21, 1973 with three or more stories and five or more residential units to evaluate the seismic safety of their buildings and to retrofit them if they are found to be seismically deficient.** Many of these buildings have "soft-stories" and are highly vulnerable to damage and collapse in earthquakes. Soft-story buildings have a weak ground floor because perimeter walls have large openings for garage doors

and windows, they lack interior partitions, and building materials have deteriorated over time.

- **Buildings should be retrofitted to a standard that will allow many of them to be occupied after a large earthquake.** Keeping San Franciscans in their homes averts a post-earthquake shelter crisis, lessens the demands placed upon emergency response services, and allows residents to remain in their neighborhoods and to help to revive them. It is feasible to retrofit this type of building so that many residents can remain in their homes after a large earthquake, even though there would be some damage and utilities might not function.
- **The City should immediately offer incentives to encourage voluntary retrofits.** The program described in this report will take time to launch, but the risk is urgent and should be addressed immediately. To get owners moving on making their buildings safer, the City should offer incentives to owners who retrofit, including expediting plan review, rebating permit fees, offering planning incentives, and seeking voter approval of a City-funded loan program. Buildings voluntarily retrofitted to an acceptable standard should be exempt from requirements created by the recommended program. Incentives need not be limited to the buildings addressed in this report.
- **The Department of Building Inspection should form a working group to develop a detailed plan to implement the recommended program.**

Many other types of buildings in San Francisco pose great threats to the City in earthquakes. In addition to the building types addressed in this report, the City should pursue policies to make other types of buildings at risk of major damage and collapse in future earthquakes safer.

Why Retrofits are Necessary

Retrofitting multi-unit, wood-frame buildings would reduce the consequences of earthquakes to San Francisco. It would retain significant amounts of housing, preserve architectural and cultural attributes, conserve energy and resources, and improve public safety. Retrofitting would shorten the time that the City requires to recover from the next large earthquake. Although other types of buildings are also vulnerable to earthquake damage and also need to be retrofitted, the buildings addressed in this report are particularly vulnerable and can be retrofitted relatively easily.

Many multi-story buildings have a structural weakness due to large openings in their perimeter walls and to a lack of interior partition walls at the ground level. Usually, perimeter wall openings at the ground level make way for garage doors or large windows. Interior spaces used for retail and garages often have few partition walls. The open condition makes the ground level significantly weaker and more flexible than the floors above it. This condition is called a "soft-story." During strong earthquake shaking, these "soft" ground level walls cannot support the side-to-side or front-to-back movement of the stiff and heavy mass of the stories above them, leading to damage and, in the worst cases, to collapse. Figure A shows examples of representative San Francisco buildings that may have soft-story weaknesses.

There are approximately 4,400 wood-frame buildings built before May 21, 1973 in San Francisco with three or more stories and five or more residential units. All of

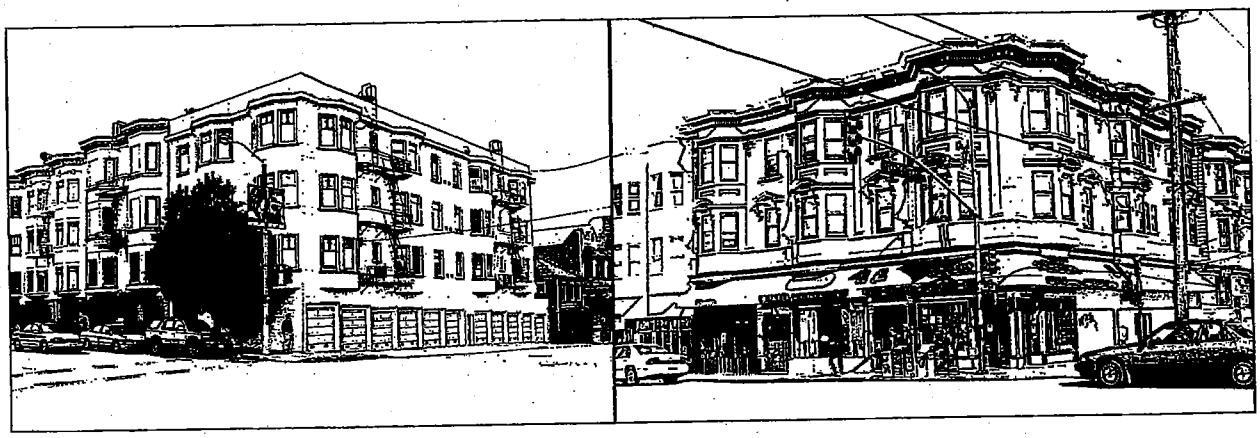


Figure A. Images of two multi-unit, wood-frame buildings that may have soft-stories.

these buildings may have a soft story condition[a]. CAPSS studied these buildings to understand better how they are being used, how they would perform in future earthquakes, how building performance could be changed through retrofitting, and what would be involved in retrofitting them.

CAPSS analyzed a subset of these buildings, to gain insight into how best to manage the larger number of potentially vulnerable buildings. CAPSS identified and evaluated roughly 2,800 buildings that have the largest perimeter wall openings and are, therefore, expected to have significant soft-story weaknesses. Findings show that dramatic damage to this subset of buildings is likely, but that vulnerability could be easily remedied:

- As they now stand, 43 to 85 percent of the multi-unit, wood-frame buildings studied by CAPSS would be posted with a red UNSAFE placard (red-tagged) after a magnitude 7.2 earthquake on the San Andreas fault. This represents 1,200 to 2,400 red-tagged buildings. Red-tagged buildings have severe damage and cannot be occupied after an earthquake until they are either repaired or replaced. Their residents would need to find new homes for those months or years that it would take to make repairs. The extensive damage predicted to these buildings suggests that buildings with smaller perimeter wall openings at the ground level would also be susceptible to significant damage.
- A quarter of these red-tagged buildings would be expected to collapse. This represents 300 to 850 multi-unit buildings. Collapses threaten lives. These buildings, most of which contain rent-controlled apartments, would be rebuilt differently, with modern materials and design. Owners might not choose to rebuild them as apartment buildings. If they did, state law dictates that the units would not be covered by rent control. The demographics and architectural character of neighborhoods that experience many collapses could change significantly.
- Nearly eight percent of the City's population, or about 58,000 people, live in this subset of buildings. The buildings house close to 2,000 businesses that employ an

[a] May 21, 1973 is the date when the San Francisco Building Code was amended to prevent design flaws that often resulted in soft-story conditions. Buildings constructed after that date, even those with open perimeter walls, should have adequate strength and stiffness at the ground level to resist earthquakes.

estimated 7,000 people. Without retrofit, the heavy damage that these buildings are likely to sustain would disrupt many neighborhoods for years after an earthquake. Tens of thousands of people would be displaced from their homes and neighborhoods and would not contribute to bringing them back to life. Small businesses along neighborhood shopping streets would suffer severe impacts.

- Seismic retrofits make a big difference and would dramatically reduce the number of collapsed buildings. With retrofit, collapses could be reduced to less than one percent of these buildings.
- Retrofitting all of the buildings in this subset to a recommended level that would allow most of them to be occupied after a large earthquake would cost approximately $260 million[b]. These retrofits would eliminate $1.5 billion in damage after a magnitude 7.2 earthquake on the San Andreas Fault. Even so, many retrofitted buildings would still require costly repairs.
- Seismic retrofits at the recommended level are likely to cost in the range of $60,000 to $130,000 per building for direct construction costs. Retrofit construction would last for two to four months and could be limited to the ground floor level, meaning that residents of upper level apartments could stay in their homes. However, construction could have significant impacts on residents and small businesses located at street level in these buildings. Ground floor tenants might temporarily need to close, relocate or deal with considerable construction inconvenience. Tenants occupying the upper floors would experience noise, dust, vibrations and other inconveniences during construction.
- The subset of buildings studied can be found throughout the City but are most common in the Mission, Western Addition, Richmond, Pacific Heights, North Beach, and Marina neighborhoods.

The Report

The following sections of this report include detailed information about the analysis and recommendations of the CAPSS Project:

- Chapter 1: San Francisco's Multi-Unit, Wood-frame Buildings

  This chapter provides details on the characteristics of these buildings, how many exist, how they are used, and where they are located.

- Chapter 2: The Risk in Doing Nothing

  This chapter outlines the damage that could occur to these buildings in future earthquakes if no action is taken.

- Chapter 3: The Consequences of Retrofitting

  This chapter describes the benefits and costs of retrofitting these buildings.

- Chapter 4: Options to Reduce The Risk

  This chapter reviews the many options available for a policy to reduce the risk to these buildings. It discusses pros and cons of various options.

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[b] The dollar values mentioned were calculated during the Fourth Quarter of 2008.

- Chapter 5: The Recommended Program

  This chapter describes the policy that the CAPSS project recommends to make multi-unit, wood-frame soft-story buildings safer and to improve San Francisco's earthquake resilience.

This report is accompanied by a companion volume, *Earthquake Safety for Soft-Story Buildings, Documentation Appendices* (ATC-52-3A Report), which details the technical methods and data used to develop the analysis and recommendations presented in this report.

This report and its recommendations address only one type of building in San Francisco. Other building types that could be damaged by earthquakes will be covered in subsequent reports of the CAPSS project. Some other building types, such as smaller wood-frame buildings, are more numerous than the subset addressed in this report. Others, such as older concrete buildings, are more subject to catastrophic failure. The CAPSS project focused first on multi-unit, wood-frame buildings not only because they are known to be highly vulnerable to earthquake shaking, but also because they are easy to identify and to retrofit. It makes sense for San Francisco to begin addressing these buildings now.

The 1989 Loma Prieta earthquake, centered about 60 miles to the south of San Francisco, caused dramatic damage and seven collapses to multi-unit, wood-frame buildings in the Marina district, including the damage shown in Figure B.

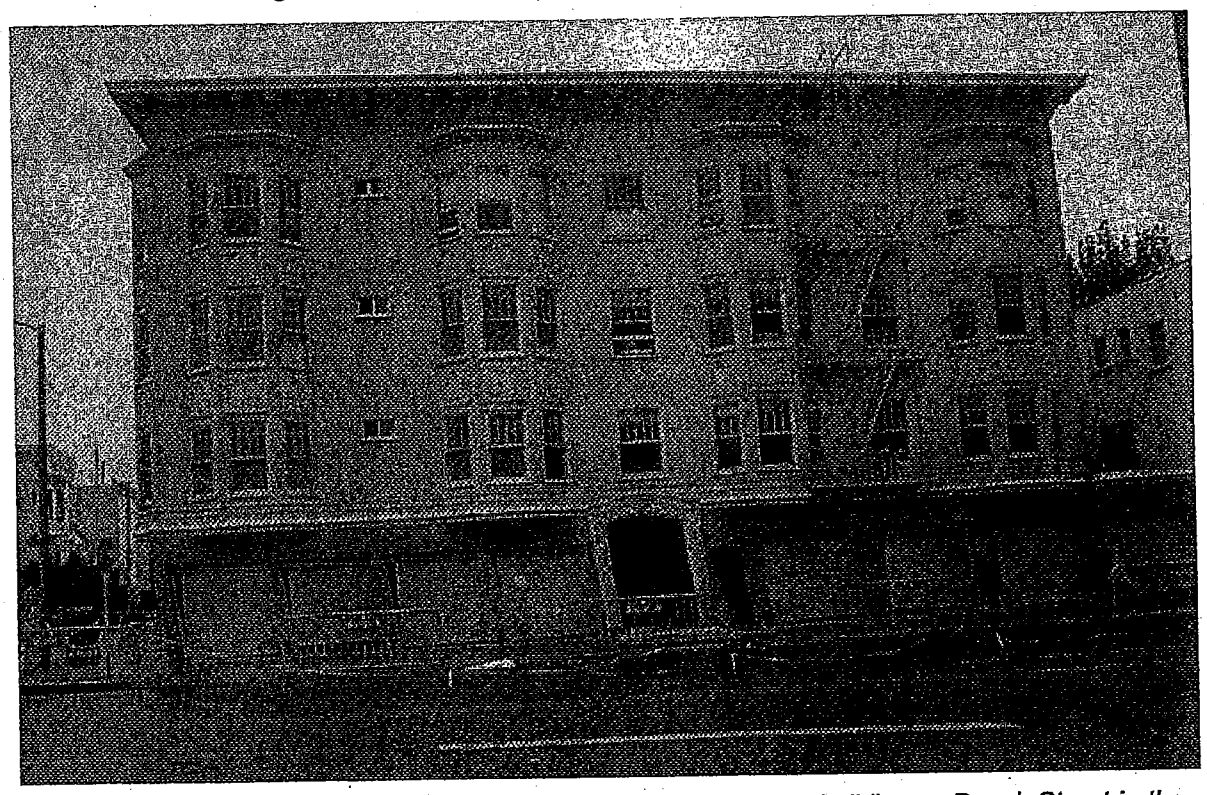

Figure B. Damage to a multi-unit, wood-frame soft-story building on Beach Street in the Marina District due to the 1989 Loma Prieta earthquake. Image by Raymond B. Seed, Courtesy of the National Information Service for Earthquake Engineering, University of California, Berkeley.

An earthquake centered closer to the City would cause far greater damage. It is time to take action to protect San Francisco's unique character, to improve its ability to respond to and recover from earthquakes, and to improve public safety by retrofitting buildings throughout the City that are similar to those that failed in the Marina District.

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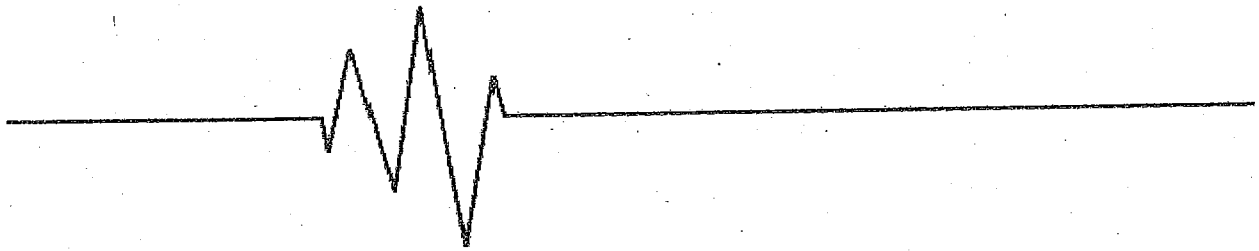

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CHAPTER 1: SAN FRANCISCO'S MULTI-UNIT, WOOD-FRAME BUILDINGS

During the 1989 Loma Prieta earthquake, a number of multi-unit, wood-frame soft-story buildings in the Marina district either collapsed or were heavily damaged (Figure 1). Thousands of similar buildings exist in neighborhoods throughout the City. The epicenter of the Loma Prieta earthquake was about 60 miles south of San Francisco. Larger or closer earthquakes, which are considered likely by seismologists, could cause much stronger shaking in many parts of the City than was felt in the Marina District. This means that thousands of buildings that house many city residents and small, local businesses are at risk.



Figure 1. Two multi-unit, wood-frame soft-story buildings that collapsed in the Marina District during the 1989 Loma Prieta earthquake. For both buildings, the second story is at street level due to the complete collapse of the first story. Image courtesy of the National Information Service for Earthquake Engineering, University of California, Berkeley.

Multi-unit, wood-frame soft-story buildings are not the only building type that would be heavily damaged in future earthquakes, but they are clearly vulnerable. This type of building houses many San Francisco residents. Many of these buildings are old and architecturally interesting; 65 percent were built before World War II. Ninety percent are occupied by renters, who have little ability to find out about or to remedy their building's seismic deficiencies. Compared to other structure types, these buildings are easy and cost-effective to make safer. For all of these reasons, it makes sense for San Francisco to address the seismic safety of these buildings now.

Soft-Story Buildings

A common building weakness is called "soft-story." The term "soft-story" describes one level of a building that is significantly more flexible than the stories above it and the floors or the foundation below it. In San Francisco's multi-unit, wood-frame buildings, weakness at the ground level stems from a lack of strong walls, both because of large openings in perimeter walls and because of few existing interior partition walls. Usually perimeter openings are for garage doors or large windows. In addition, ground floor uses such as parking or commercial space, require fewer partitions than the residential uses in the floors above. During strong earthquake shaking, the ground level walls cannot support the stiff and heavy mass of the stories above them as they move back and forth. The ground level walls can shift sideways until the building collapses, crushing the ground floor.

Figure 2 shows representative examples of what multi-unit, wood-frame buildings that probably have soft-stories look like in San Francisco. These buildings have either garage doors or large windows for commercial establishments at the ground floor. It is not possible to know for certain that a building is a soft-story building simply by looking at it from the street. Large openings at the ground level are a strong indicator that a building might have a soft-story, but many characteristics affect a building's response to earthquake shaking, and only a building-specific analysis conducted by an engineer can determine if a particular building is a soft-story building.

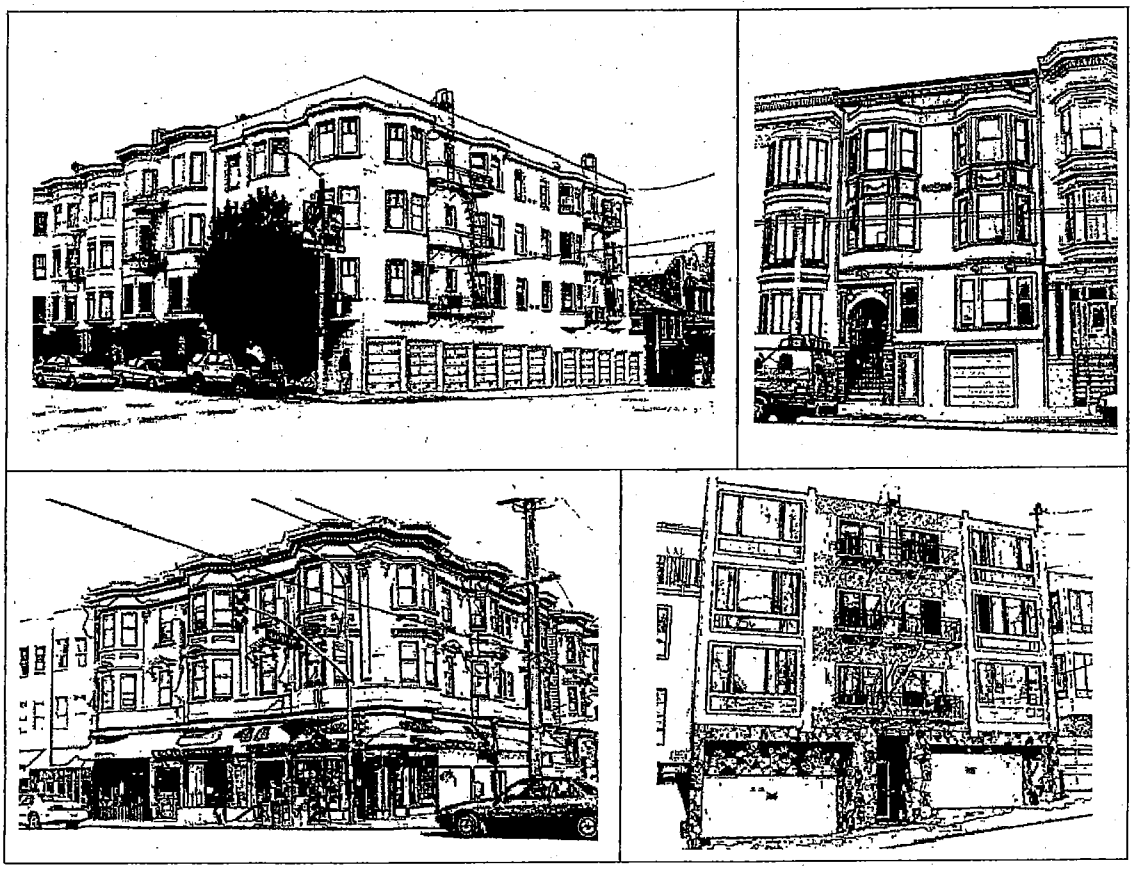

Figure 2 Sketches of four typical examples of multi-unit, wood-frame buildings that are likely soft-stories.

Number and Locations of These Buildings

San Francisco has many thousands of wood-frame buildings with an open ground floor and residential space on higher floors. This configuration is characteristic of the construction of buildings ranging from single-family homes over a garage to large, multi-unit structures. This report focuses on wood-frame buildings with three or more stories. In previous earthquakes, buildings with three or more stories have been observed to sustain greater damage than buildings with one and two stories. Local experts believe that they pose a higher risk than similar buildings with two stories. The buildings of most concern are those built before May 21, 1973. After that date, the San Francisco Building Code was changed to prevent soft-story weaknesses in wood-frame buildings.

In 2007-2008, the San Francisco Department of Building Inspection conducted a sidewalk survey of wood-frame buildings with three or more stories and five or more residential units[1]. This survey focused on buildings with five or more units, because the five-unit cutoff has been used by other City programs, such as the unreinforced masonry retrofit program and various code triggers, and because these buildings house more occupants than do buildings with fewer units[2]. This survey provides information about important characteristics that contribute to vulnerability, such as the amount of openness in ground floor exterior walls and whether buildings are located on a corner or mid-block. The Department survey identified approximately 4,400 wood-frame buildings with three or more stories and five or more residential units built in San Francisco prior to the building code change in 1973.

The CAPSS project decided to analyze a subset of these buildings, those with the largest ground floor openings, which are believed to be most vulnerable to damage. For the purposes of this project, significant ground floor openings were defined as openings (garage doors, windows, entry ways, or other openings) that span 80 percent or more of one side of a building, or 50 percent or more of two sides of a building. The Department's survey found approximately 2,800 buildings that have this level of openness. Building with less open areas can also be vulnerable.

Figure 3 illustrates how the Department survey estimated the percentage of openness of each building side. The openness criteria used to select buildings for the CAPSS analysis are not an indicator of whether a building is "safe" or "unsafe;" rather, the criteria reflect a decision to capture those buildings with the largest openings that are likely to have higher overall vulnerability. Many buildings with fewer openings in their perimeter walls were excluded from the CAPSS analysis but could also have soft-stories and could be vulnerable to significant damage and collapse.

---

[1] This survey was conducted by building inspectors, and members of two professional organizations: the Earthquake Engineering Research Institute and the Structural Engineers Association of Northern California. Results from the survey include important data that were used to make analysis assumptions for this report. The survey results are not a list of vulnerable buildings, and include no information about some important factors that contribute to whether a building is a soft-story, such as interior partitions, strength of walls and whether a building has already been retrofitted.

[2] There are an estimated 2,600 four-unit buildings and 3,400 three-unit buildings in San Francisco with three or more stories. Many of these buildings have similar risk to buildings with five or more units. It is reasonable to assume that larger buildings are often more vulnerable and, on average, buildings with five or more units are larger than those with three or four units. The CAPSS project does not have detailed data about three and four unit buildings, so they are not included in the analysis presented in this report.

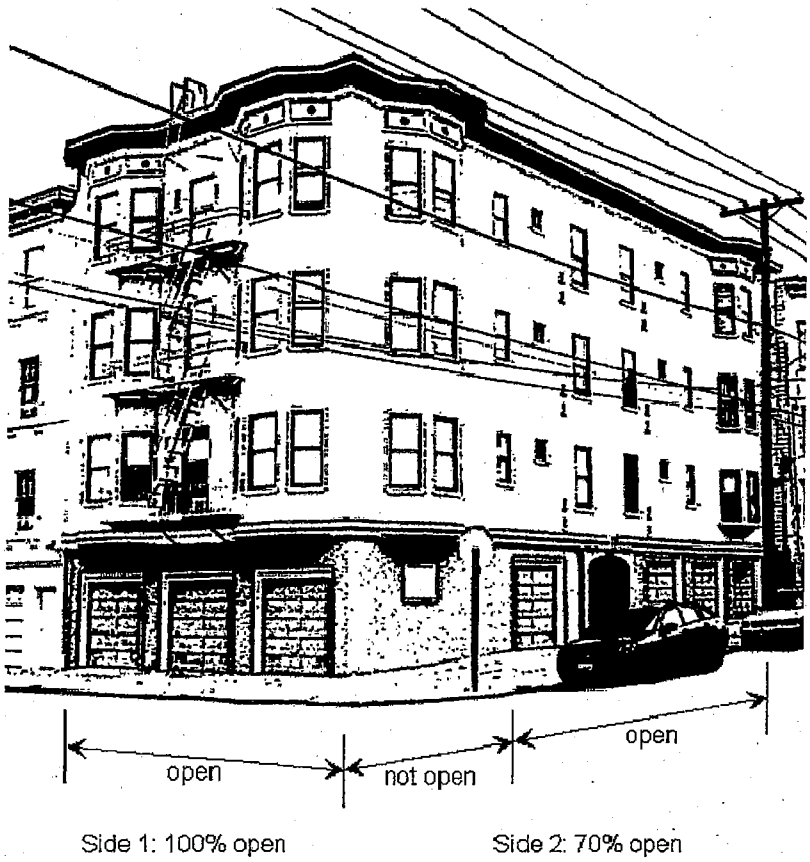

Figure 3. An example building image with lines indicating what is considered open and what is not in the Department of Building Inspection survey.

It is interesting to note that most of San Francisco's multi-unit, wood-frame buildings have large openings on at least one side. Figure 4 shows the number of buildings with varying degrees of openness on their most open side.

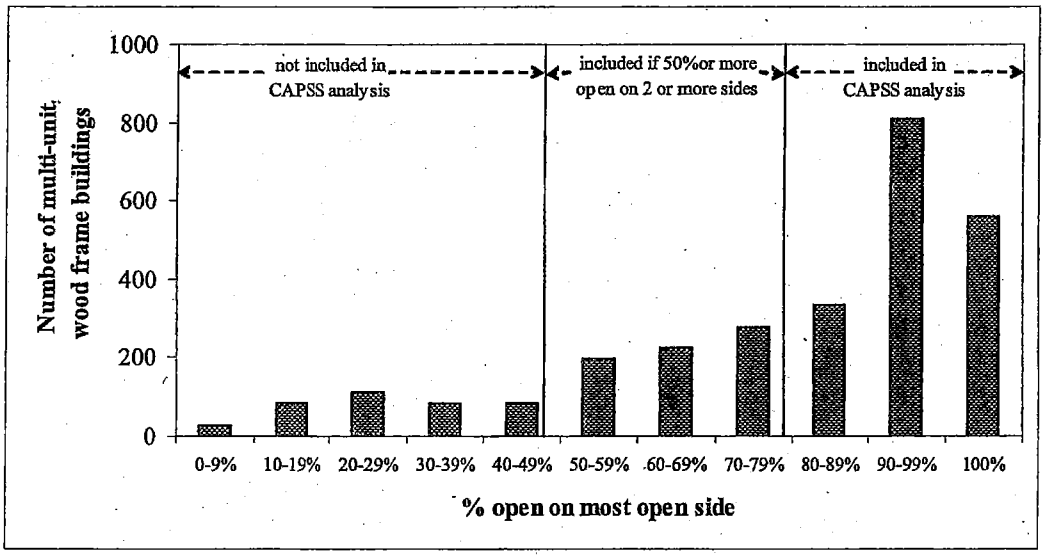

Figure 4. Range of openness of most open side of all wood-frame buildings with three or more stories and five or more residential units.

The buildings studied by CAPSS are dispersed across a number of city neighborhoods. Figure 5 shows the locations of all wood-frame buildings with three or more stories and five or more units. The subset analyzed by CAPSS, those buildings with the largest ground floor openings, are concentrated in the same neighborhoods as the larger set of buildings.

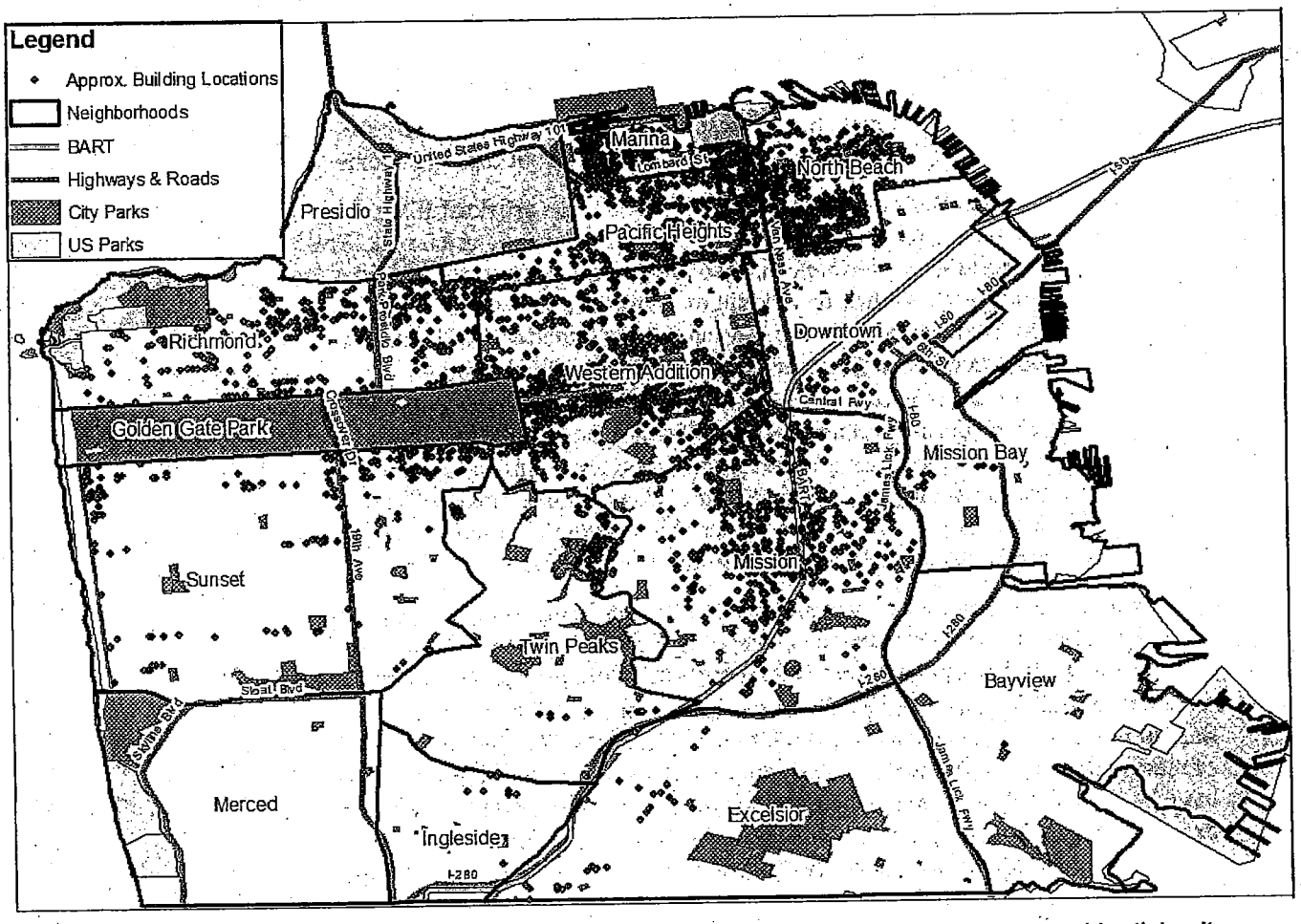

Figure 5. Locations of wood-frame buildings with three or more stories and five or more residential units.

Characteristics that Contribute to Vulnerability

A number of characteristics contribute to the vulnerability of multi-unit, wood-frame buildings. Those include the following:

- **Size of openings in ground floor perimeter walls.** Buildings with large openings at the ground level generally are more likely to be vulnerable to earthquake damage than those without large openings. Large windows or garage doors often mean that the interior also lacks partitions.
- **Length, strength, stiffness and location of interior walls and partitions.** Buildings with open ground floor areas (for parking or commercial uses) that lack structurally strong walls and partitions are more likely to be vulnerable to earthquake damage than those that have numerous walls and partitions.

- **Position within a block.** Corner buildings are generally more vulnerable than mid-block buildings. Mid-block buildings with a gap between themselves and neighboring buildings are more vulnerable than those that have buildings directly abutting them on each side. This is discussed further below.
- **Number of stories.** Taller buildings and those with more stories are heavier and, generally, more vulnerable, because the ground story walls have to support more mass. In the buildings studied by CAPSS, roughly 40 percent have three stories, 58 percent have four stories, and two percent have five or more stories.
- **Condition of wood.** Buildings with significant wood rot or pest damage have less capacity to resist earthquake forces than buildings without these problems.
- **Local soil conditions.** Buildings situated on soft soils or on artificial fill are generally damaged more than those that are located on firm soils or on rock. Soil conditions affect building performance in two ways. First, soft soils amplify ground shaking intensity, so that the amount of damage is increased. As example, during the Loma Prieta earthquake, the Marina district experienced shaking ten times stronger than neighboring Pacific Heights, due to differing soil characteristics[3]. Second, certain saturated soils can fail due to a phenomenon called "liquefaction" during earthquakes; liquefaction causes soil to spread and/or settle differentially, leading buildings to tip on their foundations. Figure 6 shows the California Geological Survey Seismic Hazard Zones map of San Francisco, indicating areas that may be susceptible to liquefaction or landslides. Other maps are available that show different soil characteristics.
- The most dramatic earthquake damage to soft-story buildings that was observed in the 1989 Loma Prieta earthquake occurred in buildings that were located at the corner of a block. Six out of the seven buildings that collapsed in the Marina were corner buildings of the type discussed in this report[4]. Corner buildings in San Francisco are typically more vulnerable to earthquake damage for a variety of reasons than are buildings in the middle of a block. Corner buildings tend to have larger ground floor openings than do buildings in the middle of a block. For example, many corner buildings have garage doors on both sides that face a street. Corner buildings with street level commercial spaces in them often have large windows that extend for much of the street frontage on both sides. These larger openings make corner buildings vulnerable to damage in earthquakes.
- In San Francisco, many midblock buildings abut their neighboring buildings with only a few inches or less between them. During an earthquake, neighboring buildings can crash into each other, in a phenomenon known as pounding, which can cause some damage. However, many experts believe that neighboring buildings also help to hold each other up by limiting side-to-side shaking. Midblock buildings without directly adjacent neighbors and corner buildings face a higher risk of damage, because they don't have the benefit of support from their next-door building.

[3] Boatwright et al., 1992.

[4] Harris and Egan, 1992.



Figure 6. California Geological Survey Hazard Zones Map of San Francisco.

Uses and Occupants of These Buildings

Residents

Wood-frame buildings with three or more stories and five or more residential units contain a significant share of the City's residential units. These buildings house approximately 45,000 units or thirteen percent of the City's housing stock. An estimated 89,000 residents, or eleven percent of the City's total population, live in these buildings.

A considerable percentage of San Francisco residents live in the 2,800 buildings analyzed by CAPSS. These buildings contain 29,000 residential units and an estimated 58,000 residents, or eight percent of San Francisco's total population. The Western Addition, Mission, Pacific Heights, Marina, and Richmond neighborhoods have the highest concentration of residential units in these buildings. As shown in Figure 7, these five neighborhoods contain more than 70 percent of the people living in multi-unit, wood-frame buildings with significant ground floor openings.

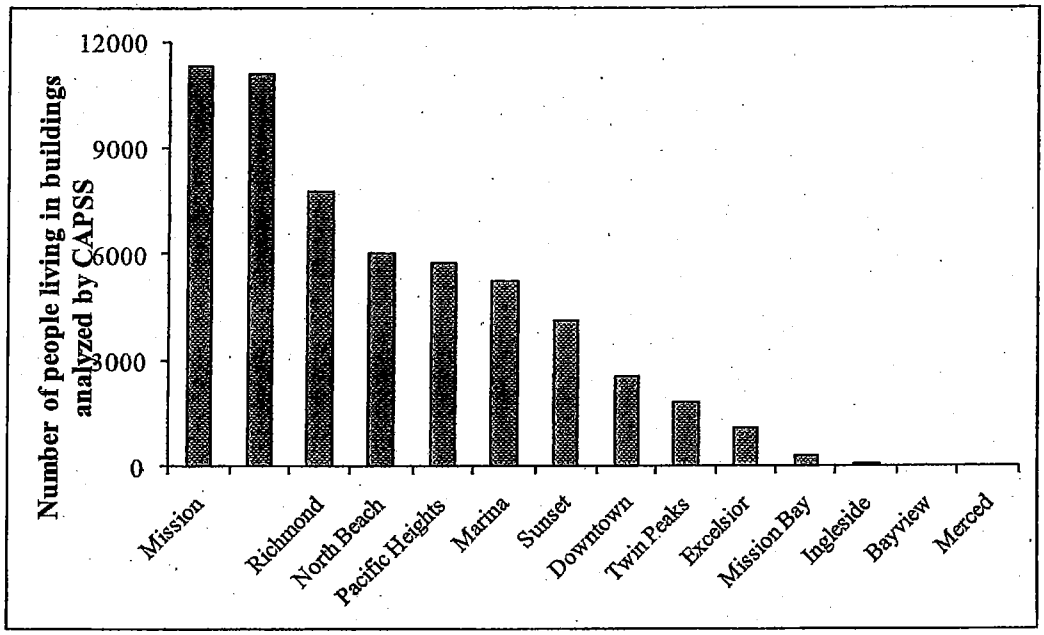

Figure 7. Estimated number of people living in the 2,800 buildings analyzed by CAPSS, by neighborhood.

Analyzing the demographic and economic characteristics of areas with the highest concentration of units in these buildings provides the following insights about households in those neighborhoods:

- **They generally have higher median incomes than the City as a whole.** Conversely, households in areas without these buildings have lower median incomes. High concentration areas have a median household income of $74,700, compared to $61,800 in areas without these buildings and $68,300 among households citywide. The geographic distribution of these buildings throughout the City explains, in part, these trends. As noted above, more affluent neighborhoods such as Pacific Heights, the Marina, and North Beach contain a major portion of San Francisco's multi-unit, wood-frame buildings, while lower-income neighborhoods such as Bayview and Ingleside contain relatively few.
- **Residents are slightly younger than the City as a whole.** Residents in high concentration areas have a median age of 39.2 years, compared to 40.2 years among residents citywide and 40.6 years among residents in low concentration areas.
- **They have lower homeownership rates than the City as a whole.** Only 19 percent of households in high concentration areas are homeowners, compared to

44 percent among households in areas without these buildings. Citywide, 35 percent of households own their home.

- **They have a higher proportion of White residents and lower proportions of African American, Asian American, and Hispanic residents than the City as a whole.** Approximately 66 percent of residents in high concentration areas are White, compared to just 32 percent in areas without these buildings and 44 percent in San Francisco as a whole. Again, this finding is largely due to the underlying demographic profile of the neighborhoods that contain a large share of these buildings.

Most of the people who live in multi-unit, wood-frame buildings are renters. Assessor's data indicate that 90 percent of these buildings are used as rental apartments, with the remaining buildings classified as condominiums or other uses. In addition, all apartment buildings built before June 1979 are subject to San Francisco's Rent Stabilization Ordinance, commonly known as rent control. All multi-unit wood-frame apartment buildings of concern are covered by rent control, because the Building Code change adopted in 1973 should prevent newer buildings from having a soft-story condition. However, due to San Francisco's high rate of apartment turnover, many of these rent-controlled units are likely to be at or near market rate rent levels[5].

Businesses

Close to 2,100 businesses operate in approximately 900 of the multi-unit, wood-frame buildings analyzed by CAPSS. This means that roughly one third of the 2,800 buildings studied contain commercial tenants. Businesses and workers located in these buildings represent a small percentage of all businesses and workers in San Francisco. Of the 73,000 businesses in San Francisco, less than three percent operate in these buildings. These businesses employ 6,900 people, accounting for one percent of jobs in the City.

The Western Addition, Mission, North Beach, and Pacific Heights contain the largest portion of businesses operating in this type of building.

Businesses housed in these buildings are concentrated in the retail, services, and food service industries. This reflects the fact that small retail shops and restaurants, along with professional and personal service establishments, often locate in mixed-use buildings along commercial corridors in San Francisco.

An extremely high percentage of the businesses located in the 2,800 buildings studied by CAPSS are small businesses. As shown in Figure 8, 84 percent of businesses in these buildings employ fewer than five people, compared to 76 percent of all San Francisco businesses. An additional 11 percent of them have between five and ten employees. The small size of businesses in these buildings suggests that many are independent, locally owned enterprises.

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[5] See Chapter 3 and the Documentation Appendices for more details on this topic.

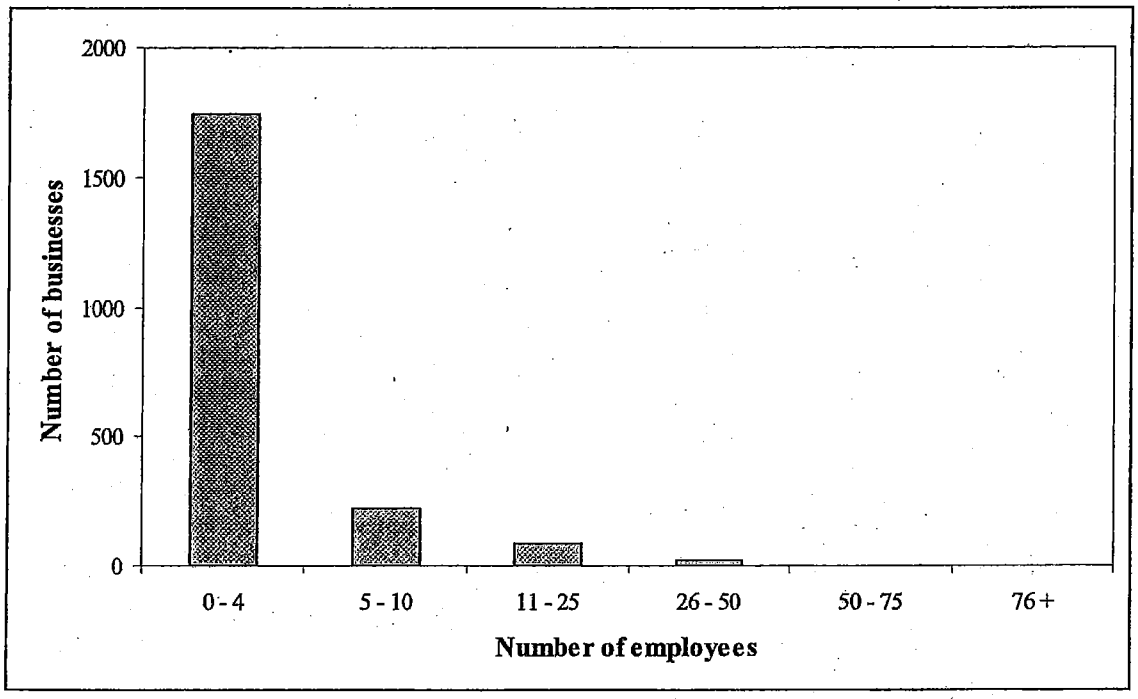


Figure 8. Size of businesses in the 2,800 buildings analyzed by CAPSS.

Architectural Character

The multi-unit, wood-frame buildings addressed in this report are common in many San Francisco neighborhoods. They shape the character and fabric of San Francisco's residential and commercial streets. If San Francisco lost many of these buildings in future earthquakes, the character of the City would change dramatically.

Many of these buildings are old, as shown in Figure 9. Sixty-five percent were built before World War II. Some of them survived the 1906 earthquake, although this does not mean that they are "safe". They may have been elevated since then, to add garages at their ground level, thereby changing their structural integrity. Many may suffer from

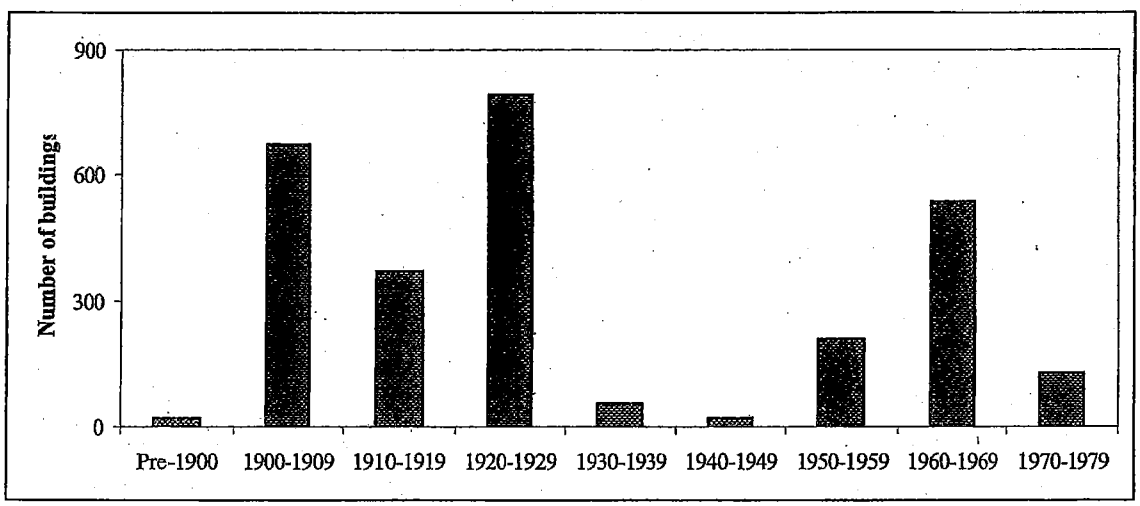


Figure 9. Decade of construction of multi-unit, wood-frame buildings studied by CAPSS.

wood deterioration that weakens their ground floor. Older buildings are not inevitably weaker; some older buildings were built with excellent quality materials. Older buildings are also not necessarily more architecturally important than newer buildings, but they are different. The materials, appearance, scale, and relationship to the streetscape of older buildings differ from those of buildings built today.

A few dozen of these buildings are officially designated (locally or on the state or national registers) as historic. These buildings cluster primarily in the Mission, Western Addition and Richmond neighborhoods. The San Francisco Planning Department is currently working to survey the historic importance of more buildings and neighborhoods, and it is likely that this number will increase. Whether or not they are officially designated as historic, these older buildings set the style and feel of many areas in San Francisco. Many include architectural articulation typical of their time of construction, such as that shown in Figure 10.

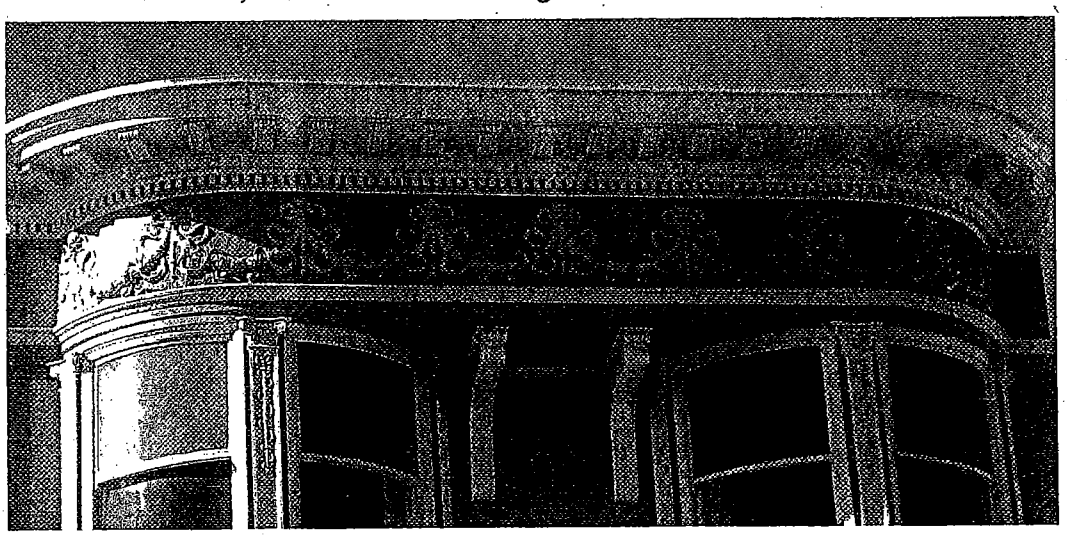
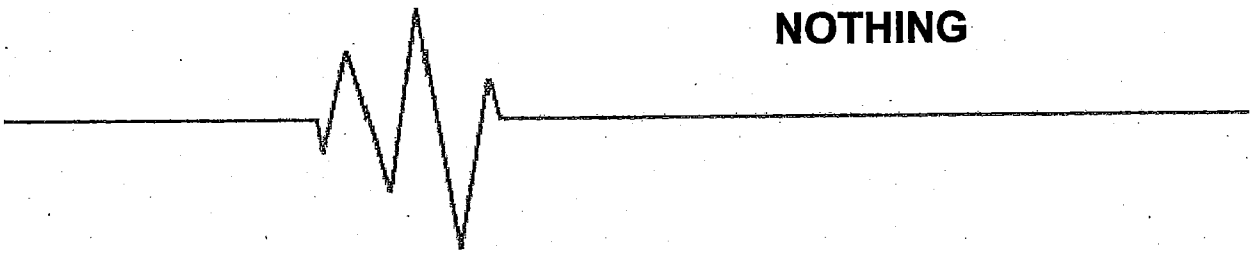


Figure 10. Close up of architectural detail on a multi-unit wood-frame building.

Multi-unit wood-frame soft-story buildings are an important part of San Francisco's neighborhoods. Those with the largest ground floor openings house nearly 60,000 people, eight percent of the City's population, most of them in rent-controlled units. They comprise a meaningful portion of the City's rental housing stock. They are often older buildings that hold an important place in the neighborhood residential and commercial streetscape. If the City lost many of these buildings to future earthquakes, it would cause dramatic social, economic and physical changes. As the next chapter makes clear, this level of damage is likely if the City takes no action to improve these buildings.

CHAPTER 2: THE RISK IN DOING NOTHING



Large earthquakes would seriously damage many of San Francisco's 4,400 multi-unit, wood-frame buildings, and a significant number could collapse. The actual number of severely damaged multi-unit, wood-frame buildings would depend on the earthquake that strikes and on other factors, but damage to buildings with soft stories would cause casualties and economic losses. The ripple effects could hinder the City's post-earthquake recovery process and could irrevocably change both the character and the affordability of the City.

Future Earthquakes

No one knows when the next large earthquake will strike San Francisco, but it is certain that a big one will come. The last significant earthquake to shake the City was Loma Prieta, which occurred on October 17, 1989. This magnitude 6.9[6] earthquake was centered about 60 miles south of San Francisco, near Santa Cruz. Despite being relatively distant from the City, this quake caused enough shaking in San Francisco to kill seven people, cause seven buildings to collapse in the Marina district, damage many more buildings, spark dozens of fires, and significantly damage the elevated Embarcadero freeway.

San Francisco is flanked by active earthquake faults. The San Andreas fault lies just off the City's western shore, and the Hayward fault cuts through the East Bay at the base of the foothills. Both of these faults are equidistant, about 10 miles, from the foot of Market Street in downtown San Francisco.

It is reasonable to expect an earthquake that is closer and, perhaps, larger than Loma Prieta to strike San Francisco soon. A recently released statewide assessment of the likelihood of earthquakes estimates that there is a 63 percent chance of at least one magnitude 6.7 or greater earthquake in the Bay Area some time in the next three decades. The Hayward-Rodgers Creek and San Andreas fault systems have the highest probabilities of generating large earthquakes in that time period[7].

The CAPSS project studied the impacts of four large and likely earthquakes in order to better understand the risks that earthquakes pose to San Francisco's multi-unit, wood-frame soft-story buildings. All of these potential earthquakes would produce shaking over large areas of the City that is two to four times stronger than the shaking that occurred in the Marina District during Loma Prieta. In other words, these

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[6] All earthquake magnitudes in this report are moment magnitudes. Moment magnitude represents the total amount of energy released in an earthquake and is the preferred scale used by earth scientists. This is similar to Richter magnitude, which is related to the peak horizontal acceleration caused by an earthquake.

[7] 2007 Working Group on Earthquake Probabilities, 2008.

potential earthquakes are significantly stronger than any earthquake that the City has experienced in over 100 years. These earthquakes are:

- **A magnitude 6.9 earthquake on the Hayward fault.** This event would rupture the entire length of the Hayward fault.
- **A magnitude 6.5 earthquake on the Peninsula segment of the San Andreas fault,** located on the portion of the San Andreas fault offshore San Francisco.
- **A magnitude 7.2 earthquake on the Peninsula segment of the San Andreas fault.** This earthquake is located on the San Andreas fault, extending north of the 1989 Loma Prieta rupture zone to Marin County.
- **A magnitude 7.9 event on the San Andreas fault,** which would be a repeat of the 1906 earthquake. This is the largest known earthquake to have occurred in northern California on the San Andreas fault.

Figure 11 shows the rupture zone of each of these scenario earthquakes. Larger magnitude earthquakes rupture a greater length along the faults. All of these earthquakes would emanate from fault segments much closer to San Francisco than the Loma Prieta earthquake.

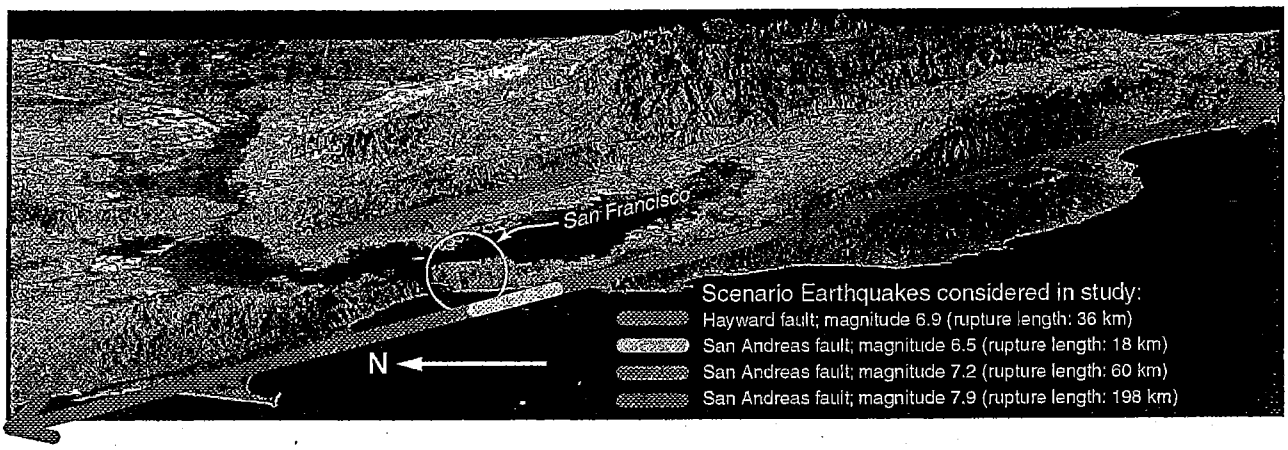

Figure 11. Rupture zones of four scenario earthquakes studied by CAPSS. Fault map courtesy of the US Geological Survey and Pacific Gas and Electric Company.

Likely Damage in Future Earthquakes

An estimated 4,400 wood-frame buildings in San Francisco with three or more stories and five or more residential units were built before the City changed the Building Code in May 1973 to prevent soft-story construction. The CAPSS project selected 2,800 of these buildings that have the largest ground floor openings for analysis. This subset of buildings is presumed to face the highest risk of damage in future earthquakes; examining this group in detail provides insights into the scope of damage that other similar buildings might experience in future earthquakes. It is important to remember that buildings with two stories, fewer units or smaller openings could also experience heavy damage in future earthquakes.

Because loss studies are uncertain by their very nature, this report presents potential losses as a range. The initial loss estimates were calculated using a numerical model derived from the nationally recognized loss estimation software developed by FEMA

known as HAZUS-MHTM, which is based on earth science, engineering, and observations made following damaging earthquakes, combined with assumptions regarding the scenario earthquake, site conditions and responses of representative buildings. HAZUS-based loss estimations can have uncertainties of a factor of two. CAPSS convened the Project Engineering Panel to review this analysis. This Panel, whose members are intimately familiar with numerical modeling and first-hand observation of earthquake damage, advised that policy makers would be better served if the results were expressed as a range rather than single numbers. The panel members developed the ranges.

Damage to these buildings was calculated for four scenario earthquakes and is presented in Table 1. While no future earthquake would be precisely like the scenarios studied, this analysis illustrates the range of possible damage for the selected scenarios.

Table 1 Estimated Damage to a Sample of 2,800 Unretrofitted Multi-Unit, Wood-Frame Soft-Story Buildings in Four Scenario Earthquakes

Scenario	Dollar Loss* ($Billions)	Estimated Distribution of 2,800 Buildings with Large Openings by Post-earthquake Safety Tagging Category			
		Green Tag (% of Buildings)	Yellow Tag (% of Buildings)	Red Tag – No Collapse (% of Buildings)	Red Tag – Collapse (% of Buildings)
Magnitude 6.9 Hayward Fault	$3.2	33 - 49	19 - 27	18 - 30	6 - 18
Magnitude 6.5 San Andreas Fault	$3.6	22 - 42	17 - 27	23 - 39	8 - 23
Magnitude 7.2 San Andreas Fault	$4.1	6 - 35	9 - 23	32 - 54	11 - 31
Magnitude 7.9 San Andreas Fault	$4.4	1 - 33	2 - 18	37 - 62	12 - 35

* The total estimated value of these buildings and their contents is approximately $14 billion. This excludes the value of the land.

M: Magnitude

Economic damage was also estimated using a model based on the HAZUS software. These estimates are subject to the same uncertainty described previously and can vary considerably. The estimated damages, expressed in dollars, are given as a single number because they are intended to be compared and each figure is derived from the same model and assumptions.

Building damage results are presented in terms of the expected safety tag (placard) assigned to buildings by inspectors after an earthquake, which are defined as follows[8]:

- **Green Tag (INSPECTED):** No apparent hazard is found although repairs might be required. Residents should be able to continue to occupy these structures.

[8] ATC-20-1, 2005.

- **Yellow Tag (RESTRICTED USE):** A hazardous condition exists or is believed to exist that requires restrictions on the occupancy or use of the structure. Residents might be able to continue to occupy some, but not all, of these structures, with restrictions.
- **Red Tag (UNSAFE):** Extreme structural or other hazard is present. There might be imminent risk of further damage or collapse from creep or aftershocks. Occupants cannot use any of these buildings. Some are collapsed. Some would need to be demolished, but others can be repaired.

Each of these potential earthquakes varies in size and location and, thus, the estimated damage that each would produce also varies; however, the overall pattern is similar for each of these events:

- Less than half of multi-unit, wood-frame buildings analyzed are expected to be green tagged and fully usable after any of these four scenarios.
- In the least damaging scenario event, about a quarter of these buildings are expected to receive red tags, which would mean that they cannot be occupied after an earthquake. In the most damaging scenario, more than 90 percent would be red tagged. These buildings house tens of thousands of residents, who would probably have to leave their neighborhoods for months or years, if not permanently, while these buildings were repaired or replaced. This could create blight in neighborhoods where many buildings would lie vacant for an extended period. This level of damage would place a significant burden on City emergency response personnel who provide rescue, fire fighting, shelter, and building inspection services.
- From 6 to 35 percent of these buildings would collapse. This outcome threatens the lives of the people who live in and use these buildings. It also would mean that rent-controlled apartments in these buildings would be permanently lost to the City. The look and feel of neighborhoods that contain these buildings would change, as the buildings were rebuilt with modern materials and design.
- For more insights, it is helpful to take a closer look at the damage that would occur due to a magnitude 7.2 earthquake on the San Andreas fault. This size earthquake would produce shaking in many parts of the City that would be similar to the "design level" shaking that San Francisco's building code requires engineers to consider when designing new buildings. In a magnitude 7.2 quake, this subset of 2,800 buildings would experience the following damage:
    - 43 to 85 percent of buildings—from 1,200 to 2,400 multi-unit buildings—would be red-tagged. This means that residents could not use them until they were repaired or replaced, which could take years. For this structure type, most of the buildings that do no collapse should be repairable, although repairs may be expensive. These red-tagged buildings contain from 12,000 to 25,000 residential units.
    - A quarter of these red-tagged buildings would collapse, from 300 to 850 buildings with approximately 3,000 to 9,000 residential units. Collapses threaten lives. They also mean that San Francisco permanently loses these buildings, their architectural character, and the rent-controlled apartments in them. When they are replaced, owners may choose to rebuild them as condominiums, and even if they are rebuilt as apartments, they will no longer be covered by rent-control under state law.

- Over $4 billion dollars in damage to building structures and their contents would be incurred. Few multi-unit buildings carry earthquake insurance, so the majority of these losses would be borne by the buildings' owners and occupants.

Figure 12 illustrates the proportion of green, yellow and red tags, including collapses, for this earthquake.

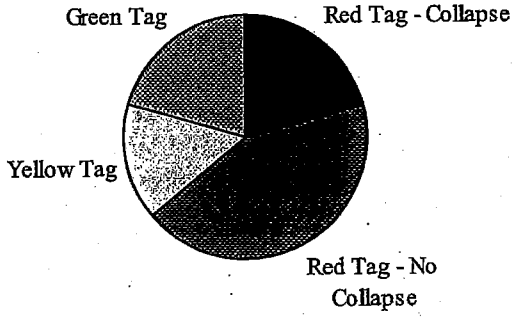

Figure 12. Approximate distribution of safety tagging of buildings studied by CAPSS for a magnitude 7.2 scenario earthquake on the San Andreas fault. The number of tags in each category could vary as shown in Table 1.

The damage estimates presented in this report do not include the impacts of post-earthquake fire. Earthquake shaking sparks fires in many ways, but a significant source of fire risk comes from damaged buildings. Wracked building walls can sever gas lines where they enter the buildings. Collapsing buildings can tip appliances with pilot lights or can drag down power lines. The heavy damage estimated for this category of building suggests that they could be responsible for sparking a number of fires. The fire in the Marina District that followed the Loma Prieta earthquake was sparked by the collapse of a multi-unit, wood-frame soft-story building[9]. Whether these fires spread into a citywide conflagration, as occurred after the 1906 earthquake, or are extinguished quickly depends on many factors, including the number of ignitions, the weather and the actions of local residents and fire fighters.

What This Damage Would Mean to San Francisco

The estimated damage to multi-unit, wood-frame soft-story buildings in each of the scenarios examined is devastating. It is important to recognize that this damage from a particular sample of buildings would be part of a larger catastrophe: many other types of buildings in San Francisco would also be damaged; other Bay Area communities would suffer similar damage; water, telephones, transportation networks, and other utilities would not be usable; and people would be killed, injured and frightened. Repairing damaged buildings and replacing destroyed buildings will consume resources and energy that would be conserved if buildings were retrofitted to resist strong ground shaking. The sections that follow examine only the impacts of damage to the 2,800 buildings studied in this report.

[9] Scawthorn, Porter and Blackburn, 1992.

Impacts on Building Residents

Residents of multi-unit, wood-frame soft-story buildings would be severely impacted by the heavy damage that these buildings would experience in a large earthquake. These impacts include:

- **A high risk of death or injury,** especially for people in ground level stores, restaurants, apartments or parking areas.
- **A high likelihood of displacement.** Without retrofit, only 1 to 49 percent of these buildings are expected to receive green tags, meaning that they can be continuously occupied. Some, but not all, yellow-tagged buildings can also be continuously occupied. In the least damaging scenario studied, over 13,000 residents would need post-earthquake shelter, many for years. Residents would face dislocation, expense, separation from neighborhood services, and possible difficulty in accessing schools and jobs due to this relocation.
- **Damage or destruction of personal possessions.** Residents could lose many or all of the things that they own and be forced to bear the cost and hassle of replacing them. Insurance may cover some losses for some residents.

Natural disasters have a particularly negative effect on lower-income households and on other vulnerable populations, such as seniors and the disabled. Lower-income households typically have fewer resources to manage their losses, to recover from economic and geographic displacement, and to return to their homes. Furthermore, many lower-income residents live in multifamily buildings, which historically have been rebuilt at slower rates than single-family units. Although on average, the residents living in the buildings studied in this report are not low-income, it is likely that many of these buildings do house long-term low-income tenants, such as seniors who live on a fixed income.

A 2006 study of New Orleans after Hurricane Katrina suggests that lower-income areas have been slower to repopulate, due to a lack of access to transportation among poor households, fewer resources to repair damaged property, and the ongoing lack of employment prospects in the City's disrupted economy[10]. The study also states that lower-income households may not be able to afford the higher rents in reconstructed buildings in New Orleans. As a result, the study predicts major demographic and socioeconomic disparities in the City's repopulation.

Research on the impacts of the Loma Prieta earthquake in Santa Cruz County shows that seniors are similarly affected by natural disasters. The elderly are less mobile and need to be near social services, grocery stores, pharmacies, shopping, entertainment, and existing community networks. These factors, combined with the general loss of affordable housing, make it particularly difficult to find replacement housing for lower-income seniors who lose their homes after a disaster.

Impacts on Housing

Multifamily housing is slow to recover following an earthquake. A 1994 study on residential rebuilding efforts after the Loma Prieta Earthquake found that one year after the earthquake, 90 percent of the multifamily units destroyed or rendered

[10] McCarthy et al., 2006.

unserviceable in the Bay Area were still out of service. Four years later, 50 percent of these units had not been repaired or replaced[11].

When multifamily properties are demolished after an earthquake, the market favors those properties being reconstructed as condominiums, rather than apartments. Development economics generally find that condominiums generate greater financial returns to developers than do apartments, even in high-priced rental markets such as San Francisco. When demolished apartments are reconstructed, the new construction is not subject to the City's Condominium Conversion Lottery, and the lost rental units may therefore be replaced as ownership units. Similarly, new apartments replacing demolished units are not subject to the City's Rent Stabilization Ordinance, commonly known as rent control. For an owner of an apartment building, the incentive to rebuild is connected to his or her ability to enhance cash flow and to service debt. Owners have little incentive to rebuild, if construction costs cannot be recovered through rents. For units serving lower-income households, access to construction financing is even more difficult. In sum, if the building owner is carrying a large debt load relative to the building's value, is making little or no profit from rental income, and if the cost to repair is high, then incentives to re-construct the property as condominiums are greater.

The current credit market would limit access to construction financing for any new residential development in the short-term. Lenders now apply tight underwriting criteria and stringent financing terms to new construction of any kind. Interviews with developers indicate that lenders are currently offering loans in amounts up to 50 percent of the building's value, compared to historical norms of 70 to 90 percent.

Affordable housing is particularly slow to recover after natural disasters. For example, after Hurricane Katrina, federal and state allocations would only suffice to replace two out of five affordable rental units in the state of Louisiana, and one out of three affordable rental units in the city of New Orleans. What is more, of the 24,600 units projected to receive assistance, only 11 percent were open for occupancy as of 2008[12].

The Loma Prieta Earthquake particularly impacted lower-income housing stock. The 1994 study of the Loma Prieta earthquake found that 75 percent of the 6,300 San Francisco units destroyed or damaged after the earthquake were rental units, and 66 percent of those units were rented by low- and moderate-income households[13]. The study also showed that federal recovery assistance was less effective at meeting repair needs for multifamily buildings and for affordable housing, in particular. While owners of multifamily buildings in strong San Francisco submarkets could rely on rental income to access rebuilding loans, owners of more marginal properties had little cash flow to leverage to secure financing.

Impacts on Owners

Building owners would bear most of the financial losses to these buildings, a figure estimated at $3.2 billion to $4.4 billion for the four scenario earthquakes studied.

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[11] Camerio, et al., 1994.

[12] Rose et al., 2008.

[13] Camerio et al., 1994.

Discussions with building owners suggest that few owners of multi-unit apartment buildings currently carry earthquake insurance. Insurance for this type of building is expensive and does not provide comprehensive coverage.

The federal government offers limited resources for rebuilding rental housing. The Federal Emergency Management Agency (FEMA) and Small Business Administration (SBA) offer a small number of programs to homeowners for rebuilding their properties following a disaster. In general, FEMA offers more financial assistance to homeowners than to renters due simply to the greater cost of reconstructing or repairing a home. Homeowners also may qualify for months of rental assistance while repairing their property.

For owners of rental properties, the SBA serves as the primary source of financial assistance for rebuilding. The SBA offers Business Physical Disaster Loans with interest rates ranging from 4.0 to 8.0 percent and with a maximum term of 30 years, although applicants who have access to credit through other means are only eligible for a maximum three-year term. Loans are limited to $2.0 million and cannot exceed the verified uninsured disaster loss.

Following Hurricane Katrina, smaller building owners could access forgivable loans through the Department of Housing and Urban Development's (HUD) Small Rental Repair Program. In contrast to the upfront grants available to homeowners for property reconstruction, the Small Rental Repair Program reimburses owners after repairs are completed and tenants are in place. A recent study found that building owners have had trouble taking advantage of the Small Rental Repair Program's reimbursements, due to difficulties in accessing private financing for repairs[14].

Building owners are obligated to act in a prudent manner to protect their building's occupants from injury, and they may be liable for damages if they know that their building has a soft-story that may be hazardous. Liability issues for older buildings are not clear-cut, but every damaging earthquake generates lawsuits relating to deaths, injuries and/or damage to personal property. A retrofit program could establish a reasonable standard for owners to meet.

Impacts on Businesses

Small businesses are more vulnerable than large firms are following a natural disaster. Small business owners often do not own their building, seldom carry insurance, and are rarely diversified in terms of the products and services that they offer. They also lack the resources to address equipment and inventory damage and interruptions in utility and transportation lifelines. Small and locally-owned businesses are therefore less likely to recover from disasters than are their chain competitors, whose profits do not depend on a single store. Given the number of small businesses located in multi-unit, wood-frame soft-story buildings, the City's economic recovery after an earthquake would be impacted by heavy damage to these buildings.

For small businesses located in older areas, structural damage can cause a number of problems that further delay and hamper recovery, such as release of hazardous materials and failure of older utility pipes, ducting, and sprinkler systems, which can cause flooding and interior damage. Small businesses often lack the resources to

[14] Rose et al., 2008.

address the damage that can occur in older buildings. If other nearby businesses and residences suffer similar damages, then customer traffic in the area may decrease, compounding the economic hardship that the neighborhood confronts.

In the case of the Northridge earthquake, businesses reported that for some time after the earthquake, residents changed their spending patterns, which further disrupted business operations. The highest job loss levels that resulted from the Northridge earthquake were in the retail industry (24 percent of total job losses). Some small businesses failed as a result of the Northridge earthquake as late as two years after the event[15].

A study of the 2001 Nisqually Earthquake in Washington State similarly highlighted the vulnerability of small retailers[16]. Of 13 industries surveyed, retail businesses reported higher rates of direct physical losses (buildings and equipment) and reduced revenue as a result of lost inventory. This was attributed to the fact that retailers have a higher percentage of their assets invested in inventory than do most businesses.

Even businesses that qualify for federal lending assistance eventually bear the full losses themselves. The SBA offers loans to businesses for the repair or replacement of real estate, inventories, machinery, equipment, and all other physical losses following a disaster. The SBA does not provide disaster grants.

While the damage to multi-unit, wood-frame soft-story buildings would impact the small businesses located in these structures most heavily, businesses of all sizes and in all locations would be affected. These buildings house people who work in many San Francisco businesses. No business can succeed without its employees.

Impacts on Neighborhoods

Evidence suggests that major earthquakes can lead to significant neighborhood transition. A study of the 1994 Northridge earthquake reported that an estimated 60,000 people migrated out of the San Fernando Valley as a result of the damage done to homes and businesses. That area had already been suffering an economic decline, due to contraction of the defense industry and to falling home values. In the years following the disaster, approximately 20,000 new residents moved into the area. Most of the newcomers were younger and poorer than the previous population had been. These new residents had different spending habits and needs, and their influx greatly altered both the retail fabric and the overall social structure of neighborhoods[17].

In some Los Angeles neighborhoods, the Northridge earthquake had an even more striking impact on neighborhood transition. In many areas that had once been middle-income neighborhoods, the damage rendered structures uninhabitable and forced some tenants to abandon their units. These neighborhoods subsequently became targets of looters, squatters, and street gangs, whose presence further undermined the quality of the neighborhood. In an already weak housing market, it was not economically viable to reconstruct the damaged housing stock, and low-income units

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[15] Petak and Elahi, 2000.

[16] Meszaros, Jacqueline and Mark Fiegener, 2002.

[17] Petak and Elahi, 2000.

were especially difficult to finance. In time, this led to a spiraling decline in affordable housing stock and to an overall decline in property values[18].

San Francisco is celebrated for the unique character and ambiance of its neighborhoods. That character is largely due to the style, scale, articulation, narrow parcels and patina of buildings that were built generations ago. Most of those buildings are wood-frame, and many have soft-story conditions. Buildings define neighborhoods, give identity to residents, create communities and attract tourists.

In a magnitude 7.2 earthquake on the San Andreas fault, from 300 to 850 of the 2,800 buildings studied are expected to collapse. The structures that replace them would be determined by the choices and the financial wherewithal of their owners. One thing is certain: the newly constructed buildings that replace those that collapse would look different from what stands today. The new structures would be built using modern materials and design aesthetics and reflecting the economic realities of the times. Their use, look, size, floor height, size of residential units and relationship to the street would all change. In some cases, owners might combine parcels to build larger developments.

The next major earthquake to strike San Francisco would cause heavy damage to multi-unit, wood-frame soft-story buildings. This damage would have serious impacts on all San Franciscans. However, as discussed in the next chapter, many of these impacts can be avoided or reduced if these buildings are seismically retrofitted.

[18] Petak and Elahi, 2000.

CHAPTER 3: THE CONSEQUENCES OF RETROFITTING

Seismic retrofits greatly reduce the likely level of damage that multi-unit, wood-frame soft-story buildings will experience in future earthquakes. Retrofitting would save lives, reduce collapses, and allow thousands of residents to remain in their homes and neighborhoods after an earthquake and contribute to reviving their community. It would preserve many units of rent-controlled housing and would maintain the vitality, character and demographic mix of neighborhood residential and commercial areas. Fewer buildings would need to be razed and replaced and resources and energy would be conserved.

These safety increases come with costs. Building owners would need to bear the costs of retrofit construction, typically $60,000 to $130,000 per building for direct construction costs[19]. Roughly 30 percent of buildings studied by CAPSS have commercial or residential uses at the ground level. Retrofit construction could require these tenants to vacate or to deal with considerable inconvenience for two to four months during construction. This could cause hardship, especially to small businesses and owners. All of these costs would be immediate and tangible. Their scale, however, is dwarfed by the costs that would be borne by all of these parties after a large earthquake, if retrofits do not occur.

Damage Avoided by Seismic Retrofits

Wood-frame soft-story buildings can be retrofitted to improve their performance in earthquakes. Retrofitting these buildings generally involves installing shear walls, steel frames or steel cantilevered columns, such as those shown in Figures 13 through 15.

However, not all retrofits are the same. The CAPSS project selected four representative buildings with large ground floor openings to evaluate the benefits and costs of retrofitting. For each building, three different retrofit designs were made, ranging from a basic retrofit to a retrofit requiring more extensive work[20]. The three retrofits were intended to achieve three different levels of performance when exposed to strong shaking:

- **Retrofit Scheme 1:** This is a minimal retrofit approach intended to reduce harm to those who live and work in or frequent the building. Collapse would be prevented, and occupants should be able to escape the building safely, but the

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19 These costs are for direct construction only and do not include other costs owners will incur. These estimated costs are explained later in this chapter.

20 Details about the representative buildings studied and the various retrofit schemes are available in the Documentation Appendices.

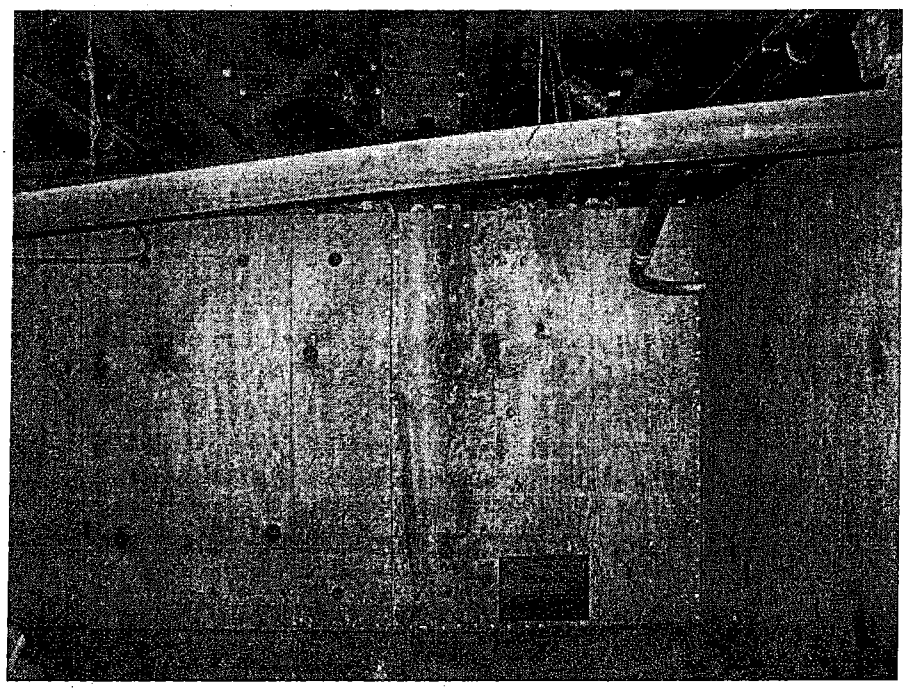

Figure 13. An example shear wall.



Figure 14 An example steel moment frame. Photo courtesy of Anderson Niswander Construction.

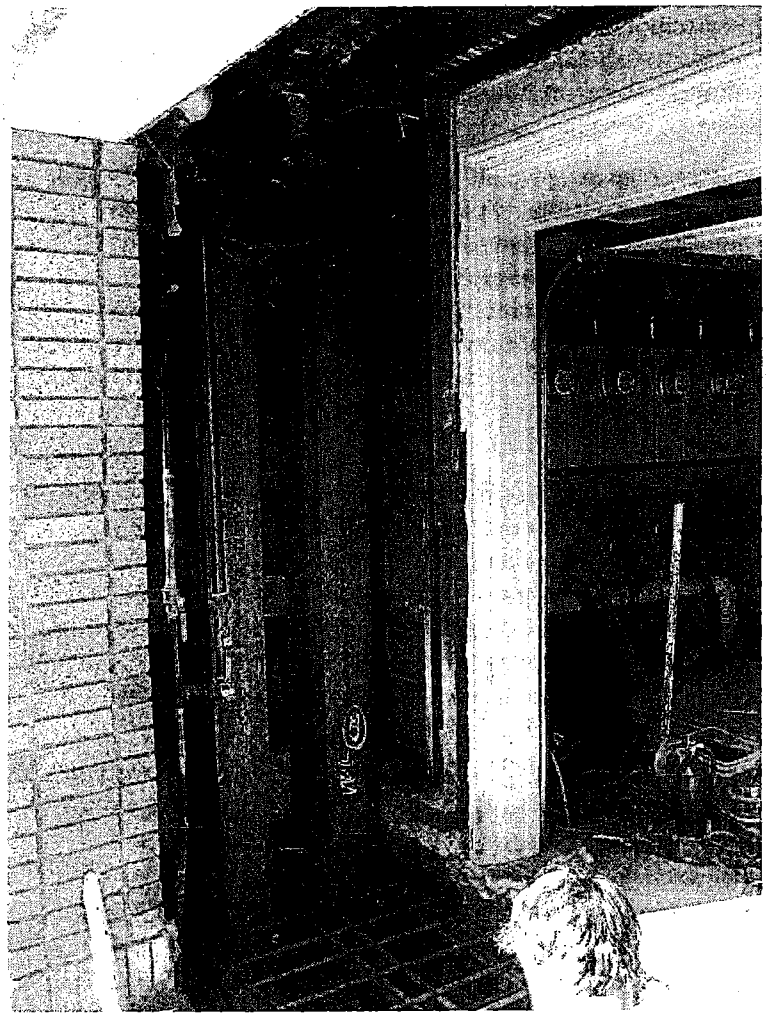

Figure 15 An example of steel cantilevered columns.

building might not be repairable or fit for occupancy after an earthquake. Rent-controlled apartments could be permanently lost.

- **Retrofit Scheme 2:** This is a moderate retrofit level that is intended to avoid demolition. It would allow significant damage, and the occupants could become homeless after a major earthquake and need to seek other lodging for the years it could take to repair the building. Repaired rental units would remain under rent control restrictions, and neighborhood character would be protected.
- **Retrofit Scheme 3:** This scheme is similar to Retrofit 2, except that it uses different structural steel members. It is intended to allow the residents to remain in their units after a major earthquake. A building retrofitted to this standard would be damaged after a major earthquake, but would be expected to withstand strong aftershocks. There might be significant damage to nonstructural building elements, utility services might not function, and some areas of the building might be off limits.

Retrofit schemes 2 and 3 use different structural systems. The differences make them difficult to compare directly because the two schemes, steel frames and steel cantilevered columns, differ in where they would be preferred. The appropriate

system depends on engineering judgment about each specific building. The differences in approaches and small differences in estimated construction costs are less important than learning that retrofitting using these systems can result in retrofitted buildings that could be occupied following earthquakes.

In reality, no retrofit can guarantee any specific performance. Any well-engineered retrofit makes it more likely that a building would be safe, repairable and fit for occupancy after an earthquake. An extensive retrofit makes these things more likely than a basic retrofit. After an earthquake, the performance of each building would vary based on the strength, duration and direction of shaking experienced at its particular location, the local soil it sits on, unique characteristics of its construction, and many other factors. If many buildings were retrofitted to one of the schemes described above, the majority of them would be expected to have the described performance, but some would fare better and some would fare worse.

All retrofits examined by the CAPSS project limited construction work to the ground floor. Construction work in upper floors would increase the costs of seismic retrofits considerably, as well as requiring upper level residential tenants to temporarily relocate. For most buildings, it should be possible to achieve the performance described above without extending work into the upper floors. The retrofits do not, however, mitigate against liquefaction damage. While the retrofits would increase the safety of buildings that experience liquefaction, it cannot be assumed that the buildings could be occupied or repaired after liquefaction. This level of performance would require costly upgrades to foundations.

The CAPSS project examined how earthquake damage would lessen in four scenario earthquakes, if all 2,800 multi-unit, wood-frame buildings with three or more stories, five or more residential units, and large ground floor openings were retrofitted to each of the three retrofit schemes. The results, presented for all scenarios in Table 2, show that seismic retrofits greatly reduce the damage expected in these buildings, although damage is not entirely eliminated. As discussed in the previous chapter, these results, based on numerical analysis and professional judgment, are presented as a range due to the uncertainty inherent in these types of estimates. The most meaningful way to interpret the economic losses, which, although not expressed as a range, also have uncertainty, is to compare the various scenarios and retrofit schemes.

A closer look at the impacts of retrofitting in one of these scenarios, a magnitude 7.2 earthquake on the San Andreas fault, provides additional insights. Key points that emerge include:

- Retrofitting would greatly reduce collapses in a magnitude 7.2 earthquake on the San Andreas. If all 2,800 buildings were retrofitted using scheme 3, collapses would be reduced to less than one percent of buildings, from an estimated 11 to 31 percent with no retrofits. Retrofit schemes 1 and 2 would also reduce collapses significantly.
- The number of buildings that receive red tags would also be significantly reduced, although many buildings would still be heavily damaged. Red-tagged buildings cannot be occupied after an earthquake and, if not collapsed or demolished, generally require costly and lengthy repairs. For this structure type, most red-tagged buildings that do not collapse can be repaired. Retrofitting all 2,800 buildings reduces red tags to 6 to 36 percent of buildings, depending on the level of retrofit, down from an estimated 43 to 85 percent red-tagged with no retrofit.

Table 2 Expected Damage Before and After Three Retrofit Schemes for a Sample of 2,800 Multi-Unit, Wood-Frame Soft-Story Buildings in Four Scenario Earthquakes

Scenario	Retrofit	Dollar Loss (Billions)*	Estimated Distribution of 2,800 Buildings with Large Openings by Post-earthquake Safety Tagging Category			
			Green Tag (% of Buildings)	Yellow Tag (% of Buildings)	Red Tag – No Collapse (% of Buildings)	Red Tag - Collapse (% of Buildings)
Magnitude 6.9 Hayward Fault	As-is	$3.2	33 – 49	19 – 27	18 – 30	6 – 18
	1	$2.4	72 – 75	18 – 20	4 – 8	1 – 2
	2	$1.8	84 – 86	10 – 11	3 – 6	0.2 – 0.3
	3	$1.7	88 – 89	9 – 10	2 – 3	0.1 – 0.2
Magnitude 6.5 San Andreas Fault	As-is	$3.6	22 – 42	17 – 27	23 – 39	8 – 23
	1	$2.7	61 – 66	23 – 26	6 – 13	2 – 4
	2	$2.2	76 – 79	15 – 17	4 – 9	0.3 – 0.5
	3	$2.1	79 – 81	15 – 16	3 – 6	0.2 – 0.3
Magnitude 7.2 San Andreas Fault	As-is	$4.1	6 – 35	9 – 23	32 – 54	11 – 31
	1	$3.4	36 – 48	28 – 34	14 – 28	4 – 8
	2	$2.9	57 – 64	24 – 27	9 – 18	0.5 – 1
	3	$2.6	67 – 71	21 – 23	6 – 12	0.3 – 0.7
Magnitude 7.9 San Andreas Fault	As-is	$4.4	1 – 33	2 – 18	37 – 62	12 – 35
	1	$4.0	13 – 35	21 – 32	26 – 52	7 – 14
	2	$5.4	23 – 40	27 – 35	24 – 47	1 – 3
	3	$4.0	28 – 44	26 – 33	22 – 44	1 – 3

*The total value of these buildings and their contents is estimated at $14 billion. This does not include the value of the land.

Figure 16 illustrates how post-earthquake safety tagging would change if buildings were retrofit to various levels (see previous chapter for a description of post-earthquake safety tagging).

The loss estimates for this project do not consider the risk of post-earthquake fire. However, damaged buildings are a major cause of fire ignitions. Retrofitting buildings reduces their damage and, consequently, reduces the number of fires that are likely to ignite.

Costs of Retrofitting

Retrofitting clearly reduces damage and collapses, but that increased performance comes at a cost. Part of this cost can be quantified in terms of financial impacts. Other elements of the cost are not financial, at least not directly, but still constitute real impacts that the community would experience over the course of retrofitting these buildings.

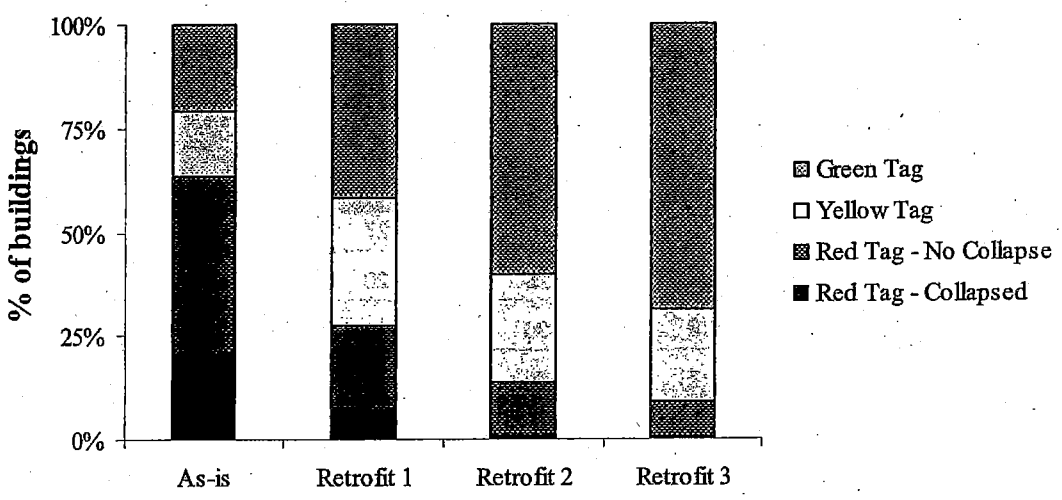

Figure 16. Approximate distribution of damage tags before and after three retrofit schemes in a scenario magnitude 7.2 earthquake on the San Andreas Fault. The number of tags in each category could vary as shown in Table 2.

Direct Construction Costs

The CAPSS project took a detailed look at the direct construction costs of each retrofit scheme for four representative San Francisco buildings. Although the actual costs of retrofitting any specific building would vary depending on the unique circumstances of each project, the cost estimates produced for these retrofits provide guidance about the overall range that should be expected and the differences in cost associated with achieving different performance levels.

Table 3 presents cost estimates for direct construction costs based on an analysis of retrofits for four representative multi-unit, wood-frame soft-story buildings. These

Table 3 Direct Construction Costs Estimated for Four Representative Multi-Unit, Wood-Frame Soft-Story Buildings for Each Retrofit Scheme

	Per Building		Per Residential Unit		Per Square Foot	
	Average	Range	Average	Range	Average	Range
Retrofit Scheme 1	$65,000	$49,000 to $79,000	$11,000	$9,000 to $13,000	$6.60	$3.00 to $9.40
Retrofit Scheme 2*	$105,000	$59,000 to $132,000	$17,000	$15,000 to $20,000	$10.00	$5.70 to $12.10
Retrofit Scheme 3*	$93,000	$58,000 to $114,000	$16,000	$13,000 to $19,000	$9.00	$4.60 to $11.10

* Although retrofit scheme 3, which provides the better performance, is less expensive than retrofit scheme 2, in general it costs more to get better performance. Retrofit 2 uses steel moment frames and plywood shear walls. Retrofit 3 uses steel cantilevered columns and plywood shear walls. Cantilevered columns generally are less expensive to construct than are moment frames, but are not always appropriate to use. Many structural engineers prefer frames to cantilevered columns. The costs of retrofitting any building will vary based on its unique circumstances. This analysis shows that a range in performance is available at a range of costs.

estimates include direct construction costs and permit fees. They do not include architectural or engineering design fees, costs of relocating any conflicting utilities, or costs associated with other circumstances described below. Engineering fees would vary, but would represent at least 10 percent of construction costs.

These costs do not include the costs of other work that might be triggered by this construction. In particular, buildings with commercial use are subject to Title 24, California Building Code, which implements the Americans with Disabilities Act (ADA). When upgrades or repairs exceeding a threshold of $119,000 are made within a particular commercial space, cumulative over a three-year period, then significant upgrades must be made to make that area of the building more accessible to the disabled. When the three-year cumulative costs of upgrades and repairs do not exceed the threshold, then the project must spend an additional 20 percent to improve handicapped access. These requirements cannot be waived for seismic safety projects. If the Title 24 threshold is triggered, the overall costs of construction rise considerably, and a number of changes might be required that impact the businesses in the affected space. For example, a restaurant with a small bathroom might be required to upgrade the bathroom to a larger size, which would reduce the amount of floor space available for customer seating. The Department of Building Inspection vigorously enforces Title 24, because it protects important civil rights.

Construction costs could be higher for many other reasons, as well. Buildings with ground floor commercial spaces may be able to keep those tenants in place by carrying out construction during off-hours, but this increases costs. Owners of historic or architecturally important buildings could see their construction costs rise by an estimated 20 to 50 percent due to efforts to maintain the architectural integrity of the building[21]. Buildings with occupied commercial or residential spaces at the ground floor could see costs rise if significant demolition and replacement of interior finishes are required. In some cases, other fire and life safety upgrades relating to issues such as egress, parapets, and façade materials could be triggered, which would add to costs. None of these issues are included in the cost estimates shown in Table 3.

Costs to Owners

Building owners would bear most of the costs of seismic retrofit construction. The financial impact of these costs on owners would vary according to each owner's particular economic circumstances. A major property owner with a diversified investment portfolio might be able to bear the costs of retrofits to this type of building without suffering significant adverse consequences. By contrast, a "mom and pop" owner who relies on the property as a major source of income, who has a significant amount of outstanding debt, or who is heavily invested in the property, could be more negatively affected by retrofit costs.

In most cases, San Francisco building owners do not rely on their properties as a primary income source. The San Francisco Board of Supervisors commissioned a survey in 2003 of owners and tenants of multi-unit rental building in San Francisco[22]. The survey revealed that most building owners were employed and tended to work in executive or professional occupations in San Francisco. Most of

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21 Tennebaum, 2009.

22 Bay Area Economics. 2003. Survey respondents totaled 693 multi-unit rental building owners, representing six percent of the total rental housing stock in San Francisco.

the survey respondents did not work primarily as property owners or managers. Owners had relatively high household incomes in comparison with San Francisco renters, with all San Francisco households, and with property owners nationwide. The owners' median annual household income was estimated at $90,900, compared to $44,800 for tenants, and $55,200 for San Francisco households overall. Most owners received the majority of their income from sources other than their rental properties in the City; only one-fourth relied on these properties for half or more of their income. The most frequently stated reason for purchasing property was to receive income from rents, and only 16 percent of owners reported purchasing the property for retirement security. Less than one-fifth of the owners indicated that they were merely breaking even or were losing money on their properties, which is nearly the same as rates nationwide, where a far lower proportion of units are covered by rent control.

In the near term, restrictive credit markets might limit the ability of landlords to secure financing for seismic improvements. Due to ongoing turmoil in the national and international credit markets, landlords could encounter difficulty in securing affordable financing for seismic improvements. Literature reviews also indicate that lenders often provide less favorable financing terms for seismic improvements, which do not increase a property's value (i.e., allow for higher rents). In fact, experience in other cities has shown that when seismic upgrading is required, owners use the retrofit as an opportunity to address other code violations and to carry out cosmetic rehabilitation work, allowing them to command higher rents as turnover occurs[23].

According to City Assessor's data, approximately 90 percent of these buildings are categorized as rental apartments, with the remaining buildings identified either as condominiums or as having other uses. Buildings that contain condominiums or tenancy-in-common units might have more difficulties in arranging financing, due to complications that arise when a building has multiple owners.

The San Francisco Rent Stabilization Ordinance governs owners' ability to pass seismic retrofit costs on to residential tenants. The Ordinance allows landlords to pass through the full cost of any seismic retrofit that is required by law, with a maximum increase of 10 percent of the tenant's base rent in any 12-month period, amortized over 20 years.

Capital improvements that are not required by law are subject to a different set of pass-through regulations. For properties with one to five residential units, 100 percent of the certified capital improvement costs can be passed through to tenants. For properties with over five units, only 50 percent of the certified capital improvement costs can be passed through to tenants. Therefore, under current law, landlords of buildings with six or more units would only be able to pass through 50 percent of total retrofit costs, if retrofits are not mandated by the City.

Table 4 compares the monthly debt service of a seismic retrofit to the permitted capital improvement pass-through to tenants who pay the average monthly rent for an example property. The analysis assumes a retrofit cost of $132,000, based on cost estimates prepared by the CAPSS team and assuming a 20-year amortization period, an 8.0 percent interest rate, and a six-unit building[24]. Rent data are drawn from

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[23] Comerio, Mary. 1987.

[24] The amortization period and interest rate are based on Rent Stabilization Ordinance requirements.

RealFacts, a private subscription data service. Under these assumptions, the building owner would have a monthly debt-service of $184, which falls well within the $240 monthly pass-through allowance for a tenant who pays the average monthly rent.

Table 4 Allowable Rent Increase for Retrofit Versus Monthly Debt Service

Cost Category	Amount
Average monthly rent in San Francisco per unit*	$2,400
Maximum allowable increase (10% of base rent)**	$240
Estimated retrofit cost†	$132,031
Monthly debt service (amortized over 20 years at 8% interest)	$1,104
Monthly debt service per unit (6 unit building)	$184

* Average rent for third quarter 2008.

** Assumes Rent Stabilization Ordinance allows 100% of qualified retrofit costs may be passed through to renters.

† Conservatively assumed highest cost estimates from CAPSS analysis. Estimates range from $49,000 to $132,000.

Basic economic principles of real estate dictate that the market establishes the maximum rent that a landlord can charge. Therefore, when rents in a building are already at market rates, a landlord who attempts to pass through seismic retrofit costs risks losing tenants. Currently, an estimated 40 to 60 percent of San Francisco apartments have rents at or close to market rate. Therefore, landlords have a limited ability to pass through costs to residential tenants. As a result, landlords might forgo a capital improvement pass-though petition with the Rent Board if roughly half of the units in a given multi-unit building could not absorb a rent increase. Under these constraints, landlords would have to absorb a large portion of the retrofit costs.

Building owners would incur expenses beyond those directly related to retrofit construction. Landlords might need to reduce rents and/or compensate tenants for lost parking and storage space during the course of construction. If ground floor commercial or residential tenants need to relocate temporarily, then the landlord might also have to compensate those tenants.

Once completed, the retrofits will have a minimal impact on leasable area. Retrofits generally should not require any permanent loss of floor space or parking space or any blockage of windows. Some structural changes, such as steel frames, might be visible inside at the ground floor. This would generally not be a concern for buildings with garages at the ground level, but extra design care might be required for buildings with street level commercial space or architectural importance.

Financial impacts to owners could be partially mitigated if the City offers certain types of incentives recommended by the CAPSS program. These incentives include rebating permit fees, allowing use changes, easing parking requirements, allowing increases in usable floor space, and offering City-funded loans, and are described in more depth in Chapter 5.

Costs to Residential Tenants

Most residential tenants would bear little disruption due to seismic retrofits. Construction for retrofits of multi-unit, wood-frame soft-story buildings can generally be limited to the ground floor. Therefore, residential tenants living above

the ground floor are protected from displacement during construction. However, construction would likely affect ground floor parking and storage for a period of two to four months. Tenants might need to seek alternative solutions for parking and storage during that time, but they might be compensated for this by their landlord. During construction, there would be some noise and other disruptions typical of construction projects.

Fourteen percent of the buildings studied by the CAPSS project had one or more residential units at the ground level. Tenants in these units might need to relocate temporarily and to deal with the resulting expense and hassle, although in some cases retrofit designs might be able to avoid construction inside these units. Under San Francisco law, tenants have the right to reoccupy their unit once construction work is complete.

Costs to Business Tenants

Commercial tenants in the ground floor of these buildings can expect to experience a greater impact from retrofits than their residential counterparts do. The seismic work would be likely to disturb operations significantly for a period of two to four months. Many small businesses lack the financial wherewithal to recover from closing for a few months. Small businesses make up a major share of commercial tenants in multi-unit, wood-frame soft-story buildings; almost 95 percent of these businesses have ten or fewer employees. With limited savings, small profit margins, and dependence upon a steady revenue stream to pay for inventory and to service debt, many small businesses, particularly those in the retail and food service industry, do not have the resources to withstand a prolonged closure. Construction can be scheduled to minimize, but not eliminate, ground floor disruption.

Because rent control laws do not apply to commercial tenants, lease rates are already at market or are limited by long-term lease provisions, and landlords have limited ability to pass through seismic retrofit costs. A 1990 study reporting on the impacts of the Los Angeles Earthquake Hazard Reduction Ordinance, Los Angeles' program to retrofit unreinforced masonry buildings, found that few owners were able to pass through costs to commercial tenants, because rents were already as high as the market could bear[25]. In the few cases in which rents were raised, the increase did not cover the full cost of seismic rehabilitation.

During construction, businesses can expect a substantial amount of noise, space constraints, visual disturbance, and dust, disrupting normal operations. In the 1990 Los Angeles study, building owners noted that it was in their best interest to retain tenants and rental income, and thus they tried to do the work in phases so as not to disturb business. Despite these efforts, however, the retrofit activity did force many businesses to close during construction.

Seismic retrofit ordinances have a limited impact on the mix of local land uses. The 1990 Los Angeles study developed detailed case studies of four different neighborhoods to examine the effect of Los Angeles' unreinforced masonry building program on local land uses. The study ultimately regarded the shifts in occupancy as a normal pattern of land use change in these neighborhoods, rather than change that reflected a direct impact of the City's program. Building owners reported that when tenants moved out permanently, new tenants with similar businesses took their place.

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[25] Blair-Tyler, Martha and Penelope A. Gregory 1990.

In some neighborhoods, the rate of turnover was approximately the same as for non-unreinforced masonry buildings. While local businesses were sometimes supplanted by national chains, this trend was already occurring throughout the neighborhood, and the seismic work provided an opening for changes that might have occurred in any case.

Benefits of Retrofitting

The costs of retrofitting are short-term and readily apparent. Most of the benefits of retrofitting, however, are not evident until after an earthquake strikes. The benefits of retrofitting are realized as losses that are avoided when earthquakes strike. Avoided repairs and/or business interruptions have direct monetary value; many other benefits of retrofits—such as avoided deaths, injuries and trauma, avoided loss of housing resources, and maintained neighborhood cohesion—cannot be so easily monetized.

Benefits to Owners

Retrofitting multi-unit, wood-frame soft-story buildings directly saves building owners money by avoiding damage, reducing the cost of post-earthquake repairs and avoiding business interruption (loss of rent). The estimated savings due to retrofit varies depending on the intensity of the earthquake and on the level to which a building has been retrofitted. In the four scenario earthquakes examined by the CAPSS project, building owners as a whole save between $400 million and $1.5 billion, depending on the level of retrofit, in reduced damage to building structure and contents. The costs of all retrofits citywide would total about $260 million, to achieve a performance that would allow most residents to remain in their damaged but safe homes after an earthquake.

From the perspective of an individual owner, resources invested in retrofit result in significant savings after an earthquake. Table 5 shows the average loss per residential unit in damage to the building structure and its contents that would be avoided if the building was retrofitted and then shaken by a magnitude 7.2 earthquake on the San Andreas Fault.

Table 5 Average Loss Avoided Through Retrofit Per Residential Unit in a Magnitude 7.2 Earthquake on the San Andreas Fault

	Average per unit $ loss avoided to structure and contents
Retrofit scheme 1	$24,000
Retrofit scheme 2	$41,000
Retrofit scheme 3	$52,000

Retrofitting increases the odds that a building can be continuously occupied or reoccupied quickly after an earthquake. This means that owners can continue to receive income from their property after an earthquake.

After every damaging earthquake, tenants file lawsuits against building owners for deaths, injuries, and damage to tenants' possessions. Owner liability for seismic safety issues of older buildings is not clear-cut. However, conducting seismic retrofits

would reduce building damage, limit whatever liability building owners have to their tenants, and lower the number of lawsuits filed.

It is important to note, nonetheless, that many retrofitted buildings could require costly repairs after an earthquake. As a general rule, the financial benefits of retrofitting decrease as the size of an earthquake increases. An extremely large earthquake, such as the magnitude 7.9 event, would cause heavy damage to buildings with or without retrofit. While retrofits would greatly reduce collapses during this size earthquake, owners could still be left with damage that could cost more than half of the value of their building to repair.

Benefits to Residents and Neighborhoods

Occupants of multi-unit, wood-frame soft-story buildings clearly benefit from retrofit. Some of their many benefits include the following:

- They are less likely to be killed or injured in an earthquake;
- Their possessions are less likely to be damaged or destroyed;
- They are more likely to be able to remain in their homes and to avoid the trauma and expense of long-term displacement; and
- They are more likely to remain close to their jobs, to services that they need to access, and to valued family or community members.

Neighborhoods benefit from retrofitting. Following earthquakes, if residents can stay in place, then they can contribute to helping to bring the community back to life. The demographic and economic mix of residents is less prone to change. Neighborhoods avoid the many negative consequences of having buildings stand vacant for extended periods of time. Neighborhood-serving businesses are more likely to survive. By reducing the number of buildings that need to be demolished, retrofits maintain the look and feel of neighborhoods. The architectural styles, scale and mix of uses are retained. Historic and interesting buildings remain. All of these benefits contribute to the resilience of the City and are critical to helping the City as a whole recover quickly from a major earthquake and avoid the long-term disruption and change that accompanies extensive loss.

Benefits to Businesses

Businesses—both those located in multi-unit, wood-frame soft-story buildings and those in other building types—also benefit from seismic retrofits. As previously discussed, most of the businesses located in multi-unit, wood-frame soft-story buildings have fewer than 10 employees. Some of the many benefits of retrofits that these businesses experience after an earthquake include the following:

- Employees and customers are less likely to be killed or injured by an earthquake;
- The business is more likely to be able to remain in its current location and to reopen quickly; and
- Inventory, equipment and supplies are less likely to be damaged or destroyed.

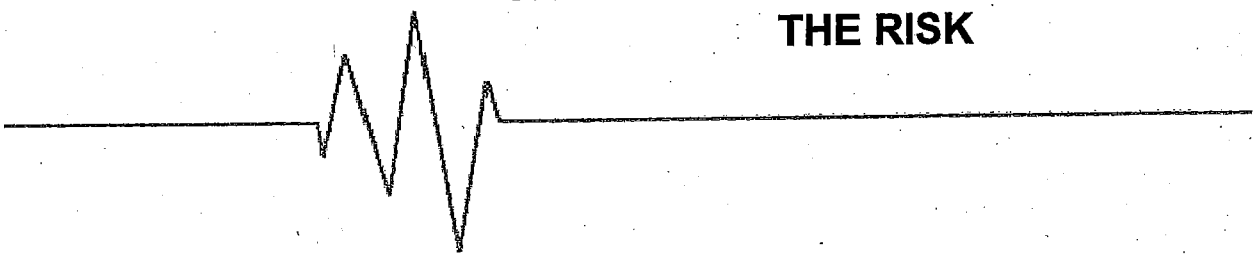
Neighborhood-serving businesses need a functioning neighborhood to serve. All businesses in neighborhoods that contain numerous multi-unit, wood-frame soft-story buildings benefit from retrofit, because less damage means that more people remain

in or quickly reoccupy their homes, shop in neighborhood stores, eat at neighborhood restaurants, and seek out the services of local businesses.

All San Francisco businesses, even those sited in neighborhoods with very few of this type of building, need places where their employees can live safely. By preserving housing stock, retrofits help to keep San Francisco's work force in San Francisco.

Perhaps the most important benefit to the San Francisco community is that less damage means that all of the people, causes and programs that make San Francisco a special place can get back up and running again quickly. The next chapter describes a range of policy options to make these buildings safer.

CHAPTER 4: OPTIONS TO REDUCE THE RISK



San Francisco could take a variety of approaches to reduce the seismic risk to its multi-unit, wood-frame soft-story buildings. This chapter outlines the range of options available to the City to manage this risk.

Elements of a Seismic Safety Program

Five key elements can be used to frame how best to develop a seismic safety program to reduce the risk to buildings. Different policy directions might be adopted for each of these interlinking elements. These elements are:

- **Performance Objective**—What level of damage to privately owned wood-frame residential and multi-use buildings is acceptable after a large earthquake?
- **Approach**—What should the City require of owners of seismically deficient buildings?
- **Scope and Priorities**—Which buildings should be covered by a program? Which should be addressed first?
- **Implementation Period**—How long should building owners be given to comply with a program's requirements?
- **Incentives**—What measures should the City offer to encourage or ease the burden of retrofitting by building owners?

Options for each of these key elements are described in depth in the sections that follow.

Performance Objectives

A performance objective defines the desired performance of a group of buildings in an earthquake. Put more simply, it defines the acceptable level of damage to the building stock after a large earthquake. Selecting a performance objective has broad implications on any policy that the City may adopt. This choice affects the number of buildings that will be considered seismically deficient (that is, buildings that will perform worse than the desired performance). It affects the extent—and cost—of seismic retrofits that buildings will need to undergo to meet the minimum standard. If heavy damage to these buildings were considered acceptable, then a modest number of buildings would need to be upgraded to a modest level. If little damage were considered acceptable, then many buildings would need to be retrofitted to a higher and costlier level.

Buildings with different uses or characteristics might be assigned different performance objectives. For example, the City might demand a higher level of performance (that is, less damage) for highly important or heavily occupied buildings

than for buildings that are rarely occupied. The buildings addressed by this report function chiefly as rental housing, condominiums, small businesses, and parking. It is possible, but unknown, that some of these buildings have other uses considered especially vulnerable, such as elder care homes, childcare centers, private schools, kidney dialysis centers, or medical clinics.

Options for Performance Objectives

The CAPSS project identified five possible performance objectives, to provide a range for consideration. These are based on performance objectives developed by San Francisco Planning and Urban Research (SPUR) in its position paper of February 2009, "*The Resilient City: Defining What San Francisco Needs from Its Seismic Mitigation Policies.*"

A. Safe and Operational
This is a high performance objective that requires robust buildings and back-up utility systems. Buildings would experience only minor damage, and all functions could continue immediately after an earthquake. Few existing buildings would meet a standard that results in this level of performance, and bringing most buildings to this level would be costly.

B. Safe and Useable Until Repair
This is a performance objective that would allow residents to remain in their homes after a major earthquake. Buildings retrofitted to a standard that results in this level of performance could have some damage after a major earthquake but would be expected to withstand strong aftershocks. There may be significant damage to nonstructural building elements, utility services may not function, and some areas of the building may be off limits. The use of these damaged buildings will depend in part on the City's post-earthquake inspection and posting policies.

C. Safe and Useable After Repair
This performance objective would allow significant damage to buildings and means that many San Franciscans would be displaced from their homes after a major earthquake. The time required to conduct repairs would range from months to years depending on factors such as the extent of damage, the availability of qualified engineers and contractors, financing, and permits. Only a few buildings meeting the standard adopted to achieve this objective would be demolished; thus, this standard would maintain repaired rental units under rent control restrictions. It would also maintain neighborhood character as defined by style of construction, building scale, and mix of uses.

D. Safe but Not Repairable
This is a minimal performance objective intended to reduce harm to those who live and work in or frequent these buildings. Collapse would be prevented, and most people would be able to escape the building safely, but some might require rescue, and fire would remain a threat. The City could permanently lose significant amounts of rent-controlled housing, as well as buildings that contribute to the architectural character of the City. While no explicit performance objective was set, this is the presumed objective achieved by the required standards for retrofit of San Francisco's approximately 2,000 unreinforced masonry buildings.

E. Unsafe, Collapse Risk

This performance objective recognizes that buildings in their current condition could be unsafe in earthquakes. Without retrofit, this is the default performance expectation of many multi-unit, wood-frame soft-story buildings.

SPUR believes that San Francisco must strive to become "resilient," that is, preparations should be made and the building stock improved, so that 95-percent of San Franciscans could safely remain in their homes or apartments following an earthquake. This goal would leave 40,000 San Franciscans seeking shelter after an earthquake. Currently, SPUR estimates it would take approximately three years for 95-percent of residents to be back in their homes after a large earthquake. This goal implies that the overall performance objective for residential buildings in San Francisco should be Performance Objective B (Safe and Useable Until Repair). Some buildings might have a higher performance than this, and others might have a lower performance, so that on average the City's housing stock performs to this level.

In reality, no retrofit can guarantee specific performance for an individual building. Retrofitting makes it more likely that a building will be safe, repairable and fit for occupancy after earthquakes. After an earthquake, the performance of each building will vary based on the strength, duration and direction of shaking experienced at its location, the local soil on which it sits, the unique characteristics of its construction, and other factors.

CAPSS Recommended Performance Objective

The CAPSS project recommends that the City and County of San Francisco adopt Performance Objective B, Safe and Useable Until Repair, to apply to multi-unit, wood-frame buildings with three or more stories with residential uses or mixed residential and commercial uses. The City should consider requiring any critical uses to relocate, or for those buildings' retrofits to meet performance Objective A, Safe and Operational.

The CAPSS project believes that it is important to keep San Franciscans in San Francisco after an earthquake. Performance Objective B is necessary to let people remain in their homes, resume their normal lives, reopen local businesses, and contribute to the rebuilding of San Francisco. Greater levels of damage and disruption could cause the City to reach a tipping point, at which recovery would become prolonged, and many of the people who would leave the City would never return. Performance Objective B would keep people out of emergency shelters, preserve rent-controlled housing in the City and retain the architectural feel of San Francisco's neighborhoods.

The CAPSS project recommends that the Board of Supervisors enact minimum retrofit standards applicable to three story and taller wood-frame buildings with five or more residential units that would result in most retrofitted buildings meeting the adopted performance objective. This standard should be based on an existing retrofit code but may need to adapt an existing code to control building deformation. This standard would replace the standard in the San Francisco Building Code chapter 3400 provisions (often referred to as 104(f)) that applies to wood-frame, soft-story buildings with three or more stories undergoing expansion or change of use.

Approach

Approaches that the City could use to reduce damage in multi-unit, wood-frame soft-story buildings can be summarized in three distinctly different intervention approaches. The details of each of these options could vary in numerous ways, and different approaches could be applied to buildings with different characteristics.

- **Option 1: Provide information and encouragement**

  The City would give an official notice to owners of buildings suspected to be seismically deficient, informing them that they are on a City list of potentially seismically deficient buildings. Owners would be encouraged to do the "right thing" and would be offered incentives to evaluate their buildings and retrofit, if necessary. The City would continue to enforce Building Code Chapter 3400, which requires retrofitting of buildings when certain changes of use or additions are undertaken. The Department would be required to report to the Mayor and Board of Supervisors after four years on the accomplishments of this program.

- **Option 2: Require analysis**

  The City would require owners to undertake an engineering evaluation of their buildings and to compare the results to a designated minimum seismic retrofit standard. Owners would submit a report to the City with their engineering evaluation and a letter describing what action they intend to take in response to the report's findings. Deadlines would be established for submitting reports and owner statements. Owners of buildings that do not meet the City's standard would be required to inform tenants, prospective buyers, insurers and lenders, and to post signs at the entrances regarding their building's vulnerability. The City would continue to enforce San Francisco Building Code Chapter 3400, which requires retrofitting of buildings when certain changes of use or additions are undertaken. The Department would be required to report to the Mayor and Board of Supervisors after four years on the accomplishments of this program.

- **Option 3: Require retrofit**

  The City would require owners to retrofit seismically deficient buildings. Owners with buildings that do not meet the City's standard would be required to inform tenants, prospective buyers, insurers and lenders, and retrofit according to a schedule and established priorities. This approach is similar to the City's unreinforced masonry building program.

There are endless ways in which the three approaches described here could be varied. Currently, the City requires buildings to conduct seismic upgrades when specific changes in use or additions are undertaken. There are a variety of other occasions that the City could use to trigger requirements for evaluations, retrofits, tenant notification, or other actions, including the sale of a building, transfer of a building title, submission of an application for condominium conversion, or vacancy of ground floor tenants.

Lessons from Other Communities

Decades of experience show that building owners rarely retrofit unless required by law to do so. In 1986, the State of California passed a law requiring communities to develop a program to reduce risk in unreinforced masonry buildings (UMBs). Local governments were required to inventory all unreinforced masonry buildings within

their jurisdiction, to notify the owners that their building is of a type that performs poorly in earthquakes, and to adopt a risk reduction program. Many communities, including San Francisco, elected to require owners of unreinforced masonry buildings to retrofit them. Other communities left seismic retrofits as voluntary. Communities with voluntary programs have had little success in achieving safer buildings, as shown in Table 6. Despite incontrovertible evidence that unreinforced masonry buildings collapse and kill their occupants and nearby persons in moderate and large earthquakes, the majority of owners have not chosen to pay for seismic retrofits when given the choice.

Table 6 Rates of Retrofit or Demolition of Unreinforced Masonry Buildings in Communities with Voluntary and Mandatory Programs[26].

	Mandatory Programs	Voluntary Programs*	Notification Only**	Other Programs†
Percent of UMB's retrofitted or demolished	87%	24%	13%	26%
Number of cities or counties with this type of program	134	39	46	41

* Voluntary programs: communities set a retrofit standard, require owners to evaluate buildings and write letter stating intentions.

** Notification only programs: communities send a letter to owners stating their building type is known to perform poorly in earthquakes.

† Other programs are variations of the other program types with unique requirements and ranges of effectiveness.

There are a few cases in which voluntary building retrofits have been somewhat effective. Two of these examples come from the City of Berkeley. In Berkeley, a transfer tax is charged when residential properties are sold, and the new owner can choose to use a portion of those funds for seismic upgrades on the property, in lieu of paying the tax. A large number of homes, from 40 to 60 percent in the City, have been improved with some retrofit measures because of this program.

The City of Berkeley also requires owners of multi-unit, wood-frame soft-story buildings to submit an engineering report evaluating the seismic performance of their building. Buildings with seismic weaknesses are required to post this information at entrances and to notify tenants. Berkeley began this program in October 2005. In response to this mandate, 33 buildings (about 10 percent of their inventory) had elected to voluntarily seismically retrofit their buildings as of October 2008, either instead of or in addition to producing an engineering report and notifying tenants. Berkeley might seek to make retrofit mandatory for multi-unit wood-frame soft-story buildings in the near future.

CAPSS Recommended Approach

The CAPSS project recommends that the City require owners to retrofit wood-frame buildings with three or more stories and five or more units that have a soft-story.

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[26] California Seismic Safety Commission, 2006, p7.

Under this approach, building owners would be required to hire an engineer or architect to conduct a simple analysis of their building's seismic safety. Buildings shown to have adequate seismic capacity would be required to take no further action. Owners of buildings that have a soft-story condition would be required to inform tenants, prospective buyers, insurers and lenders, and to retrofit according to a timeline and standards set by the City. The City would offer incentives to ease the burden of retrofits on building owners and would impose meaningful sanctions on owners that did not comply with the ordinance. This approach is similar to the City's Unreinforced Masonry Building program.

Scope and Priorities

San Francisco needs to decide which multi-unit, wood-frame buildings should be covered by a city program to reduce soft-story risk. Further, it needs to decide if the program should have phases, with some buildings addressed first and others addressed later.

There are approximately 4,400 three-story wood-frame buildings with five or more residential units in San Francisco that were built before May 1973, when building codes were improved. There are approximately 2,600 more three-story buildings with four units and 3,400 more with three units. All of these buildings could potentially have soft-story weaknesses. Realistically, the City cannot effectively administer a program to address the risk in all of these buildings at once. It makes sense for the City to prioritize these buildings and to address those of greatest concern first.

Specific features of buildings indicate higher risks of damage in earthquakes (see Chapter 1). These include the following:

- Having larger openings in perimeter walls and few interior walls at the ground level;
- Being located on a corner;
- Being located mid-block with a gap between one or both adjacent buildings;
- Having wood deterioration due to rot or pest damage;
- Being located on soft soils; and
- Having three or more stories.

Other characteristics that affect how damage to a particular building would impact the broader community include the following:

- The number of residential units in the building;
- Uses of the ground floor of the building; and
- The building's historic and architectural distinction.

CAPSS Recommended Scope and Priorities

CAPSS recommends that the City's initial program focus on wood-frame buildings with three or more stories and five or more residential units built before May 1973. While some three-story buildings with three and four residential units may face risk similar to five unit buildings, buildings with five or more units are generally larger and each contain more residential units. The City established a reasonable precedent of focusing on buildings with five or more units in its unreinforced masonry building

program. Using the five-unit cutoff restricts the City's program to a scope that will be manageable to administer. However, the vulnerability of buildings not meeting these criteria can be substantial and should be addressed in a different program.

The CAPSS project recommends that the program not be limited to those buildings with significant ground floor openings in external walls, because buildings with smaller openings in the ground floor perimeter walls could also have significant structural weaknesses due to lack of interior partitions or deteriorated materials. Instead, the City should create a simple screening protocol that an engineer or architect will follow to determine whether a building is likely to have a soft-story weakness. All owners of wood-frame buildings built after May 1973 with three or more stories and five or more units should be required to hire an engineer or architect to complete the screening protocol.

Buildings covered by the program should be addressed in order of greatest concern, based on the consequences of damage to the neighborhood, City and occupants. A Working Group should be convened by the City to develop details of how a City program will be implemented, including how to prioritize which types of buildings (e.g., corner buildings, those located on soft soils, historic buildings) should comply with a City program first.

Implementation Period

Any time line adopted by the City must balance hardships associated with deadlines with the potential for earthquakes striking San Francisco: this is a race for safety. The timeline that the City puts in place for a program must consider many factors, including the following:

- How long the City is willing to wait for the building stock to be strengthened;
- How many buildings can be processed by the program administrators within the City during a given interval; and
- How much time building owners can reasonably be given to comply with any requirements.

The City's program to require owners to retrofit unreinforced masonry buildings covered 2,000 buildings and spanned 14 years, beginning in 1992. Retrofitting wood-frame buildings would involve easier construction, cost less, and be less disruptive to residential tenants than retrofitting unreinforced masonry buildings.

CAPSS Recommended Implementation Period

The CAPSS project recommends that the program allow owners about four years to comply with retrofit requirements, dating from the time when they receive notice that their building is on the Department's list of potentially seismically deficient buildings. Owners need time to make decisions and to arrange for financing, and there are a limited number of qualified engineers and architects available to do this work.

Implementing the entire program will take longer. The first task, initiating the program, requires assigning and training specialized staff members within the Department of Building Inspection, refining the list of building owners, preparing outreach materials, adopting a minimum seismic retrofit standard and creating a screening protocol. These steps could take about one year to complete.

The next task is to notify owners that they must comply with this program and to respond to their questions and to questions raised by design professionals. The CAPSS project recommends that notices be mailed to owners divided into two or more categories, with owners of those buildings most likely to have significant impacts on the community if damaged being noticed first. Assuming that the 4,400 buildings at issue were divided into two categories and that mailing notices would require one year for each category of owners, this pace would require mailing on average 40 to 45 notices a week, and fielding the resulting questions.

This schedule suggests that, assuming the start up tasks take one year, the program could be completed in seven years.

Incentives

It makes sense for the City to encourage compliance with a program, given that there are benefits to retrofitting that accrue to the general public and not just to owners and tenants, and yet owners must bear most of the costs. Incentives for seismic retrofits could be offered to encourage voluntary retrofits or to ease the impact of mandated seismic upgrades.

Building retrofit incentives can be divided into the following categories:

- **Financial incentives:** grants, rebates, credits, loans, loan interest reductions, deferred loans, transfer tax set asides, donated and reduced-rate labor, insurance premium savings, fee waivers;
- **Policy incentives:** zoning incentives, allowing use changes, easing parking requirements, allowing increases in usable floor space, transfer of development rights, expedited processing of permit applications and loan applications, waiving property restrictions;
- **Technical assistance incentives:** advice on retrofitting, standard details, help with garnering incentives, assistance with contracting questions and motivational literature;
- **Information incentives:** Notice to prospective buyers, tenants and visitors.

Options for each of these incentive categories are discussed in depth in the companion volume containing the Documentation Appendices.

Offering multiple incentives is most effective, because no single incentive or combination of incentives would serve the interests of every building owner. Building owners range from a city resident who owns one apartment building that he or she lives in to a corporation, and these owners have different knowledge, resources and motivation. A variety of incentives would allow owners to assemble unique combinations to satisfy their particular needs.

Communities throughout the state have been required to develop programs to address the risk of unreinforced masonry buildings. Incentives have been found to be somewhat effective in encouraging seismic retrofit: eight cities with voluntary programs and economic incentives have an average retrofit rate of 20-percent of unreinforced masonry buildings, compared to a 14-percent rate for the 31 jurisdictions without incentives[27].

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[27] California Seismic Safety Commission, 2006, p 8.

CAPSS Recommended Incentives

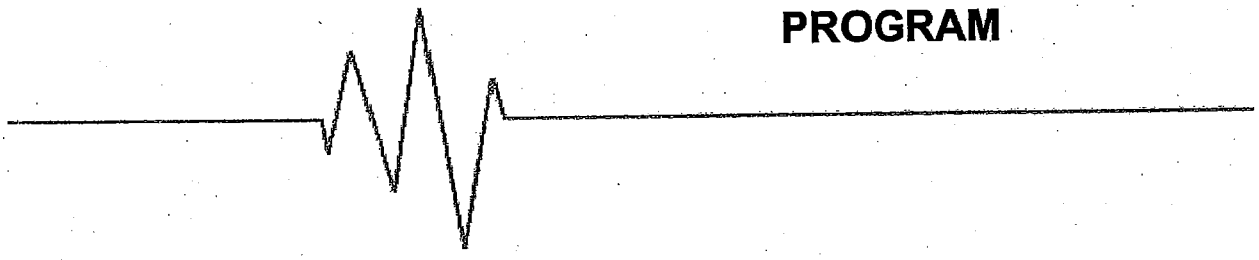
CAPSS recommends that the City put together a strong package of incentives to help building owners to retrofit and tenants to cope with the hardships presented by increased rents. The City has a vital interest in encouraging owners to retrofit their buildings. Retrofits to these buildings protect affordable housing and maintain the cultural and architectural character of San Francisco neighborhoods. By investing in earthquake mitigation through targeted incentives, the City can help to protect these community values. However, the ability to pay for retrofitting or endure disruption is not universal. Retrofitting costs would cause great hardship for some tenants and owners, especially those with limited income.

Incentives alone will not lead many owners to retrofit, which is why CAPSS recommends that owners be required to do so. However, launching a mandatory retrofit program for multi-unit wood-frame soft-story buildings will take time. Due to the urgent nature of the risk that these buildings pose, CAPSS recommends that the City offer a strong package of incentives immediately, before a mandatory program is established, and that it maintain these incentives once retrofit is mandated.

The City should consider ways to offset the cost of the incentives that it offers; possible offsets include seeking grants from the Federal Emergency Management Agency, using fines assessed on owners who fail to comply with retrofit program requirements, or forming special assessment districts.

The City could choose many paths to address the earthquake risk of multi-unit, wood-frame soft-story buildings, but not all choices will be effective in making the City safer. The next chapter describes in detail the program that the CAPSS project recommends.

CHAPTER 5: THE RECOMMENDED PROGRAM



The CAPSS project recommends that the City require owners of wood-frame buildings constructed before May 21, 1973 with three or more stories and five or more residential units with a soft-story condition to seismically retrofit them to a standard that would allow residents in most of the retrofitted buildings to remain in their homes after a large earthquake.

This chapter describes the key elements of the recommended program. Many details of how this program would be implemented would be worked out as the program moves forward, based both on community comments and on considerations of the Department of Building Inspection regarding how the program should best be administered. The CAPSS project recommendations are based on technical analysis and on discussions in public meetings. This work has been guided and reviewed by a dedicated Advisory Committee made up of community members.

It is important to emphasize that many other building types are also vulnerable to earthquake damage. The CAPSS project advises that the City address other building types and will recommend additional programs in the future.

The Mayor and Board of Supervisors should:

- **Adopt a policy statement declaring that the City and County of San Francisco desires that multi-unit, wood-frame soft-story buildings be suitable for occupancy after large earthquakes[28].** This objective would guide the development of the minimum retrofit standard in the building code. It would allow many residents to stay in their homes and neighborhoods following an earthquake, would improve San Francisco's resilience and would protect its unique attributes. It would reduce casualties and lessen post-earthquake emergency response and shelter demands.
- **Direct the Department of Building Inspection and the Building Inspection Commission to develop code language for a retrofit standard.** This minimum retrofit standard would implement the performance objective policy statement, as it applies to multi-unit wood-frame buildings with three or more stories and five or more residential units. The standard would be used to identify seismically deficient buildings and to set the minimum requirements that must be met through retrofitting. The Department of Building Inspection should convene a panel to assist with this task. This panel should consider developing a standard

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28 This would meet Performance Objective B, described in Chapter 4. Most residents could stay in their homes until repairs are made, even though there may be damage and no working utilities. However, there would be no guarantee that all retrofitted buildings would perform in this manner. This objective represents the desired overall performance for the entire stock of retrofitted multi-unit, wood-frame soft-story buildings in San Francisco.

that accounts for building deformation during earthquakes[29] and reduces fire ignitions. The standard should not require retrofit measures that extend above the ground floor, except in unusual cases in which the Department of Building Inspection decides that this is necessary. Buildings that do not meet the defined standard would be deemed "seismically deficient."

- **Direct the Department of Building Inspection to create and maintain a list of wood-frame buildings considered potentially seismically deficient.** This list initially would include all wood-frame buildings that were constructed before May 21, 1973 that have three or more stories and five or more residential units.
- **Direct the Department of Building Inspection to develop a simple screening protocol that owners would hire an architect or engineer to complete.** This protocol would indicate whether buildings are likely to have a soft-story. It should be designed to be inexpensive to complete and should not require extensive analysis. It could be based on a modified version of the Area Demand Ratio, which is a ratio of square footage of building floors and roof to linear length of solid walls in each direction[30]. The panel convened to develop building code language for a retrofit standard could also assist in developing this screening protocol.
- **Direct the Department of Building Inspection to establish a program that requires owners to retrofit multi-unit, wood-frame soft-story buildings.** A Working Group should be convened to define details of how the program should be implemented.
- **Direct the Department of Building Inspection to notify owners of the potentially seismically deficient buildings on their list that they are required to take the following actions:**
  - Submit a form completed by an architect or engineer. First, this form would indicate whether their building meets the requirements to be included in this program (date of construction, completed retrofit work, number of units, location, etc.). For buildings that are included within the scope of the program, the architect or engineer would complete the screening protocol that identifies whether the building is likely to have a soft-story. Owners of buildings outside the scope of the program or who can demonstrate that their building does not have a soft-story would have no further action required. All others proceed to the next step.
  - Inform current and prospective tenants of the notice from the Department of Building Inspection and of the steps to be taken to comply with program requirements. Owners would update tenants annually in writing on their progress in complying with the program requirements, until they have completed the necessary actions. The Department of Building Inspection should specify the content of these letters. This information also would be

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[29] The current San Francisco Building Code requires engineers to design retrofits to resist base shear force but does not require limiting building deformations, yet building deformation, a function of strength and stiffness, is more directly linked to a building's earthquake performance. Code provisions that address or are based on deformation would allow retrofits to provide the desired performance more effectively and efficiently. Deformation-based engineering standards currently exist.

[30] The Area Demand Ration is proposed by Cobeen, Russell and Dolan, 2004.

recorded with the City and County Recorder's office and reported in Reports of Residential Building Records (known as 3R reports). Owners who retrofit their buildings to the minimum retrofit standard or provide evidence that their building is not seismically deficient can have these records changed.

- Seismically retrofit their buildings. Owners can opt first to conduct a more rigorous engineering analysis of their building, which if it shows their building to have sufficient capacity to meet the retrofit standard, would mean they would not need to retrofit. If it shows their building is seismically deficient, they would then need to retrofit.

- **Direct the Department of Building Inspection to establish a program with the following timeline:**
  - The Department should divide all multi-unit, wood-frame buildings into two or more categories, as defined by the Working Group that develops implementation procedures. The number and characteristics of buildings in each category should be based on the potential consequences of earthquake damage and on the Department's capacity to administer the program.
  - Owners should have about four years from the time when the Department notifies them to complete the retrofit of seismically deficient buildings.
  - The entire program could be completed in seven years after the Department issues its first notices, depending on the Department's pace of notification and time required for start-up activities.
  - Any time extensions would depend on an appeal process that would include an opportunity for a public hearing. The appeal process would consider time extension requests from owners who claim that unique circumstances prevent them from meeting program deadlines. Circumstances might include measures to minimize disruption of ground-floor residential units and/or commercial uses or other conditions that justify according the owner additional time to complete the retrofit.

- **Direct the Department of Building Inspection to expand the current requirements in Chapter 34 of the San Francisco Building code to include the minimum retrofit standard developed for this program and to make it applicable to all wood-frame buildings with three or more stories.** The requirements in Chapter 3400 that are triggered by building expansion and change of use should be consistent with the standard developed for the buildings covered by this program.

- **Require new owners and those who subdivide buildings on the list into condominiums to comply with these requirements as part of the conversion process.** This will apply to owners who receive approval to convert buildings to condominiums after the effective date of the enacting ordinance.

- **Assure that all retrofits of historic buildings preserve the architectural character of the buildings.** Permit applications for retrofitting buildings designated as historic on a local, state or federal list should be reviewed by the City of San Francisco Planning Department and the San Francisco Historic Preservation Commission. The purpose of this review will be to protect the architectural and historic integrity of designated and contributing buildings.

- **Direct the Department of Building Inspection to remove from the list of seismically deficient buildings those buildings that comply with the program.** This includes buildings that are retrofitted or shown by owners to be outside the scope of the program or not seismically deficient. All notices on titles would be removed, and requirements for informing tenants would cease.

- **Direct the relevant City departments to offer incentives to building owners and tenants.** The program described in this report will take time to launch, but the urgent nature of the risk described in this report should be addressed immediately. The following incentives should be offered as soon as possible to encourage voluntary retrofits, and should continue once a mandatory program is established. These incentives will make compliance with the program less burdensome for owners and tenants. These incentives also should be offered to owners of seismically deficient wood-frame soft-story buildings outside the mandatory scope of this program.

    - The Department of Building Inspection should define criteria for "qualified seismic retrofits" that are eligible for the incentives listed below. Qualified retrofits would include retrofit measures directly attributable and necessary to meet the City's minimum retrofit standard, and could include measures to mitigate against earthquake-induced ground failure, achieve higher performance levels, repair and replace deteriorated materials, or reduce earthquake-caused fire ignitions.

    - The Department of Building Inspection, the Planning Department, the Historic Preservation Commission, and all other City departments that review building plans in this program should expedite the review of retrofit permit applications.

    - All City departments should rebate building permit fees upon successful completion of the measures required to meet the minimum retrofit standard.

    - The City should endeavor to establish a City lending program to help owners finance retrofit projects and to cover costs incurred by tenants. This program should use existing bond capacity that is available because of the incomplete use of General Obligation bonds authorized for retrofitting unreinforced masonry buildings. The lending program should be designed to be simple to use and attractive to building owners, and the conditions that made use of these funds unattractive to owners of unreinforced masonry buildings should be amended. These funds should be available for use on all qualified seismic retrofits and not be limited to the types of buildings that are mandated to retrofit by this program. The program could include grants to offset rent increases in cases of hardship. Establishment of this program should be placed before voters at the earliest opportunity.

    - The Department of Planning should provide incentives to encourage and facilitate retrofitting, such as waiving parking requirements, allowing use changes, or allowing increased usable floor space, in return for completing qualified retrofits in accordance with this program.

    - The San Francisco Rent Ordinance Section 37.7 should be amended to allow owners who voluntarily undertake qualified seismic retrofits to pass through to tenants 100-percent of the cost of qualified seismic retrofits over a twenty-year period. The details of how this would be implemented should be

developed through discussions between owners and tenants to ensure that an evenhanded process is established.

- The San Francisco Residential Rent Stabilization and Arbitration Board should expedite action on applications from owners to pass through the cost of qualified seismic retrofits. The Board should also assist tenants and owners in resolving temporary relocation issues caused by the need to carry out construction in areas used for parking, storage and residential occupancy.
- The Assessor should advertise and facilitate owners' use of the provisions to avoid increased assessments due to expenditures on qualified seismic retrofits, as provided by Article 13A, Section 2(c)(4) of the California Constitution.
- The City should promote the recently-authorized use of one-third of the real estate transfer tax for seismic retrofitting purposes.
- The Department of Building Inspection should create the position of Earthquake Programs Facilitator. The Facilitator would advise and assist building owners and others in understanding the program, its requirements and its procedures. This office would support permit applicants and retrofit projects by preparing literature and offering training to owners, tenants, engineers, contractors and realtors about the program, compliance procedures and requirements. The facilitator would work with other City departments to facilitate retrofit projects.
- The Board of Supervisors should adopt language that prevents the City from imposing additional retrofit requirements on buildings for 15 years following the notice of completion of the measures to comply with this program.
- The Department of Building Inspection should endeavor to conduct demonstration projects with owners of representative buildings to publicize the program and build the capacity of owners, engineers and architects to carry out the program.
- The Department of Emergency Management should seek Federal Emergency Management Agency funds for the Department of Building Inspection to cover the cost of waiving fees, creating the position of Earthquake Programs Facilitator, conducting demonstration projects, and providing services such as training programs for owners and design professionals, as well as to facilitate building retrofit.
- The Mayor should contact members of the California Legislature and the United States Congress to request that economic stimulus funds be spent in San Francisco on the retrofit of seismically deficient residential buildings and that the tax codes be revised to offer an income tax credit for and accelerated depreciation of the cost of qualified seismic retrofit projects.

- **Direct the City Planning Code to be changed to prevent owners from benefitting from policies guiding the replacement of earthquake-damaged buildings if they do not comply with this program.** The City Planning Code should be changed to prohibit the replacement of a damaged apartment building with condominiums, or rebuilding non-conforming conditions, if the owner has been notified by the Department of Building Inspection that his/her building is on

the list of buildings considered to be potentially seismically deficient and if the owner has failed to comply with the program schedule.

- **Request the San Francisco Chapter of the American Institute of Architects to draft retrofit guidelines.** These guidelines should be designed to help owners of multi-unit, wood-frame soft-story buildings to protect their architectural character when undergoing retrofit.
- **Require the Department of Building Inspection to monitor the program, collect data on all retrofitting, and recommend program changes.** The Department of Building Inspection should document progress, collect data, publicize lessons learned, and report annually to the Mayor and Board of Supervisors on progress, problems and policy changes needed to improve effectiveness and reduce the cost of compliance. It should also track seismic retrofits for all building types in its records system.
- **Grant the Department of Building Inspection powers to enforce this program.** These powers should include imposing graduated fines on owners who do not comply with program requirements according to the specified timeline and requiring the posting of placards describing the building's potentially hazardous condition at all entrances. The Department should be encouraged to use its receivership authority under existing law to complete the necessary work when owners do not comply.
- **Direct the Department of Building Inspection to clarify and publicize its procedures for enforcing compliance with this program.**

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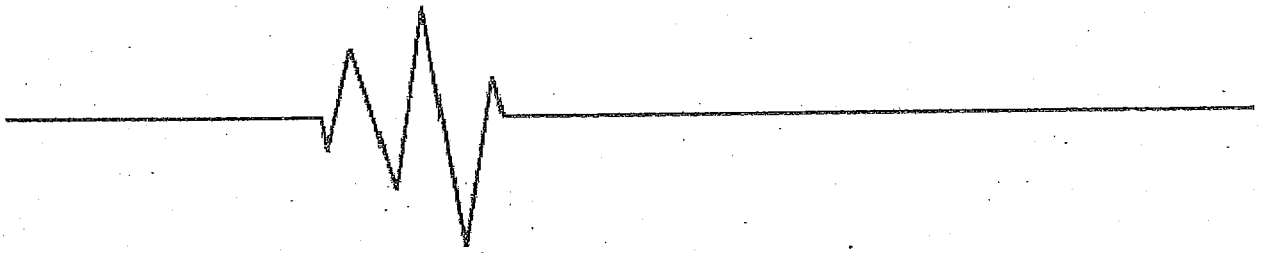

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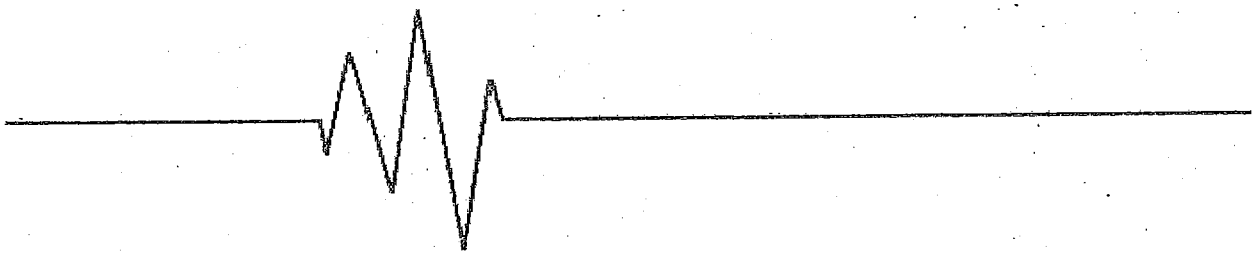

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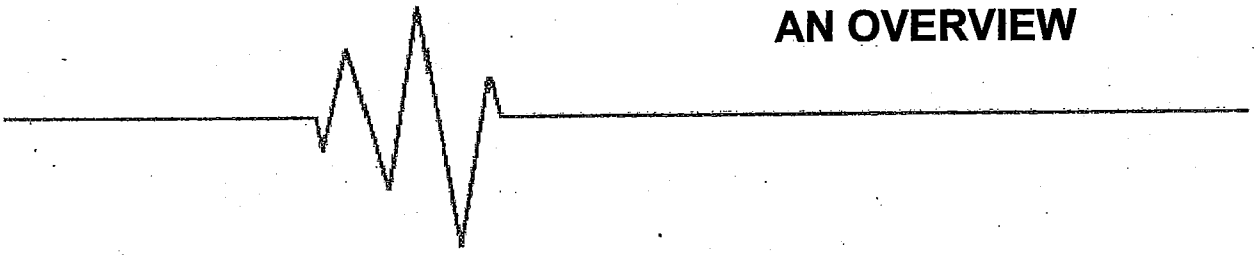
APPLIED TECHNOLOGY COUNCIL: AN OVERVIEW



The Applied Technology Council (ATC) is a nonprofit corporation founded to protect life and property through the advancement of science and engineering technology. With a focus on seismic engineering, and a growing involvement in wind and coastal engineering, ATC's mission is to develop state-of-the-art, user-friendly resources and engineering applications to mitigate the effects of natural and other hazards on the built environment.

ATC fulfills a unique role in funded information transfer by developing nonproprietary consensus opinions on structural engineering issues. ATC also identifies and encourages needed research and disseminates its technological developments through guidelines and manuals, seminars, workshops, forums, and electronic media, including its web site (www.ATCouncil.org) and other emerging technologies.

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Since its inception in the early 1970s, the Applied Technology Council has developed numerous, highly respected, award-winning, technical reports that have dramatically influenced structural engineering practice. Of the more than 100 major publications offered by ATC and its Joint Venture partners, the following have had exceptional influence on earthquake engineering practice:

ATC-3-06, *Tentative Provisions for the Development of Seismic Regulations for Buildings*, funded by the National Science Foundation (NSF) and the National Bureau of Standards and completed in 1978, provides the technical basis for seismic provisions in the current *International Building Code* and other model U. S. seismic codes.

ATC-14, *Evaluating the Seismic Resistance of Existing Buildings*, funded by NSF and completed in 1987, provides the technical basis for the current American Society of Civil Engineers (ASCE) Standard 31, *Seismic Evaluation of Existing Buildings* (the national standard for seismic evaluation of buildings).

ATC-20, *Procedures for Postearthquake Safety Evaluation of Buildings*, funded by the California Office of Emergency Services and the California Office of Statewide Health Planning and Development, is the *de facto* national standard for determining if buildings can be safely occupied after damaging earthquakes. The document has been used to evaluate tens of thousands of buildings since its introduction two weeks before the 1989 Loma Prieta earthquake in Northern California.

ATC-40, *Seismic Evaluation and Retrofit of Concrete Buildings*, funded by the California Seismic Safety Commission and completed in 1996, won the Western States Seismic Policy Council' s "Overall Excellence and New Technology Award" in 1997.

FEMA 273, *NEHRP Guidelines for the Seismic Rehabilitation of Existing Buildings,* funded by the Federal Emergency Management Agency (FEMA) and completed in 1997 under the ATC-33 Project, provides the technical basis for the current American Society of Civil Engineers (ASCE) Standard 41, *Seismic Rehabilitation of Existing Buildings* (the national standard for seismic rehabilitation of buildings).

FEMA 306, *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Basic Procedures Manual,* **FEMA 307,** *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Technical Resources,* and **FEMA 308,** *The Repair of Earthquake Damaged Concrete and Masonry Wall Buildings,* funded by FEMA and completed in 1998 under the ATC-43 Project, provide nationally applicable consensus guidelines for the evaluation and repair of concrete and masonry wall buildings damaged by earthquakes.

FEMA 352, *Recommended Post-earthquake Evaluation and Repair Criteria for Welded Steel Moment-Frame Buildings,* funded by FEMA and developed by the SAC Joint Venture, a partnership of the Structural Engineers Association of California, the Applied Technology Council, and California Universities for Research in Earthquake Engineering, provides nationally applicable consensus guidelines for the evaluation and repair of welded steel moment frame buildings damaged by earthquakes.

FEMA P646, *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis,* funded by FEMA and completed in 2008 under the ATC-64 Project, provides state-of-the-art guidance for designing, locating and sizing structures to resist the effects of tsunamis and thereby provide safe evacuation refuge in affected coastal areas.

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With offices in California, Delaware, and Virginia, ATC's corporate personnel include an executive director, senior-level project managers and administrators, and technical and administrative support staff. The organization is guided by a distinguished Board of Directors comprised of representatives appointed by the American Society of Civil Engineers, the National Council of Structural Engineers Associations, the Structural Engineers Association of California, the Structural Engineers Association of New York, the Western Council of Structural Engineers Associations, and four at-large representatives.

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ATC-52-3A

Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco

Earthquake Safety for Soft-Story Buildings Documentation Appendices

Prepared for the

DEPARTMENT OF BUILDING INSPECTION (DBI)
CITY AND COUNTY OF SAN FRANCISCO
under the Community Action Plan for Seismic Safety (CAPSS) Project

Prepared by the

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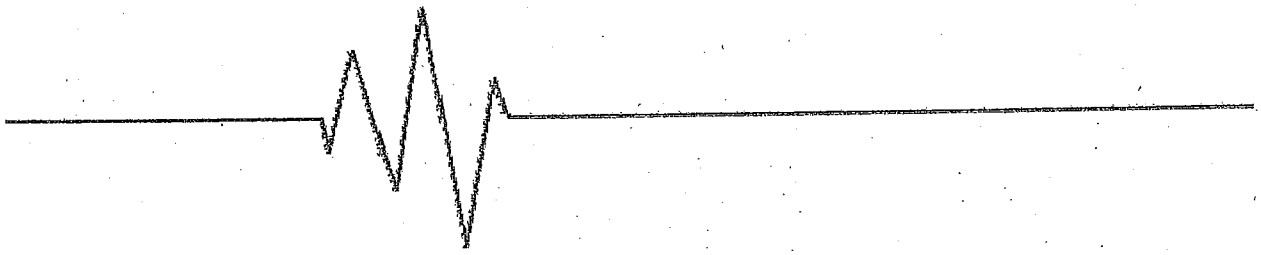
PREFACE



San Francisco has thousands of wood-frame buildings with a soft-story at the ground level. These buildings—used as apartments, condominiums, stores, and restaurants, among many other ways—are vulnerable to major damage in future earthquakes, with significant consequences on San Francisco's residents and way of life. The risk of these buildings, the impacts of likely damage, and a recommended policy for the City to reduce the risk are presented in a companion report, *Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco, Earthquake Safety for Soft-Story Buildings*, developed for the City of San Francisco as part of the Community Action Plan for Seismic Safety (CAPSS) project.

This report presents the technical methods, sources, assumptions, and calculations behind the results in the companion *Earthquake Safety for Soft-Story Buildings* report. While that report is written for a broad audience, this report will be of interest primarily to readers with a technical background. It is written assuming that readers have some knowledge of structural engineering and earthquake risk analysis; however some chapters will be accessible to readers of all backgrounds who are interested in details of the work.

We offer our sincere thanks to all of the volunteer participants in the CAPSS Advisory Committee meetings, other project meetings, and the project workshop that focused on the development of recommendations for this special class of buildings. The names and affiliations of these individuals are provided in the list of Project Participants section at the end of this report.

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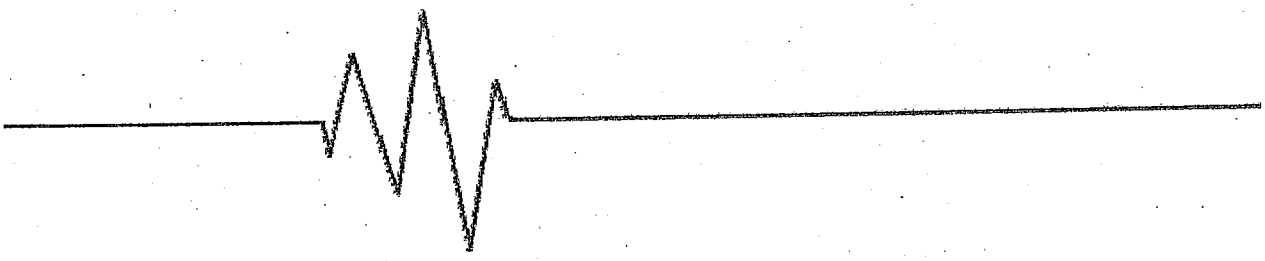
EXECUTIVE SUMMARY



This volume presents the analysis methods that were used to produce the companion report *Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco, Earthquake Safety for Soft-Story Buildings*. The purpose of this volume is to provide detailed information about how the Community Action Plan for Seismic Safety (CAPSS) project team developed the numbers and policy conclusions in that report. Some sections in this companion volume are quite technical in nature and will be of interest primarily to technical specialists; other sections could be interesting to general readers with a desire for detailed knowledge in particular topics.

This overview provides a brief description of each appendix in this volume, to help orient readers toward those parts that may be of interest to them. It also provides a brief summary of the key recommendations and findings from the report *Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco, Earthquake Safety for Soft-Story Buildings*, taken from that report's Executive Summary.

1. Overview of This Report

Overview of Appendix 1: Description of DBI's Inventory of Multi-Family Wood-Frame Buildings

This appendix discusses the process that was used to collect data on multi-family wood-frame buildings in San Francisco. It describes the San Francisco Department of Building Inspection (DBI) survey used to collect this data and the participants in the survey process. It also discusses limitations of the data collected.

Overview of Appendix 2: Analysis of DBI Database of Multi-Family Wood-Frame Buildings

This appendix summarizes the contents of the database of wood-frame buildings with three or more stories and five or more residential units. Data are discussed and presented in a variety of forms, including categorizing buildings (mid-block and corner) by the size of their openings at the ground floor, their number of stories and units, whether or not they are located in a liquefaction or landslide zone, their first floor use, and their date of construction.

Overview of Appendix 3: Maps of Multi-Unit Wood-Frame Buildings

This appendix shows maps of the locations of wood-frame buildings in San Francisco with three or more stories and five or more residential units. It includes maps of all of these buildings, as well as the subset of 2,800 buildings that were analyzed in depth by the CAPSS project. Maps with National Earthquake Hazards Reduction Program (NHERP) soil categories and liquefaction susceptibility are also included.

Overview of Appendix 4: Design of Conceptual Retrofits and Development of Capacity Curves

This appendix presents the conceptual retrofits that were designed for four prototype, wood-frame soft-story buildings. Plans and sketches of each of the prototype buildings are presented, along with the process to select these prototypes. The process and rationale used to develop conceptual retrofits are described, and plans for three conceptual retrofits for each prototype building are presented (a total of 12 retrofits). Capacity curves are presented for each of these buildings, with no retrofit and with each of the retrofits developed. There is some discussion of materials properties and the performance of the study buildings.

Overview of Appendix 5: Cost Estimates for Retrofits

This appendix presents detailed construction cost estimates for the prototype buildings studied. Cost estimates are presented in tabular form for four buildings, each with three possible retrofit approaches. These cost estimates are based on the schematic plans presented in the previous appendix.

Overview of Appendix 6: Procedures to Evaluate Seismic Hazards

This appendix describes the scenario earthquakes that were used to produce loss estimates. It describes how the ground shaking was estimated for those events. It discusses local site conditions and the process used to evaluate susceptibility to liquefaction.

Overview of Appendix 7: Component Fragility Functions for Older Wood-Frame Construction

This appendix describes how fragility functions that were used to estimate losses to San Francisco's wood-frame soft-story buildings were developed. Laboratory tests and observations of earthquake performance were used to estimate the fragility of building components. Drift thresholds associated with various building-component damage states were associated with values of peak transient interstory drift. Damage states were equated with performance categories developed by San Francisco Planning and Urban Research (SPUR) and with ATC-20 post-earthquake safety inspection placard colors *green*, *yellow*, and *red*.

Overview of Appendix 8: Seismic Vulnerability of Four Soft-Story Wood-Frame Index Buildings and Their Retrofits

This appendix describes how seismic vulnerability relationships were developed for the project's four index or prototype buildings. These relationships give the mean damage factor (repair cost as a fraction of replacement cost) and damage state probabilities for each building as functions of spectral acceleration response, earthquake magnitude, fault rupture distance, and NEHRP site soil classes.

Overview of Appendix 9: Estimates of Earthquake Scenario Losses to Large Soft-Story Wood-Frame Buildings in San Francisco

This appendix describes the process used to select a loss-estimation methodology and presents the results of that work. It describes how the seismic hazard and capacity and fragility analyses described previously were combined to produce loss and damage estimates for multifamily wood-frame soft-story buildings. It also applies this method to wood-frame corner buildings in the Marina District of San Francisco for Loma Prieta earthquake shaking levels and compares the results to observed damage.

Overview of Appendix 10: Community and Economic Impacts of Soft-Story Risk and Mitigation

This appendix evaluates socio-economic issues related to San Francisco's wood-frame soft-story buildings. It begins by analyzing the types of residents and businesses that occupy soft-story buildings in San Francisco. It then examines the impacts of both a retrofit policy for soft-story wood-frame residences and a major earthquake on tenants, businesses, and building owners.

Overview of Appendix 11: Soft-Story Mitigation Programs in Other Communities

This appendix describes programs developed in other communities to regulate and study the risk of wood-frame soft-story buildings, as of Fall 2008. Detailed information is provided about programs in the cities of Berkeley, Fremont, Santa Monica and Los Angeles. Brief descriptions of activities in Oakland, San Jose, Burbank, San Leandro, and Campbell are also included.

Overview of Appendix 12: Incentives to Encourage Seismic Retrofits

This appendix reviews numerous types of incentives that can be offered to encourage building owners to undertake voluntary seismic retrofits or to ease the burden of conducting mandated seismic retrofits. When possible, specific experiences of communities that have tried various types of incentives are described, and San Francisco-specific information relating to the feasibility of various incentives is discussed.

2. Summary of Recommendations and Findings in Companion Report

Key Recommendations in Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco, Earthquake Safety for Soft-Story Buildings

The report recommends that:

- **The Department of Building Inspection should establish a program that requires owners of wood-frame buildings built before May 21, 1973 with three or more stories and five or more residential units to evaluate the seismic safety of their buildings and to retrofit them if they are found to be seismically deficient.** Many of these buildings have "soft-stories" and are highly vulnerable to damage and collapse in earthquakes. Soft-story buildings have a weak ground floor, because perimeter walls have large openings for garage doors and windows, because they often lack interior partitions, and/or because building materials have deteriorated over time.

- **Buildings should be retrofitted to a standard that will allow many of them to be occupied after a large earthquake.** Keeping San Franciscans in their homes helps to avert a post-earthquake shelter crisis, lessens the demands placed upon emergency response services, and allows residents to remain in their neighborhoods and to help to revive them. It is feasible to retrofit this type of building so that many residents can remain in their homes after a large earthquake, even though some damage would occur and utilities might not function.

- **The City should immediately offer incentives to encourage voluntary retrofits.** The program described in this report will take time to launch, but the risk is urgent and should be addressed immediately. To get owners moving on making their buildings safer, the City should offer incentives to owners who retrofit, including expediting plan review, rebating permit fees, offering planning incentives, and seeking voter approval of a City-funded loan program. Buildings voluntarily retrofitted to an acceptable standard should be exempt from requirements created by the recommended program. Incentives need not be limited to the buildings addressed in this report.
- **The Department of Building Inspection should form a working group to develop a detailed plan to implement the recommended program.**

Many other types of buildings in San Francisco pose great threats to the City in earthquakes. In addition to addressing the building types analyzed in this report, the City should pursue policies to make other types of buildings that are at risk of major damage and collapse in future earthquakes safer.

Key Findings in Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco, Earthquake Safety for Soft-Story Buildings

Retrofitting multi-unit, wood-frame buildings would reduce the consequences of earthquakes to San Francisco. It would retain significant amounts of housing, preserve architectural and cultural attributes, conserve energy and resources, and improve public safety. Retrofitting would shorten the time that the City requires to recover from the next large earthquake. Although other types of buildings are also vulnerable to earthquake damage and also need to be retrofitted, the buildings addressed in this report are particularly vulnerable and can be retrofitted relatively easily.

Many multi-story buildings have a structural weakness due to large openings in their perimeter walls and to a lack of interior partition walls at the ground level. Usually, perimeter wall openings at the ground level make way for garage doors or large windows. Interior spaces used for retail and garages often have few partition walls. The open condition makes the ground level significantly weaker and more flexible than the floors above it. This condition is called a "soft-story." During strong earthquake shaking, these "soft" ground level walls cannot support the side-to-side or front-to-back movement of the stiff and heavy mass of the stories above them, leading to damage and, in the worst cases, to collapse.

There are approximately 4,400 wood-frame buildings built before May 21, 1973[1] in San Francisco with three or more stories and five or more residential units. All of these buildings may have a soft-story condition[1]. CAPSS studied these buildings to understand better how they are being used, how they would perform in future earthquakes, how building performance could be changed through retrofitting, and what would be involved in retrofitting them.

CAPSS analyzed a subset of these buildings, to gain insight into how best to manage the larger number of potentially vulnerable buildings. CAPSS identified and

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[1] May 21, 1973 is the date when the San Francisco Building Code was amended to prevent design flaws that often resulted in soft-story conditions. Buildings constructed after that date, even those with open perimeter walls, should have adequate strength and stiffness at the ground level to resist earthquakes.

evaluated roughly 2,800 buildings that have the largest perimeter wall openings and are, therefore, expected to have significant soft-story weaknesses. Findings show that dramatic damage to this subset of buildings is likely, but that vulnerability could be easily remedied:

- As they now stand, 43 to 85 percent of the multi-unit, wood-frame buildings studied by CAPSS would be posted with a red UNSAFE placard (red-tagged) after a magnitude 7.2 earthquake on the San Andreas fault. This represents 1,200 to 2,400 red-tagged buildings. Red-tagged buildings have severe damage and cannot be occupied after an earthquake, until they are either repaired or replaced. Their residents would need to find new homes for those months or years that it would take to make repairs. The extensive damage predicted to these buildings suggests that buildings with smaller perimeter wall openings at the ground level would also be susceptible to significant damage.
- A quarter of these red-tagged buildings would be expected to collapse. This represents 300 to 850 multi-unit buildings. Collapses threaten lives. These buildings, most of which contain rent-controlled apartments, would be rebuilt differently, using modern materials and design. Owners might not choose to rebuild them as apartment buildings. If they did, then state law dictates that the units would not be covered by rent control. The demographics and architectural character of neighborhoods that experience many collapses could change significantly.
- Nearly 8 percent of the City's population, or about 58,000 people, live in this subset of buildings. The buildings house close to 2,000 businesses that employ an estimated 7,000 people. Without retrofit, the heavy damage that these buildings are likely to sustain would disrupt many neighborhoods for years after an earthquake. Tens of thousands of people would be displaced from their homes and neighborhoods and would not contribute to bringing them back to life. Small businesses along neighborhood shopping streets would suffer severe impacts.
- Seismic retrofits make a big difference and would dramatically reduce the number of collapsed buildings. With retrofit, collapses could be reduced to less than 1 percent of these buildings.
- Retrofitting all of the buildings in this subset to a recommended level that would allow most of them to be occupied after a large earthquake would cost approximately $260 million[2]. These retrofits would eliminate $1.5 billion in damage after a magnitude 7.2 earthquake on the San Andreas Fault. Even so, many retrofitted buildings would still require costly repairs.
- Seismic retrofits at the recommended level are likely to cost in the range of $60,000 to $130,000 per building for direct construction costs. Retrofit construction would last for two to four months and could be limited to the ground floor level, meaning that residents of upper level apartments could stay in their homes. However, construction could have significant impacts on residents and small businesses located at street level in these buildings. Ground floor tenants might temporarily need to close, relocate or deal with considerable construction inconvenience. Tenants occupying the upper floors would experience noise, dust, vibrations and other inconveniences during construction.

[2] The dollar values mentioned were calculated during the Fourth Quarter of 2008.

- The subset of buildings studied can be found throughout the City but the buildings are most common in the Mission, Western Addition, Richmond, Pacific Heights, North Beach, and Marina neighborhoods.

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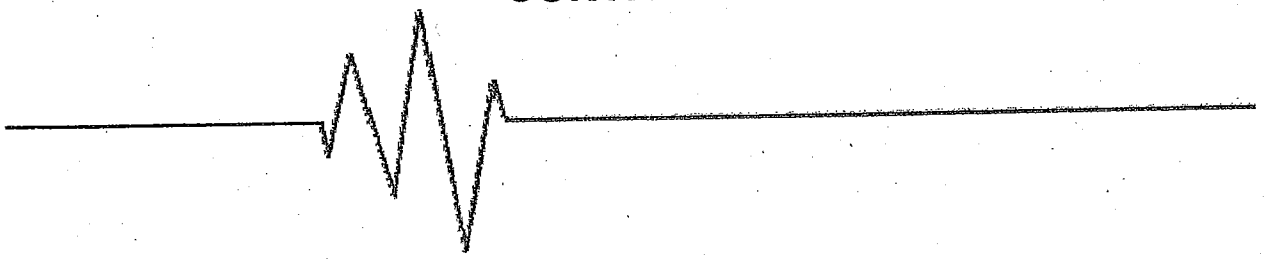

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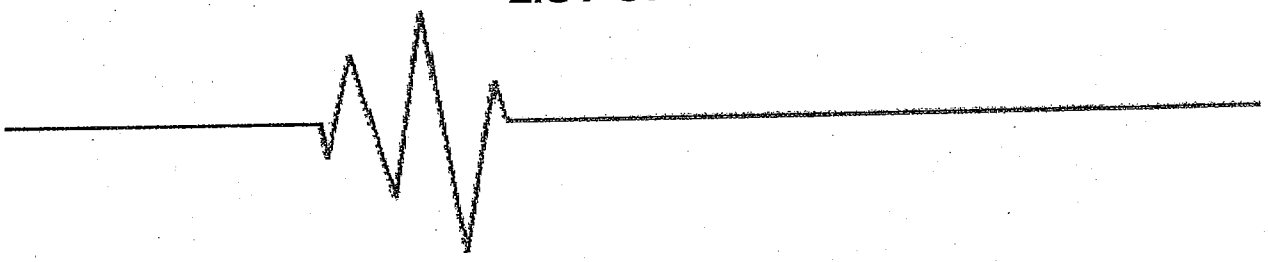

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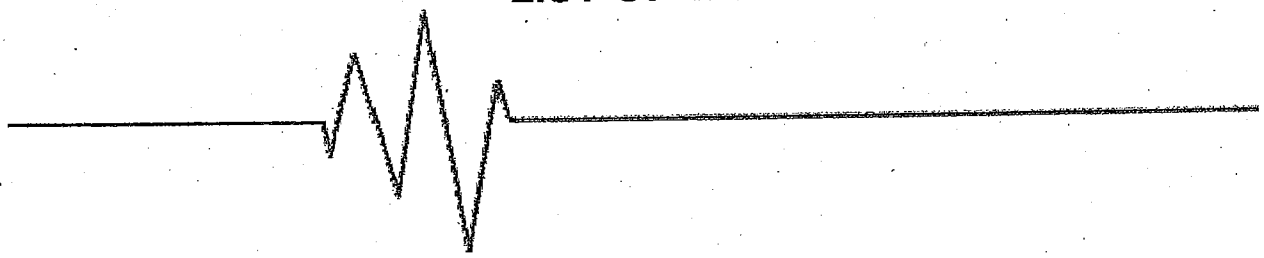

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APPENDIX 1: DESCRIPTION OF DBI'S INVENTORY OF MULTI-FAMILY WOOD-FRAME BUILDINGS

1.1 Overview

The San Francisco Department of Building Inspection (DBI) developed a database of all wood-frame buildings in the City that have five or more residential units and three or more stories. This database includes information about characteristics that affect a building's earthquake performance. It was developed by DBI staff and volunteer professionals, who walked many City blocks to note specific building characteristics. These data were used by the Community Action Plan for Seismic Safety (CAPSS) project team to analyze the risk of multi-family buildings in future earthquakes.

1.2 Process Used to Develop Database

DBI staff began by reviewing City databases with information about buildings, in particular the Housing Database, maintained by the Housing Inspection Division within the DBI. This database contains information about all properties in San Francisco with three or more residential units. The database includes information about the number of residential units, number of stories, and type of construction.

Analysis of this database indicated that there were approximately 4,500 three-unit buildings with three or more stories, 3,500 four unit-buildings, and 6,000 buildings with five or more units. DBI decided to focus its survey on those buildings with five or more units because that was a manageable number of buildings to survey, because the City's Unreinforced Masonry Building (UMB) program addressed buildings with five or more units, and because the five-unit cutoff is used elsewhere in City codes. It chose to focus on buildings with three or more stories, because those are believed to be more vulnerable to earthquake shaking than are buildings with fewer stories.

DBI approached two local professional organizations for help in organizing the survey: the Structural Engineers Association of Northern California (SEAONC) and the Earthquake Engineering Research Institute, Northern California Chapter (EERI-NC). Volunteers from both of these organizations worked with DBI to plan the survey process.

DBI, SEAONC and EERI-NC developed a form for volunteers to complete during the walking survey. This form included the following information:

- Address
- Number of stories
- Number of dwelling units
- Whether the first floor was wood frame (Yes or No)
- Whether there was clear evidence of seismic retrofit (Yes or No)

- Whether a building was located on a corner (Yes or No)
- Whether a building was located on a sloped site (Yes or No)
- First floor uses
- The percent open at the first story, for all visible sides
- Other comments

DBI input address and unit number information into the survey form for the approximately 6,000 buildings identified from the Housing Database as being wood-frame, three or more stories, and five or more residential units. Information on the City block and lot numbers, a numbering scheme used by the City to identify locations, was also input. A separate form was printed for each city block. These forms were paired with City maps that showed the locations of the buildings identified in the Housing Database.

DBI, SEAONC and EERI-NC mobilized approximately 150 volunteers to participate in a survey, walking City blocks in neighborhoods with many multifamily, wood-frame buildings. Volunteers from SEAONC and EERI-NC were joined by members of the San Francisco branches of the American Institute of Architects (AIA), American Society of Civil Engineers (ASCE), and graduate students from the University of California at Berkeley, San Francisco State University, and Stanford University. A number of these volunteers were identified to serve as team leaders and to manage the efforts of a subset of volunteers. Each team leader was responsible for collecting data for a specific area of the City.

DBI, SEAONC and EERI-NC created training materials for the volunteers, to teach them how to complete the survey forms consistently. All volunteers participated in a training session on the morning of February 24, 2007. This training clarified issues such as the following:

- The percent open on each side of the first floor should be estimated in multiples of 10%
- Doors, large openings, windows and nominal piers between openings count as open areas
- Stories that are partially above ground and partially below ground count as a story, in accordance with standing DBI definitions, but attics with pitched roofs do not count as a story
- Only evidence of seismic retrofits that is clearly visible should be noted
- Corner buildings have street frontage on more than one side
- Buildings should have more than six feet change in elevation from the downhill side to the uphill side to be considered as being located on a sloped site

The walking survey occurred on February 24, 2007. All of the volunteers met at DBI's offices in the morning, received training in the survey program, were divided into groups, and were given maps and survey forms with information for the area they would be surveying. Volunteers were told to verify the data provided from City databases, to correct any information (such as number of units) that was incorrect, and to add any buildings to the form that were not listed but that met the program's criteria. The survey forms all included blank lines for adding buildings. Volunteers

surveyed City blocks for a half or full day, then reconvened to give the data they had collected to organizers and to discuss issues.

During this one day event, volunteers were able to survey approximately 50 percent of City blocks, and about 75 percent of wood-frame buildings with three or more units. In the following months, DBI staff members surveyed the remaining City blocks. A small number of City blocks were surveyed using digital image databases, such as http://www.mapjack.com/, instead of having volunteers walking each block. A small number of wood-frame buildings with three or more stories and five or more residential units were not included in the database, because DBI staff knew those buildings to be constructed after the May 1973 code changes, which eliminated most soft-story conditions, were in effect. DBI staff and interns manually entered the data collected by volunteers into an Excel spreadsheet.

The next appendix describes the way that this database was used for the Community Action Plan for Seismic Safety (CAPSS) project.

1.3 Limitations of Database

The DBI database provides an accurate picture of the citywide and neighborhood characteristics of multi-family wood-frame buildings. It is a useful tool to analyze the City's risk from wood-frame soft-story buildings and to guide broad policy decisions. It is not an accurate list of wood-frame soft-story buildings, nor is it, in its current state, a list of buildings that the City should use to notify building owners of requirements of any future programs. To know definitively whether or not a specific building has a soft-story, a qualified engineer must evaluate it in detail; that level of effort was not possible for this survey.

The DBI survey collected information about one characteristic—the portion of open wall line at the first story—that is a rough but reasonable indicator of whether or not a building has a soft story. This information is useful for characterizing the building stock as a whole and for estimating the broad effects of certain policy options, but it does not include all relevant information for individual buildings, such as the amount and characteristics of interior walls in each building, and the building's proximity to neighbor buildings. San Francisco is a large city, and DBI staff and volunteers were able to walk most, but not all, blocks. As described above, some areas were surveyed using online resources for digital images of buildings. In some neighborhoods, specific areas were not surveyed, because they were known by DBI staff to have buildings constructed after code changes eliminated most soft-story conditions in new construction. Due to differences in surveying techniques and individuals, there may be inconsistencies, errors and omissions in the database.

APPENDIX 2: ANALYSIS OF DBI DATABASE OF MULTI-FAMILY WOOD-FRAME BUILDINGS

The Department of Building Inspection (DBI) surveyed all wood-frame buildings that have three or more stories and five or more residential units, as described in Appendix 1. This section summarizes the data collected by that survey. It also describes characteristics of the surveyed buildings that were assessed through comparison with other City databases. DBI data were matched with the following other databases:

- San Francisco City Assessor's Data;
- San Francisco Planning Department database of properties with historic characteristics;
- Map of liquefaction risk: *Preliminary Maps of Quaternary Deposits and Liquefaction Susceptibility, Nine-Counties San Francisco Bay Region: A Digital Database (*Knudsen, et al., 2000);
- *California Geological Survey Seismic Hazard Zones Map*;
- Dun and Bradstreet Data (findings from matching to this database are described in Appendix 10); and
- United States Census (findings from matching to this database are described in Appendix 10).

2.1 Overview

DBI provided the CAPSS project team with a database containing 5,472 entries. After review and revision by the project team to consolidate all information into single building records, there were 4,572 buildings in the database. (The reduction in number is primarily due to condominiums having been listed as individual data records.) The survey and subsequent analyses yielded the following information:

- 4,374 of these buildings were built before the May 21, 1973 Building Code was in effect;
- 2,928 of these buildings (64%) were identified by the project team as having significant openings in their exterior walls, meaning that they are 80% open or more on one side or 50% open or more on two sides; and
- 2,830 of these buildings meet the openness criteria described, have square footage data in the City's assessor's file, and have a known lot and block number (location identifiers).

Openings in exterior walls are a good indicator that buildings may have a "soft" or weak ground floor and be highly vulnerable to earthquake shaking. However, it is

not known if these are soft-story buildings, until they are analyzed by an engineer. Further, buildings without significant exterior openings can also have weak ground floors.

In this appendix, results are sometimes reported separately for corner buildings, because they are presumed to have more risk. However some mid-block buildings may not have directly adjacent buildings and may also face higher risk.

Findings are presented by neighborhood, as defined by the Department of Public Works. This scheme of dividing the city was used in the preliminary CAPSS earthquake loss analysis conducted early on in the project. Golden Gate Park, the Presidio and Treasure Island are excluded from the study (see Figure 2-1).

For the mid-block and corner buildings surveyed, the following characteristics were documented:

- Openings of various sizes at the ground floor;
- Number of stories and units;
- Located in a liquefaction or landslide zone;
- First floor use; and
- Date of construction.

Note that some wood-frame buildings with three or more stories and five or more units were not surveyed by DBI, because they were known to be built after May 1973. DBI's database may contain errors and omissions. The findings presented here should be viewed as indicative of city trends for this building type, rather than as definitive numbers.

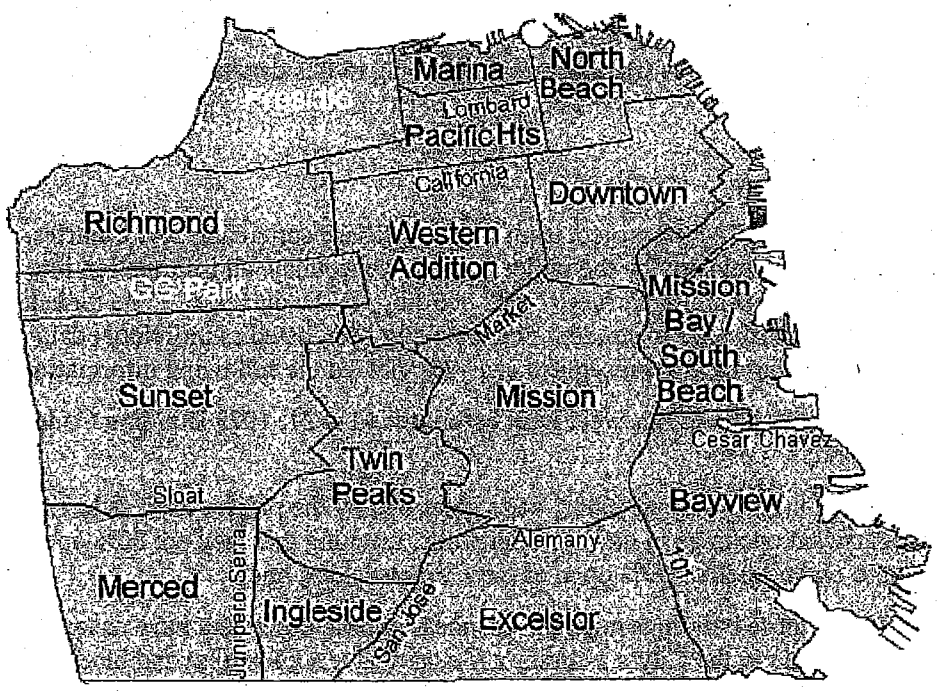


Figure 2-1 Neighborhood division used by the CAPSS project, taken from the Department of Public Works. The Presidio and Golden Gate (GG) Park (shown with white print) are excluded from this study.

2.2 Openness Characteristics

The total number of wood-frame buildings with three or more stories, and five or more residential units in DBI's database, by neighborhood, along with the number of buildings that have significant openings at the ground floor and the number that are corner buildings with significant openings, are summarized in Table 2-1.

Table 2-1 Total Number of Buildings and Buildings with Significant Openings (80% or More Open on One Side or 50% or More Open on Two Sides) in DBI Database, by Neighborhood

Neighborhood	Number of Wood-Frame Buildings with 3+Stories, 5+Units	Number of Buildings with Significant Openings at Ground Floor	Number of Corner Buildings with Significant Openings
Bayview	2	0	0
Downtown	194	111	39
Excelsior	37	32	20
Ingleside	10	3	2
Marina	362	265	114
Merced	1	0	0
Mission	809	531	187
Mission Bay	24	21	6
North Beach	781	364	130
Pacific Heights	504	330	98
Richmond	434	367	158
Sunset	236	190	87
Twin Peaks	119	102	53
Western Addition	1,053	608	236
Unknown	6	4	3
TOTAL	4,572	2,928	1,133

The definition for significant ground floor openings used for the CAPSS analysis is 80% open or more on one side or 50% open or more on two sides. There are other reasonable definitions. Table 2-2 provides information on the range of openness for the most open side of multifamily wood-frame buildings with three or more stories and five or more residential units that are included in DBI's database. Table 2-3 provides information on the range of openness for the two most open sides for corner buildings, presented by the number of buildings. Table 2-4 provides information on the range of openness for the two most open sides for corner buildings, presented by the number of residential units. A building categorized as 100% open has no wall on one side, only columns.

The total number of buildings in Tables 2-2, 2-3, and 2-4 differs slightly from the totals in Table 2-1, due to various data discrepancies. It is most accurate to round these numbers to two significant digits.

Table 2-2 Range of Ground-Floor Openness on Most Open Side in Wood-Frame Buildings with Three Stories or More and Five Residential Units or More

Percent Open on Most Open Side	Mid Block Buildings		Corner Buildings	
	Number of Buildings	Number of Residential Units	Number of Buildings	Number of Residential Units
0-9%	34	295	18	265
10-19%	61	646	62	588
20-29%	99	924	67	811
30-39%	88	775	53	650
40-49%	79	847	40	445
50-59%	219	2,169	104	1,064
60-69%	245	2,189	134	1,448
70-79%	296	2,639	127	1,651
80-89%	376	3,401	145	1,570
90-99%	760	6,723	512	5,954
100%	590	5,407	306	4,070
TOTAL	2,849	26,026	1,568	18,516

Table 2-3 Range of Ground-Floor Openness on the Two Most Open Sides for Corner Buildings, by Number of Buildings

2nd Most Open Side	Most Open Side*											
	0-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-99%	100%	Total
0-9%	18	35	36	14	10	20	30	16	35	186	33	433
10-19%		27	21	16	5	14	11	15	17	66	12	204
20-29%			10	14	9	22	15	14	15	36	19	154
30-39%				9	12	16	14	13	9	25	22	120
40-49%					4	15	15	15	15	19	23	106
50-59%						17	31	24	17	46	55	190
60-69%							18	18	15	39	44	134
70-79%								12	14	29	33	88
80-89%									8	30	26	64
90-99%										36	22	58
100%											17	17
Total	18	62	67	53	40	104	134	127	145	512	306	1,568

*note: grey highlight indicates buildings that are 80% or more open on one side or 50% or more open on two sides.

Table 2-4 Range of Ground-Floor Openness on the Two Most Open Sides for Corner Buildings, by Number of Residential Units

2nd Most Open Side	Most Open Side*											
	0-9%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-99%	100%	Total
0-9%	265	323	420	141	109	204	320	88	336	2,037	371	4,614
10-19%		265	311	205	39	124	107	142	146	652	137	2,128
20-29%			80	203	106	277	200	170	168	412	217	1,833
30-39%				101	126	133	138	113	102	273	215	1,201
40-49%					65	172	140	207	168	204	267	1,223
50-59%						154	352	292	197	543	591	2,129
60-69%							191	295	202	453	667	1,808
70-79%								344	168	310	480	1,302
80-89%									83	524	386	993
90-99%										546	308	854
100%											431	431
Total	**265**	**588**	**811**	**650**	**445**	**1,064**	**1,448**	**1,651**	**1,570**	**5,954**	**4,070**	**18,516**

*note: grey highlight indicates buildings that are 80% or more open on one side or 50% or more open on two sides.

2.3 Number of Stories

Table 2-5 provides the distribution of number of stories in the inventory of wood-frame buildings with three or more stories and five or more residential units. The totals in Table 2-5 vary from totals in other tables, due to various discrepancies in the databases used to compile this information. However, the overall general numbers and overall trends shown in this table are consistent with numbers reported elsewhere.

Table 2-5 Number of Stories in Multi-Family Wood-Frame Buildings

Building Type	3 stories		4 stories		5 or more stories	
	Number of Buildings	Number of Residential Units	Number of Buildings	Number of Residential Units	Number of Buildings	Number of Residential Units
All buildings	1,662	13,395	2,630	28,965	121	2,159
Buildings with significant ground floor openings	1,087	9,197	1,594	17,809	55	1,082
Corner buildings with significant ground floor openings	387	3,783	626	8,184	27	586

(Significant ground-floor openings refers to buildings that are 80% open or more on one side or 50% open or more on two sides.)

2.4 Landslide and Liquefaction Zones

The number of buildings with significant openings at the ground floor are reported in Table 2-6. The zone data were developed through use of the following maps:

- Liquefaction hazard: *Preliminary Maps of Quaternary Deposits and Liquefaction Susceptibility, Nine-Counties San Francisco Bay Region: A Digital Database* (Knudsen, et al., 2000).
- Landslide hazard: *California Geological Survey Seismic Hazard Zone Map.*

Table 2-6 Buildings with Significant Openings in the Ground Floor Located in Liquefaction and Landslide Zones, by Neighborhood

Neighborhood	Number of Buildings in Very High Liquefaction Zone	Number of Corner Buildings in Very High Liquefaction Zone	Number of Buildings in Landslide Zone	Number of Corner Buildings in Landslide Zone
Bayview	0	0	0	0
Downtown	35	13	0	0
Excelsior	0	0	0	0
Ingleside	0	0	0	0
Marina	148	67	0	0
Merced	0	0	0	0
Mission	100	29	3	1
Mission Bay	1	1	0	0
North Beach	45	20	4	1
Pacific Heights	26	14	0	0
Richmond	0	0	0	0
Sunset	13	7	1	1
Twin Peaks	0	0	16	10
Western Addition	13	2	0	0
TOTAL	381	153	24	13

2.5 First Floor Use

The number of buildings with significant ground floor openings having different uses at the ground floor level are provided in Table 2-7. This information has been divided by neighborhood but is not presented here, due to its complexity. Neighborhoods with significant numbers of buildings with ground floor openings and ground floor commercial use are: North Beach, Mission, and Western Addition.

Table 2-7 First Floor Use of Buildings with Significant Openings

First Floor Use	Number of Buildings with Significant Openings	Number of Corner Buildings with Significant Openings
Commercial	395	199
Garage & Commercial	90	59
Garage/Parking	1,917	713
Basement	5	0
Residential	423	111
Hotel/Motel	14	8
Unknown	84	43
TOTAL	2,928	1,133

2.6 Date of Construction

Data summarizing the number of buildings with significant ground opening by date of construction and neighborhood are provided in Table 2-8. Date of construction comes from City Assessor's Data. Note however, that all buildings in the Assessor's data have a date of construction. All apartment buildings built before June 1979 are covered by rent control law. An estimated 2,592 buildings with significant openings at the ground level are apartment buildings and presumably are covered by rent control law.

Table 2-8 Year of Construction of Buildings with Significant Ground Floor Openings, by Neighborhood

Neighborhood	Pre-1900	1900-1909	1910-1919	1920-1929	1930-1939	1940-1949	1950-1959	1960-1969	1970-1979	Post-1980
Bayview	0	0	0	0	0	0	0	0	0	0
Downtown	0	37	49	11	0	0	1	2	1	9
Excelsior	0	3	0	5	0	0	5	9	4	5
Ingleside	0	0	0	0	0	0	0	3	0	0
Marina	0	3	2	193	24	0	12	14	7	8
Merced	0	0	0	0	0	0	0	0	0	0
Mission	10	194	72	84	4	1	21	103	16	15
Mission Bay	0	1	2	1	0	0	2	14	1	0
North Beach	0	114	111	61	6	4	12	24	13	14
Pacific Heights	1	86	38	89	6	4	31	57	9	5
Richmond	0	17	20	147	8	4	27	115	21	3
Sunset	0	6	6	37	0	4	41	69	21	3
Twin Peaks	0	0	0	2	1	1	11	69	13	1
Western Addition	10	212	71	163	6	4	44	60	22	14
TOTAL	21	673	371	793	55	22	207	539	128	77

APPENDIX 3: MAPS OF MULTI-UNIT WOOD-FRAME BUILDINGS

This appendix contains maps showing locations of various groupings of wood-frame buildings with three or more stories and five or more residential units. Figure 3-1 shows all such buildings, Figure 3-2 shows all such buildings, but differentiates those with significant first floor openings from all others. Buildings with significant ground-floor openings are those with 80% or more openings on one side, or with 50% or more openings on two sides. Figure 3-3 shows only wood-frame buildings with three or more stories and five or more residential units with significant ground-floor openings. Figure 3-4 shows the same buildings as Figure 3-3 (those with significant first-floor openings) plotted on a map of the National Earthquake Hazards Reduction Program (NEHRP) soil types. Figure 3-5 shows all wood-frame buildings with three or more stories and five or more residential units, plotted on a map showing very high liquefaction susceptibility zones.

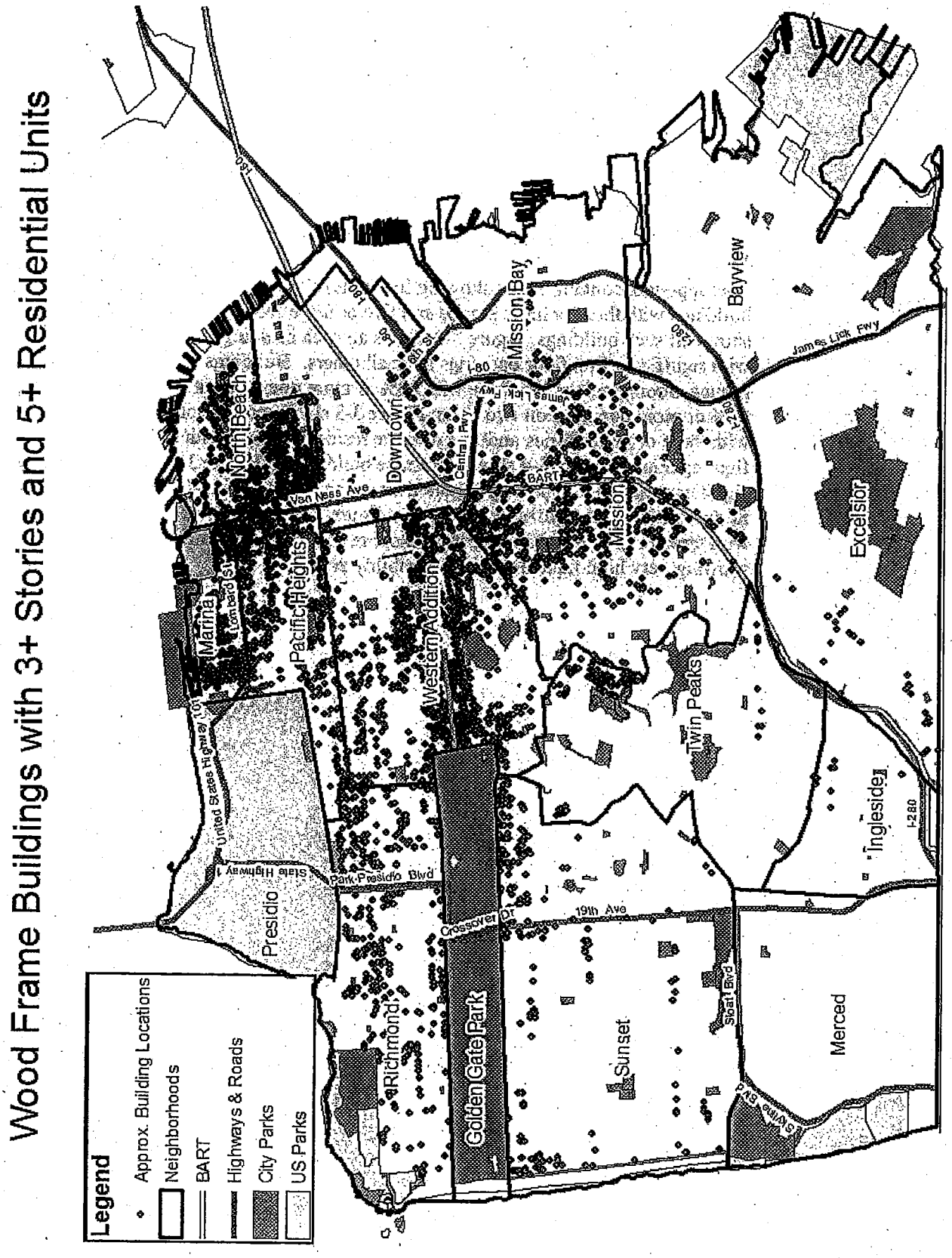


Figure 3-1 Map showing all wood-frame buildings with 3 or more stories and 5 or more residential units.

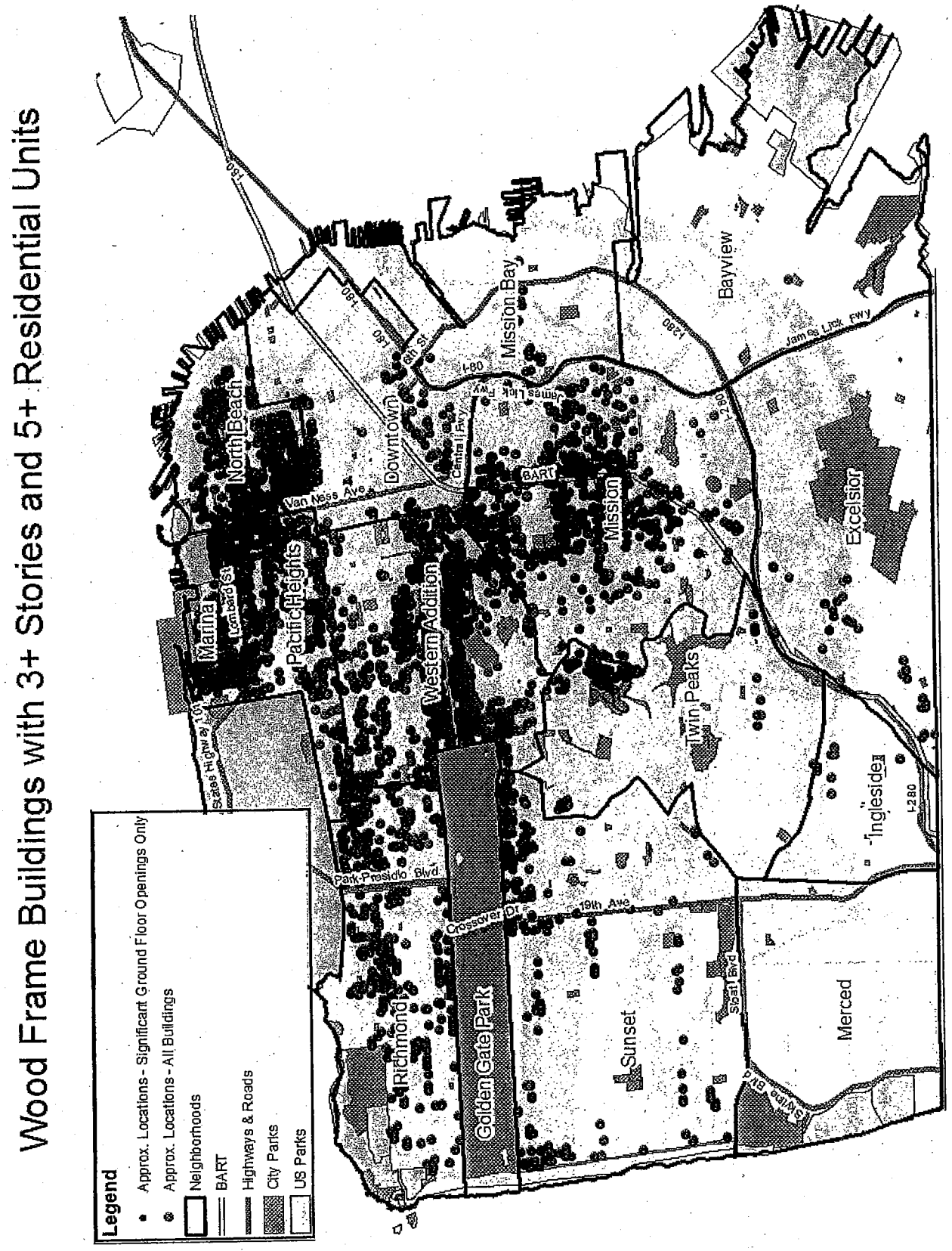


Figure 3-2 Map showing two groups of wood-frame buildings with 3 or more stories and 5 or more residential units: those with significant ground floor openings and all others.

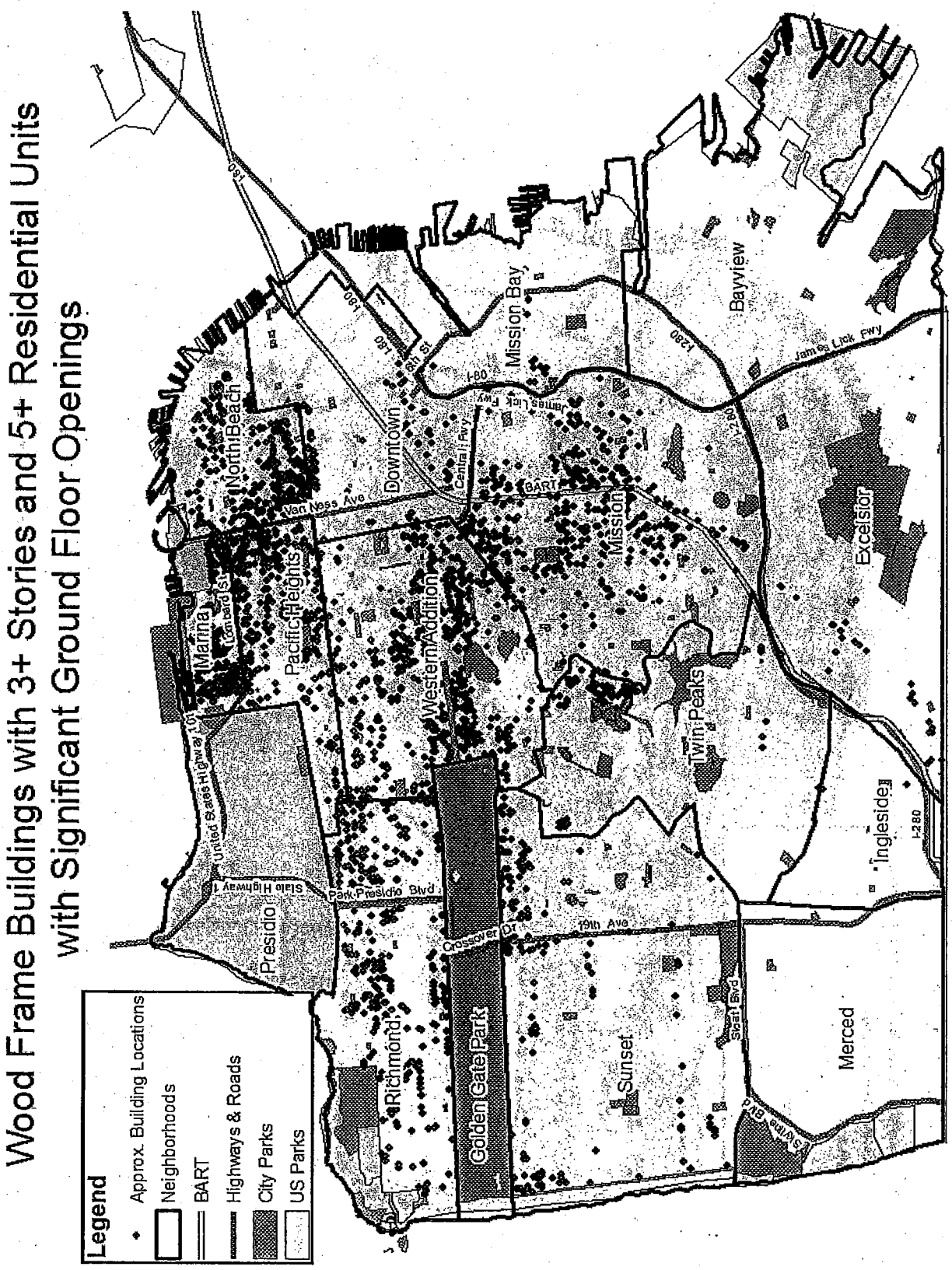


Figure 3-3 Wood-frame buildings with 3 or more stories and 5 residential units with significant ground-floor openings.

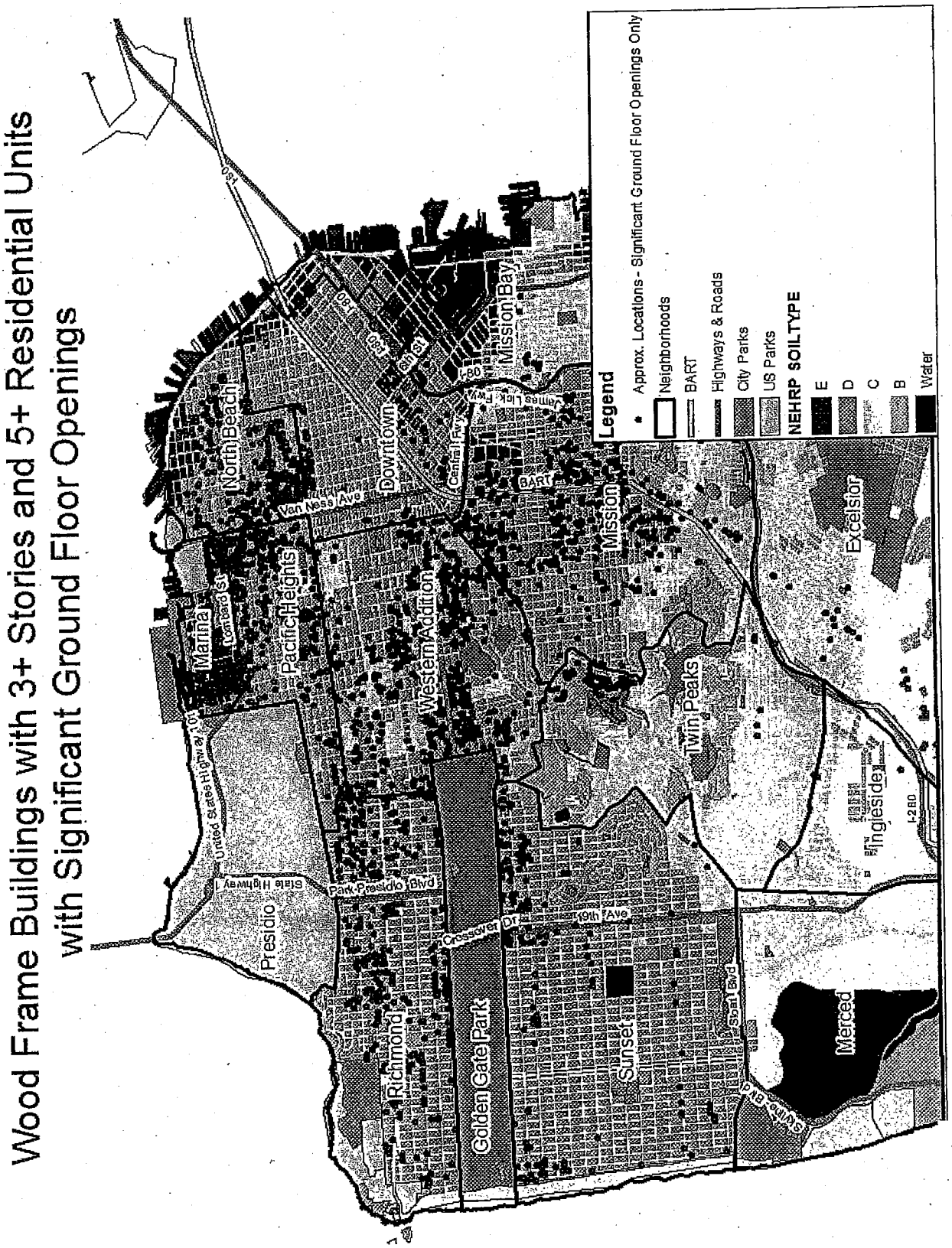


Figure 3-4 Map showing NEHRP soil type and wood-frame buildings with 3 or more stories and 5 or more residential units with significant ground-floor openings.

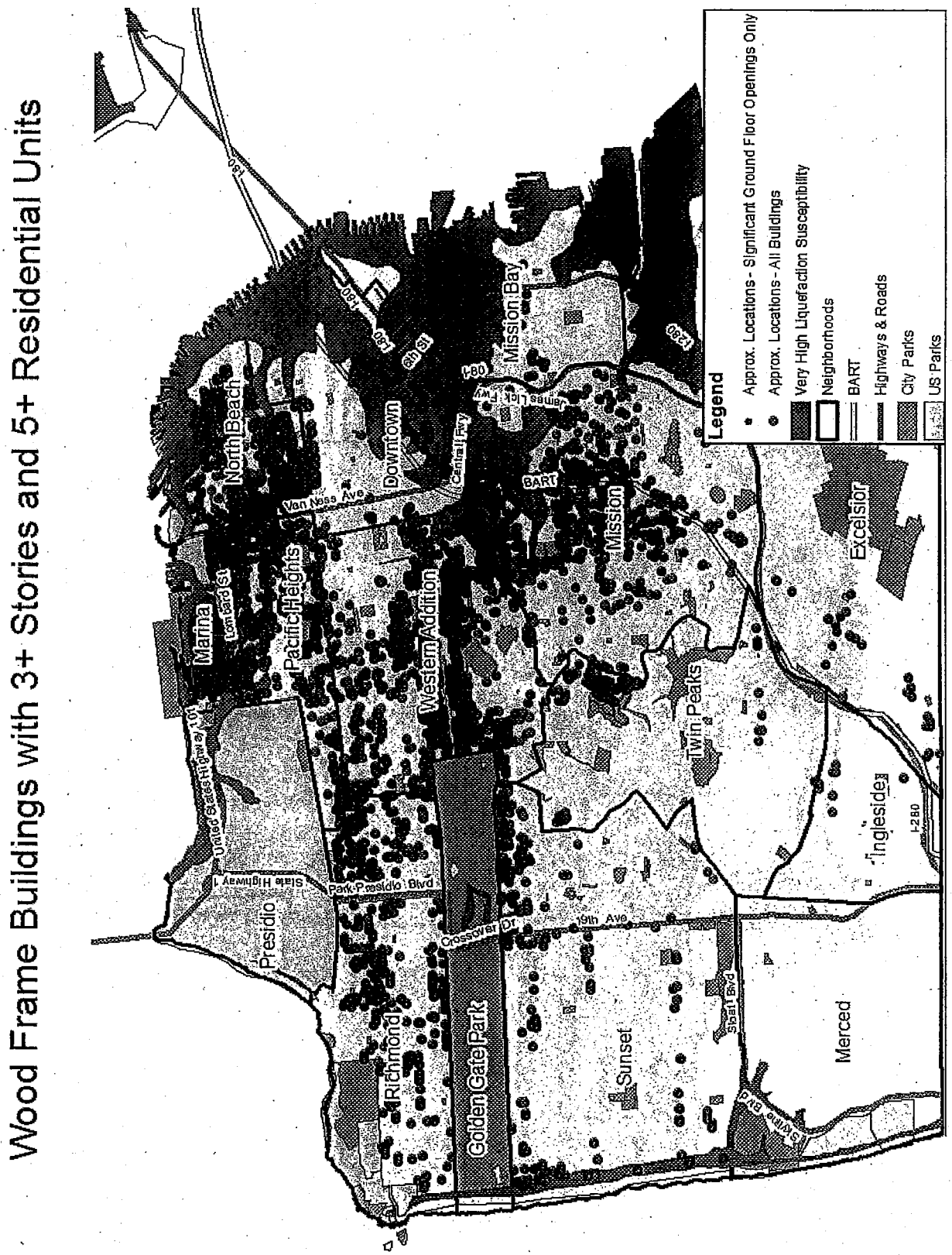


Figure 3-5 Map showing very high liquefaction susceptibility and wood-frame buildings with 3 or more stories and 5 or more residential units, including those with significant floor openings and all others.

APPENDIX 4: DESIGN OF CONCEPTUAL RETROFITS AND DEVELOPMENT OF CAPACITY CURVES

4.1 Introduction

Four San Francisco open wall Index Buildings were selected for study. The term "open wall" is used to describe buildings with ground stories in which the amount of exterior or interior wall is significantly less than at the stories above. For each Index Building, conceptual seismic retrofits were developed for three levels of performance. Capacity curve parameters of spectral acceleration and displacement at yield and peak capacity were developed to allow for analysis of earthquake losses and costs of retrofit construction.

4.2 CAPSS Retrofit Design Charette

Plans and street front elevations for candidate Index Buildings were compiled by San Francisco DBI staff for consideration. With the candidate buildings as a starting point, a design charette was held on 12 September 2008 to get input on selection of Index Buildings, retrofit approaches, and performance expectations. The charette attendees included design engineers, contractors, San Francisco DBI representatives and project members. The attendee list is included in the list of Project Participants (back of document).

Discussion of performance expectations was framed around comparison of building code forces levels, ASCE 41 performance objectives (ASCE, 2006), and four levels of performance defined by the San Francisco Planning + Urban Research Association (SPUR). See section 5 of the SPUR report, "The Resilient City: Defining What San Francisco Needs from Its Seismic Mitigation Policies," for further discussion of the SPUR performance levels (SPUR, 2009). The four SPUR levels are:

- Level A: Safe and operational;
- Level B: Safe and usable during repair;
- Level C: Safe and usable after repair; and
- Level D: Safe but not repairable.

The participants were asked which levels they believed were possible and practical to design for, and how they would approach design for the levels of interest. These questions led to far-ranging responses, varying from the highest performance level (SPUR Level A) being prudent for some buildings, to the expense of obtaining a high performance level being much too great, and moderate-to-low performance being reasonable targets. Methods proposed to achieve performance in retrofit design included using a percentage of current building code forces levels to targeting drift limits for each performance, such as those suggested in ASCE 41 Table C3-1 (ASCE, 2006).

Participants pointed out a number of other issues that affect both safety and habitability of buildings following an earthquake. These included the availability of water, power, and other services not controlled by the property owner; the effects of nonstructural damage, including heating systems, and; the effects of damage to masonry chimneys and veneer. These items complicate targeting higher levels of performance.

4.3 Selection of Index Buildings

Using the candidate Index Buildings compiled by DBI staff, four buildings were selected for study. It was decided to use two corner buildings and two mid-block buildings. Variables chosen included the number of stories, the size of the building footprint, and the construction materials. Hillside buildings were not included, because a large number of the buildings are on relatively level sites, and because there were concerns regarding the accuracy of hillside building analysis. Each of the Index Buildings has an open-wall ground floor, accommodating parking and storage areas, while the upper stories have residential units with a significant amount of interior partition wall. The open wall ground floor could, in other cases, be used for commercial space; the use of the ground floor does not have a great impact for the buildings and retrofits chosen. Table 4-1 describes characteristics of the four Index Buildings. Plans and illustrations for the four Index Buildings are provided in Figures 4-1 through 4-12.

Table 4-1 Description of Index Buildings Selected for Study

Building Number	Location in Block	Number of Stories	Plan Area Per Floor (Ft^2)	Number of Units	Interior Wall Finish
1	Corner	3	3610	6	Plaster & wood lath
2	Corner	4	5800	8	Plaster & wood lath
3	Mid-block	4	2270	6	Plaster & wood lath
4	Mid-block	3	1750	4	Gypsum Wallboard

4.4 Retrofit Designs

Three levels of retrofit design were selected as being reasonable to pursue and were applied to all four Index Buildings. The SPUR levels were used as a target for performance. It must be kept in mind, however, that using a performance description for a target does not translate into certainty that the performance description will be met for individual buildings. Significant variations in building configuration, building construction, and earthquake ground motion will yield a range of performance for buildings with the same target performance.

Retrofit 1 targeted SPUR Level D as the intended performance. This was approached by identifying and retrofitting the specific exterior wall lines that were clearly vulnerable. This approach assumed that by addressing the obvious vulnerability, the performance of the building would increase to match the performance of similar buildings without the obvious vulnerability. Typical retrofit measures included steel moment frames and oriented strand board (OSB) shear walls being added in the

ground story. Locations of and reasons for vertical retrofit elements are shown in Table 4-2.

Table 4-2 Retrofit 1 Elements

Building	Element	Location	Reason
1	Steel moment frames	Street front	Obvious lack of bracing wall length
	OSB shear walls	Transverse end walls	Obvious lack of bracing wall length, vulnerability observed in CUREE-Caltech Wood-Frame Project testing
2	Steel moment frames	Street front	Obvious lack of bracing wall length
	OSB shear walls	Street front	Obvious lack of bracing wall length
3	OSB shear walls	Transverse direction	Obvious lack of transverse bracing
4	OSB shear walls	Rear transverse wall and longitudinal walls	Lack of transverse bracing was addressed by sheathing existing walls. This requires a significantly lower level of effort than adding new steel elements for this building type.

Retrofit 2 targeted SPUR Level C as the intended performance. This was approached by providing retrofits of all of the vertical resisting elements in the entire ground story. Retrofit 2, like Retrofit 1, typically involved use of steel moment frames and OSB shear walls. A greater extent of OSB shear wall was provided in Retrofit 2 than in Retrofit 1.

Retrofit 3 targeted performance in the range between SPUR Levels B and C. This was approached by replacing the steel moment frames with steel cantilevered columns, while maintaining the seismic force level used for proportioning the system. Because the cantilevered columns are designed using an R factor of 2.5 rather than the moment frame R of 8, their use led to lower deflections, which should translate to a lower cost of repair.

In proportioning the retrofit systems, the seismic demand used an S_{DS} of 1.17. This is based on a mapped S_1 value that falls near the center of San Francisco and a default site class D. Vertical elements for all three retrofit levels were proportioned using 75% of the equivalent lateral seismic force required by the *San Francisco Building Code* (SFBC) (City and County of San Francisco, 2007). In addition, vertical elements were checked against SFBC drift requirements. The seismic design coefficients for the systems used are shown in Table 4-3. A triangular vertical distribution was used, consistent with new building design.

The design of the retrofits was carried out on a line by line basis, in the spirit of ASCE 7 (ASCE, 2005) Section 12.2.3.2, which allows the R factor to vary by line but is limited to buildings of two stories or less. This approach is of great benefit in retrofits that incorporate vertical elements with varying R factors.

Retrofit plans for the three levels and four buildings are provided in Figures 4-13 through 4-23.

Table 4-3 Seismic Design Coefficients for Vertical Elements Used in Retrofit Designs

Vertical Element Type	R factor	C_d factor	Allowable Drift
OSB Shear Wall	6.5	4	.02h
Special Steel Moment Frame	8	5.5	.02h
Special Cantilevered Column	2.5	2.5	.02h

4.5 Development of Capacity Parameters

For each of the Index Buildings, a series of capacity curves were developed to describe the building load-deflection behavior. From these curves, yield and peak capacity forces and displacements were identified and converted to spectral accelerations and displacements.

For development of the capacity curves, load deflection behavior from a variety of sources was viewed. These sources included:

Plaster over wood lath:

- Forest Products Laboratory (1956), Test 11
- Ben Schmid (Schmid, 1984)
- ASCE 41 (ASCE, 2006)

Straight horizontal sheathing:

- Forest Products Laboratory (1956), Test 4
- AF&PA Special Design Provisions for Wind and Seismic (SPDWS) (AF&PA, 2005),
- ASCE 41 (ASCE, 2006)

Gypsum wallboard:

- ASCE 41 (ASCE, 2006)

OSB shear walls:

- AF&PA SDPWS (AF&PA, 2005)

Using these references, capacities and deflections were identified for a typical one story wall at yield and peak capacity. For the most part, best estimate values from available information were used. In the case of gypsum wallboard, used exclusively in the upper stories of Index Building 4, four sources of existing data provided two low capacities and two high capacities; the low values were chosen, since they could confidently be met or exceeded. Use of the high values would have made Building 4 performance similar to Buildings 1 and 2. The values used are shown in Table 4. These values assume the sheathing material being applied to one face of the wall and are adjusted where sheathing is applied to both faces. It should be noted that testing of wood shear wall systems generally does not reveal a clearly discernable yield point, where stiffness changes significantly but rather, shows loss of stiffness starting

at very low load levels. For this reason, a yield point is considered to be artificial in wood frame systems. However, because definition of a yield was required for loss estimation analysis, yield was identified consistent with ASCE 41 default assumptions.

Table 4-4 Shear Wall Capacities and Deflections at Yield and Peak Loads

Sheathing Material	Yield Capacity	Deflection at Yield	Peak Capacity	Deflection at Peak
Plaster over Wood Lath	350 plf	0.5"	400 plf	0.7"
Straight Horizontal Sheathing	160 plf	0.8"	200 plf	3.0"
Gypsum Wallboard	67 plf	0.1"	100 plf	0.5"
OSB Sheathing	67% peak capacity per ASCE 41	Per SDPWS deflection equation	Per SDPWS tabulated nominal capacity	Per SDPWS deflection equation

For steel moment frames and steel cantilevered columns, yield force and deflection were calculated based on initial member yield. Peak capacity was calculated assuming that a full plastic hinge had developed and including a multiplier of 1.1, to account for strain hardening effects. Deflection at peak capacity was calculated using ASCE 41 tabulated multipliers between yield and peak capacity displacements.

These material values were used as bi-linear load deflection curves, and the yield and peak capacities for each story and building were developed from these curves. For vertical distribution of seismic demands, a triangular seismic force distribution was used. Building deflections were calculated for the longitudinal and transverse directions at the center of the floor considering combined materials and, where applicable, increased in deflection due to diaphragm rotation. Resulting bi-linear capacity curves are provided in Figures 4-24 through 4-27.

4.6 Comments on Building Behavior

As part of the calculation of the push over curves, it was possible to compare the seismic capacities of the ground floor to upper floors. From this, some observations can be drawn regarding the need to retrofit upper stories of open-wall buildings. Upper story yield and peak capacities used in developing the capacity curves were dependant exclusively on the interior finish material: plaster over wood lath for Buildings 1, 2 and 3, and gypsum wallboard for Building 4. The contribution of other materials was minimal, due to high flexibility and low capacity. Using this approach, up to peak capacity of the ground floor retrofit, the upper stories of Buildings 1 and 2 remained at or below yield capacity for the plaster. This suggested that, given the construction materials and the retrofit approaches used in this study, it is very reasonable to limit the retrofit work to the ground story, without concern that damage causing life-safety concerns will occur at upper floors. For Building 3 in the transverse direction and Building 4, upper story capacities did control the building peak capacity for some of the retrofits. Although this suggests that damage might

occur in upper stories, the history of performance of residential light-frame construction suggests that this is not as big a concern as the analysis suggested.

Building 1 displayed significant torsional response under longitudinal loading, in both the original building configuration and Retrofit 1. In the original building configuration, the center of rigidity was at the rear longitudinal wall, while in Retrofit 1, the center of rigidity moved very close to the street front at the added moment frames. The effect of the torsion is to put very high demands on the end transverse walls. For a ground motion at an angle to the primary axes, the combination of direct and torsional load on these walls is significant and of concern. Significant damage to end transverse walls was identified in CUREE-Caltech Project testing of an open wall building on the Berkeley shake table (Mosalam et al., 2002). The particular vulnerability of this geometry of building should be taken into consideration. This behavior was not an issue on Building 2, due to the contribution of interior walls.

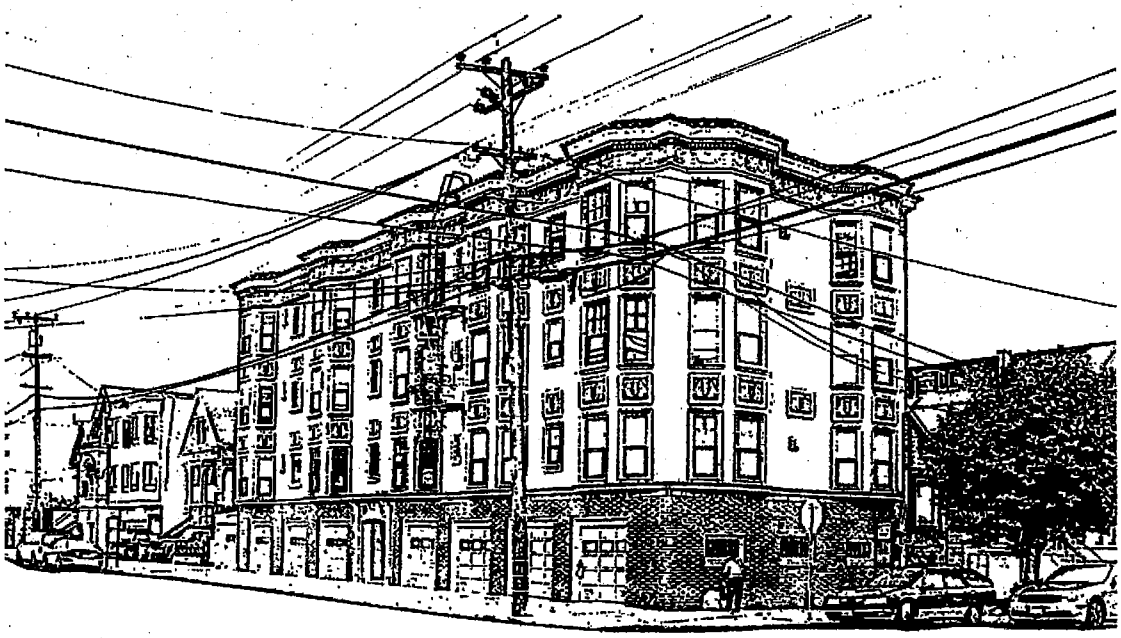


Figure 4-1 Index Building 1 elevation.

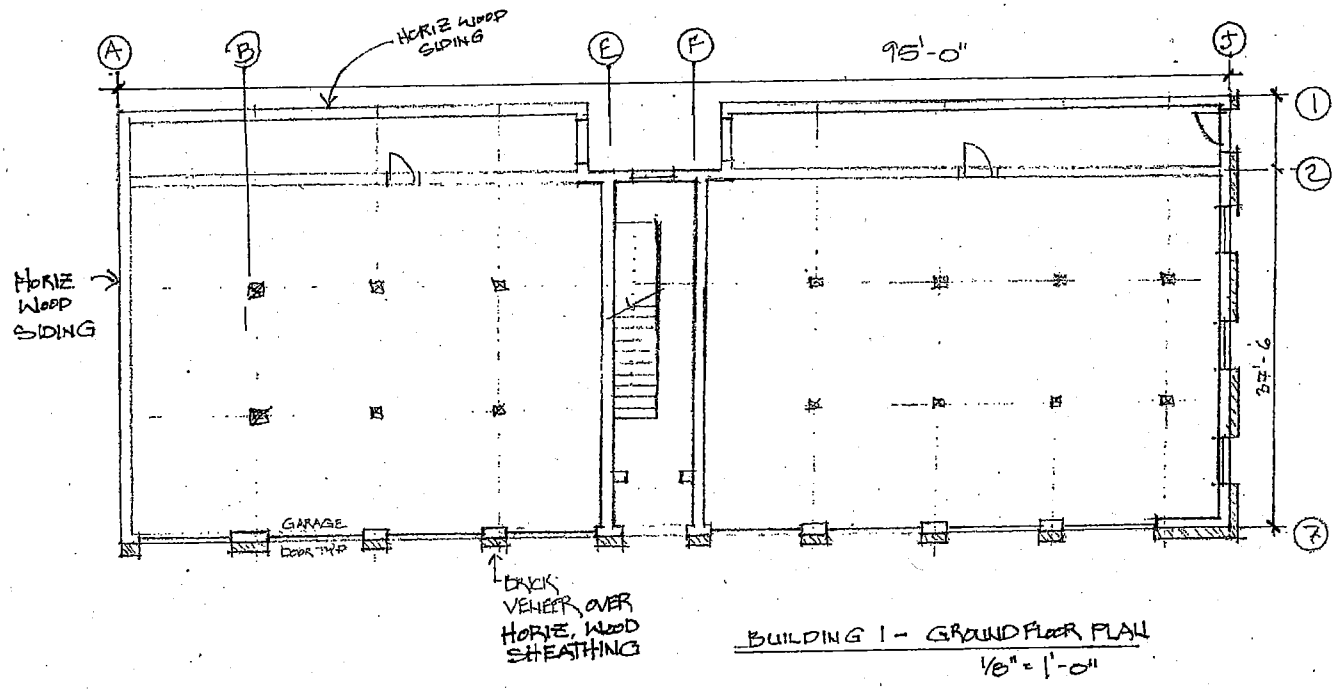


Figure 4-2 *Index Building 1 ground floor plan.*

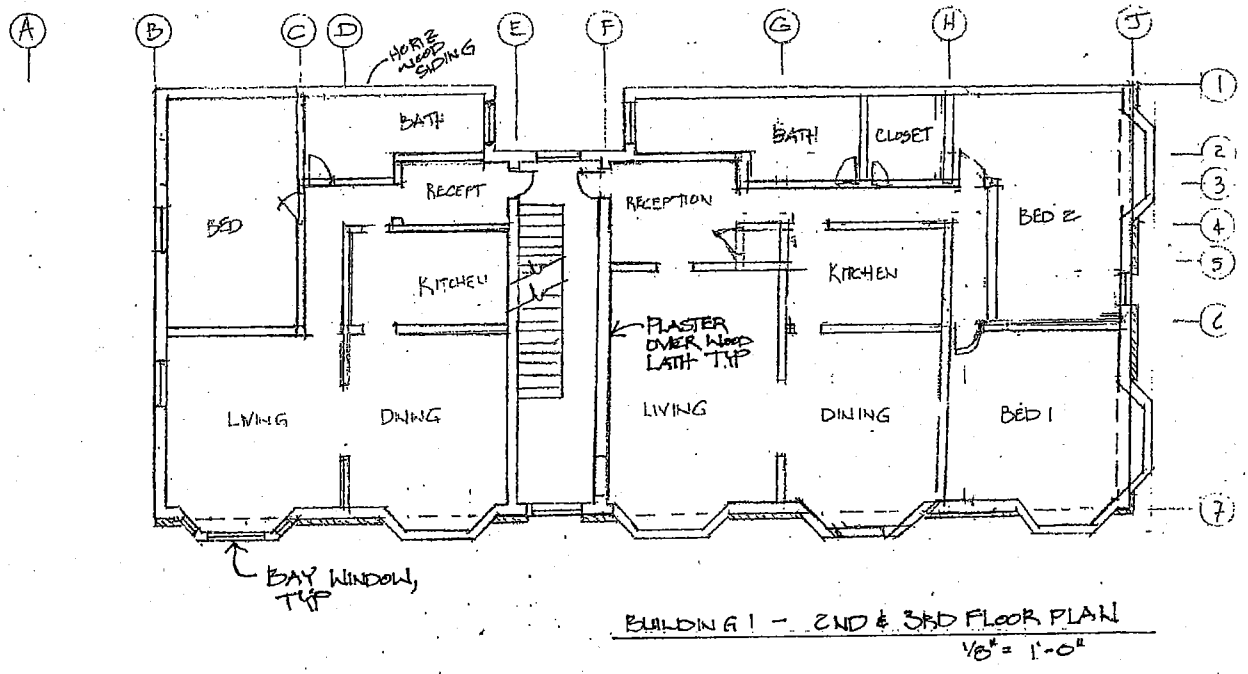


Figure 4-3 *Index Building 1 second and third floor plan.*



Figure 4-4 Index Building 2 elevation.

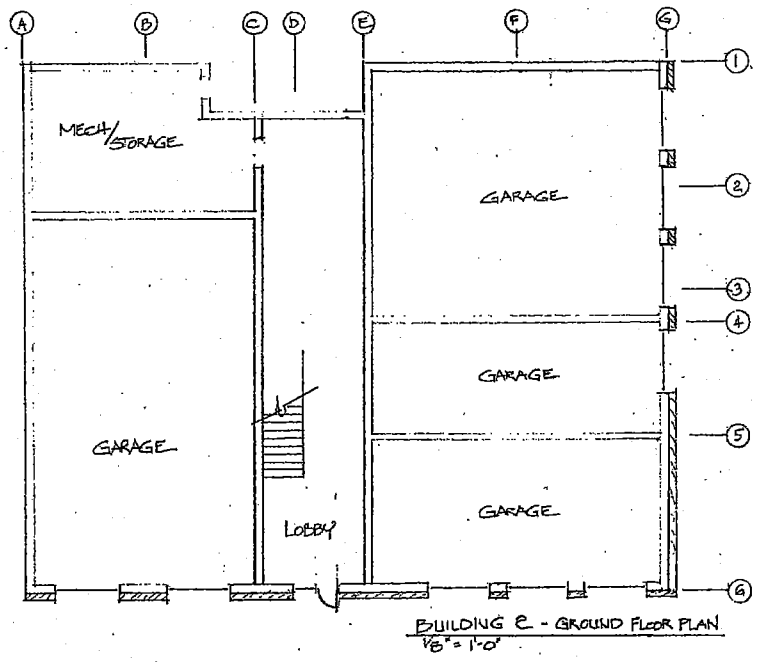


Figure 4-5 Index Building 2 ground floor plan.

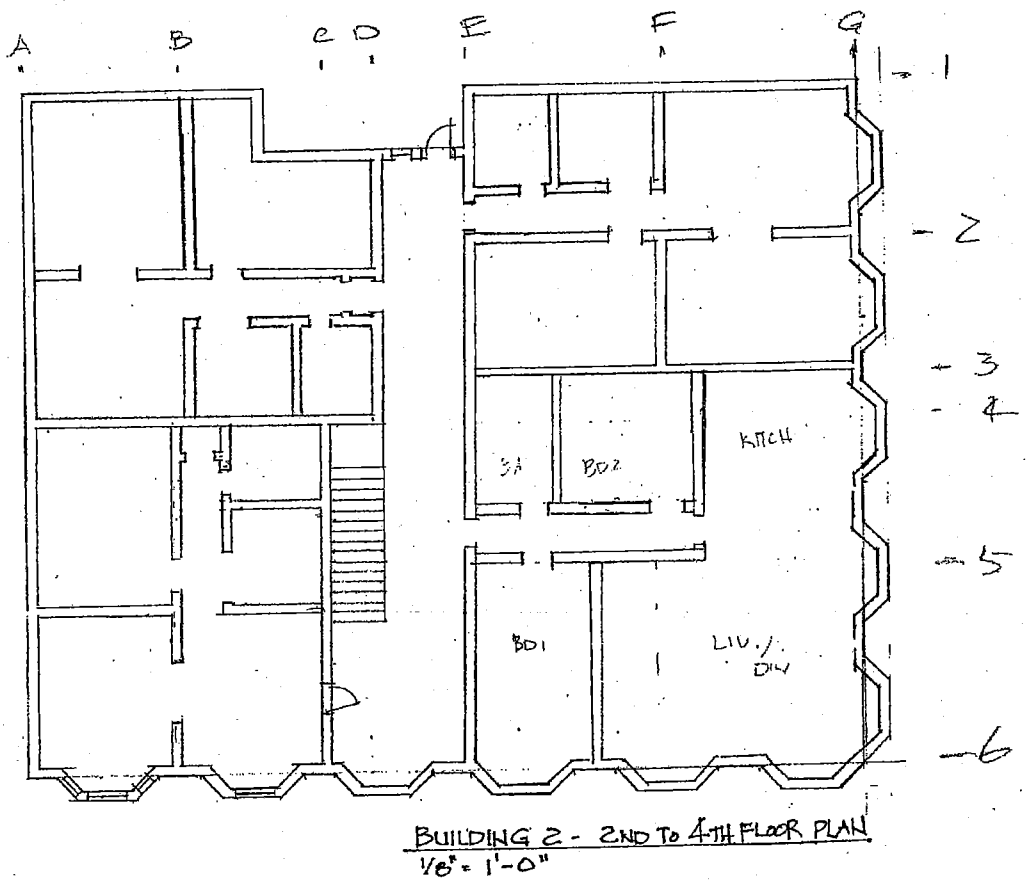


Figure Index 4-6 *Building 2 second to fourth floor plan.*

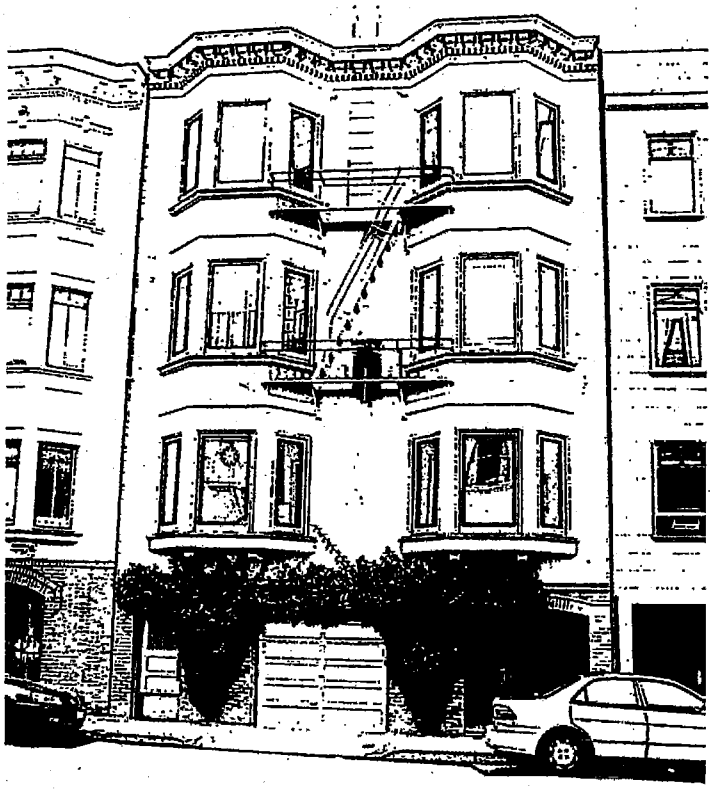


Figure 4-7 Index Building 3 elevation.

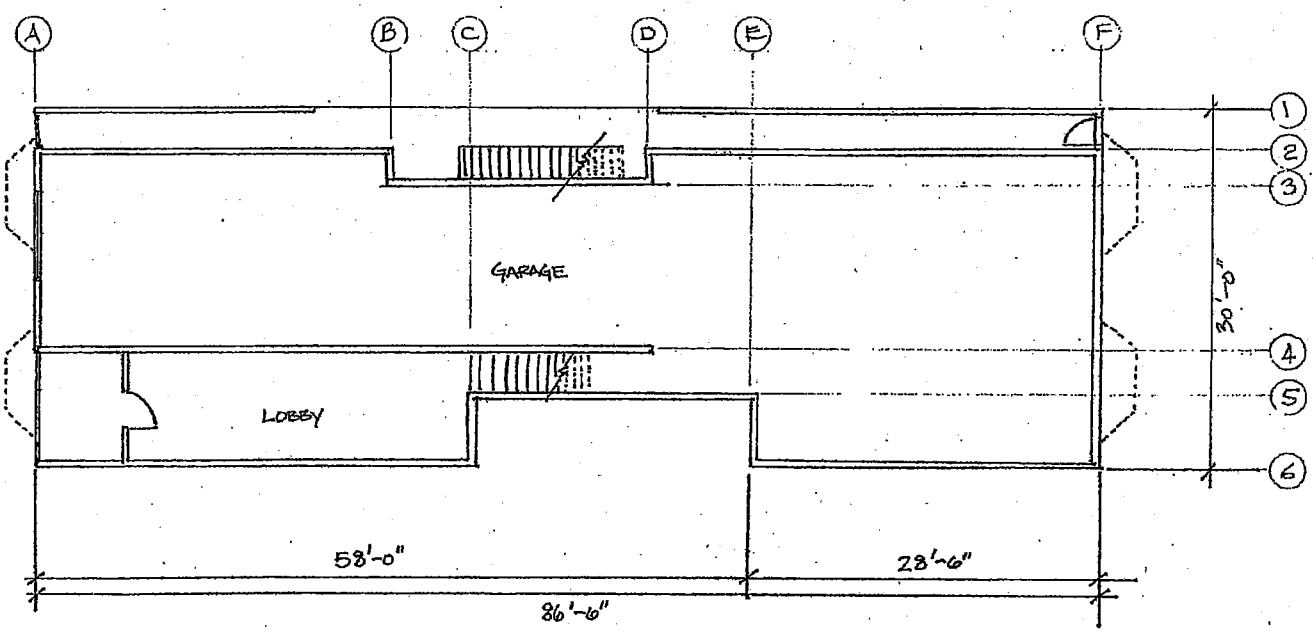


Figure 4-8 Index Building 3 ground floor plan.

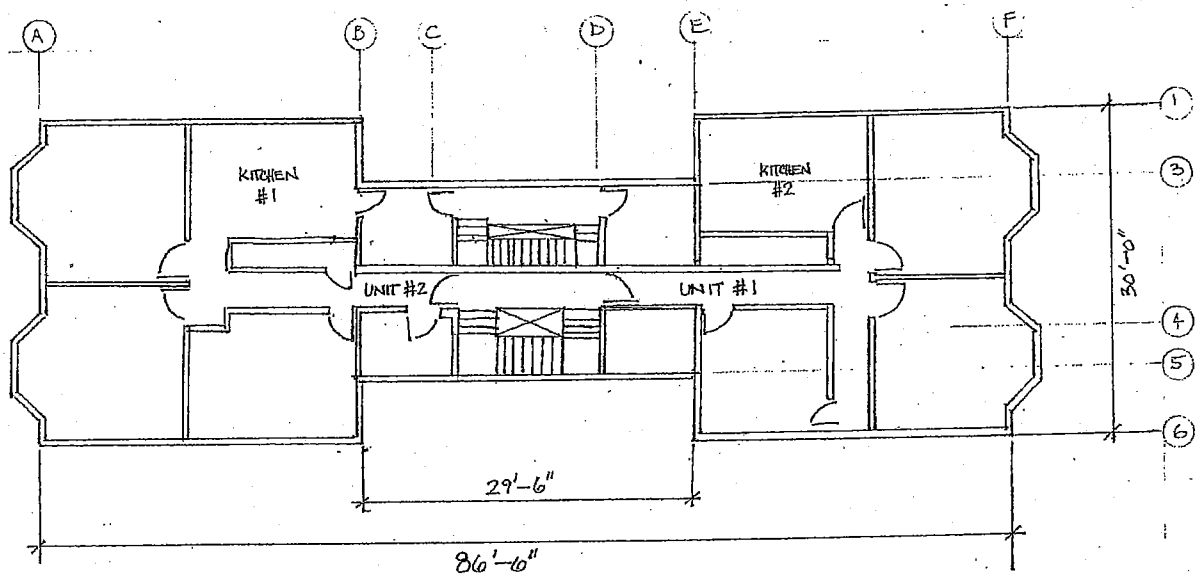


Figure 4-9 Index Building 3 second to fourth floor plan.

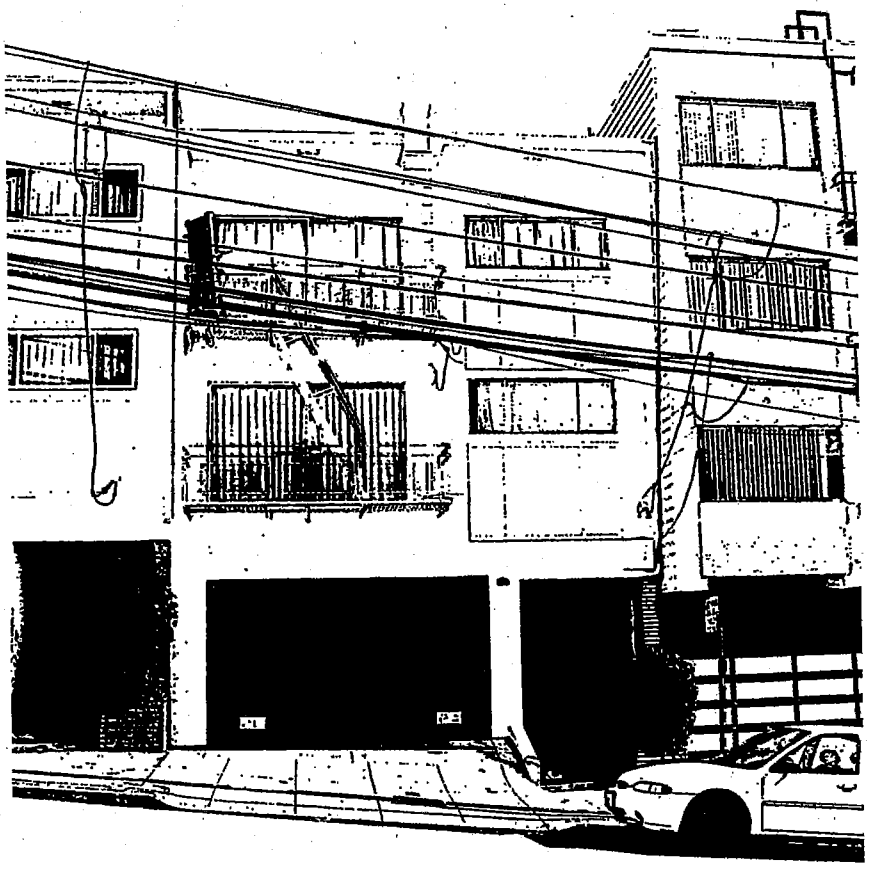


Figure 4-10 Index Building 4 elevation.

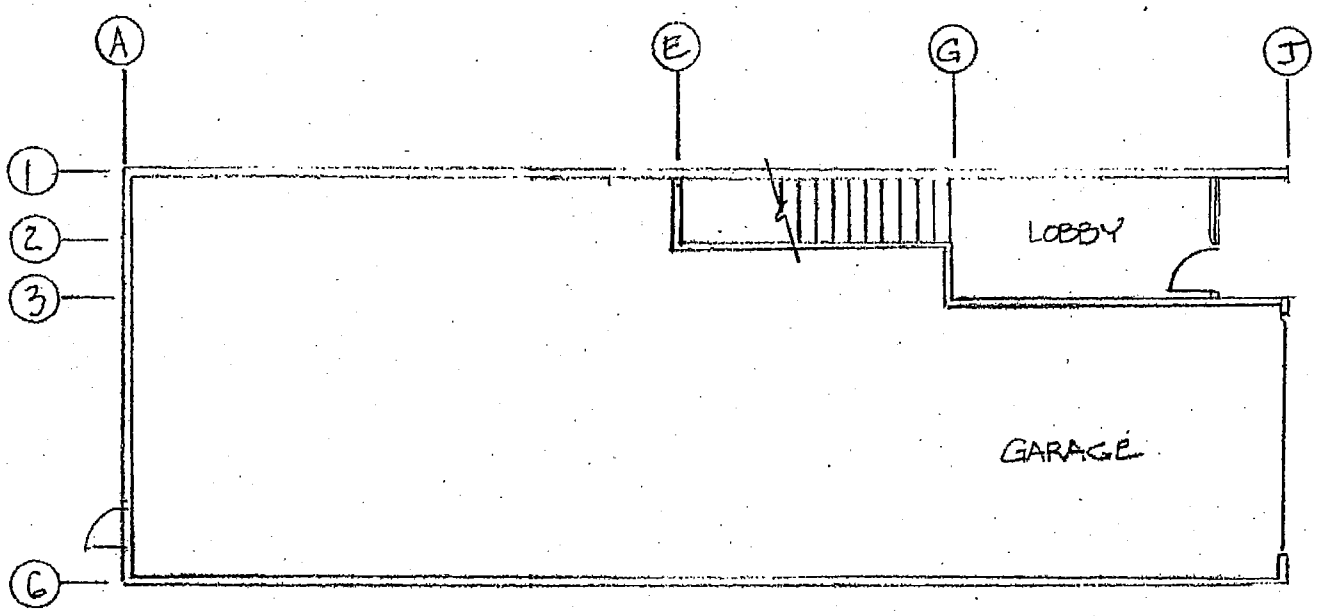


Figure 4-11 Index Building 4 ground floor plan.

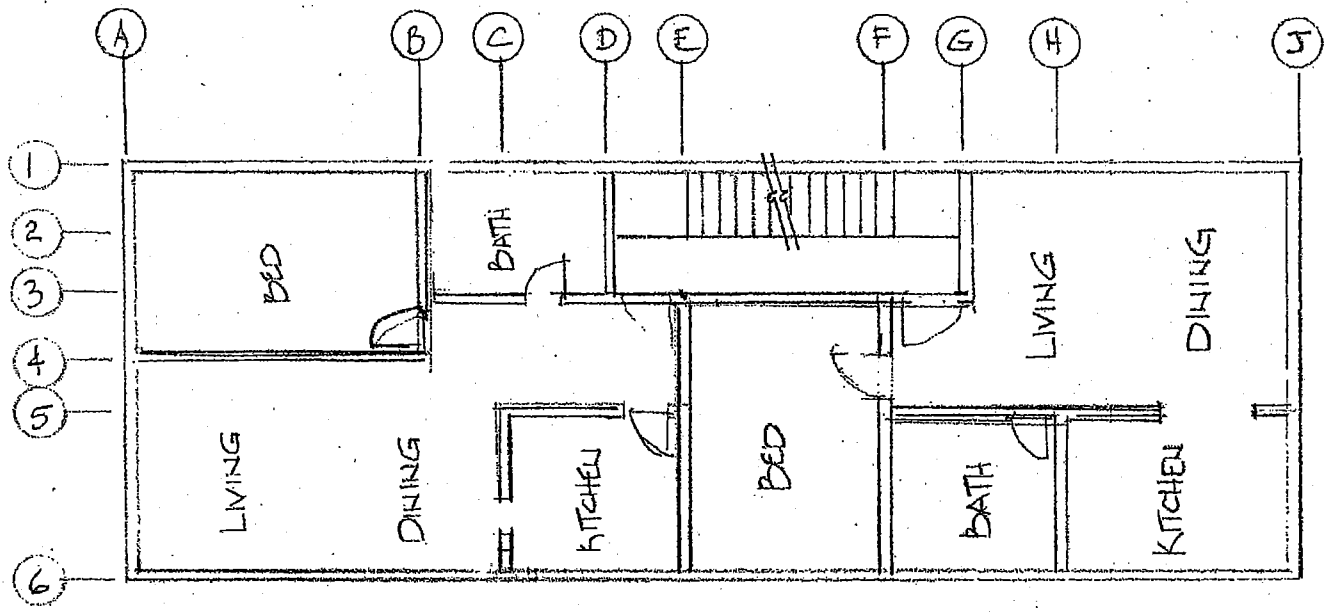


Figure 4-12 Index Building 4 second to fourth floor plan.

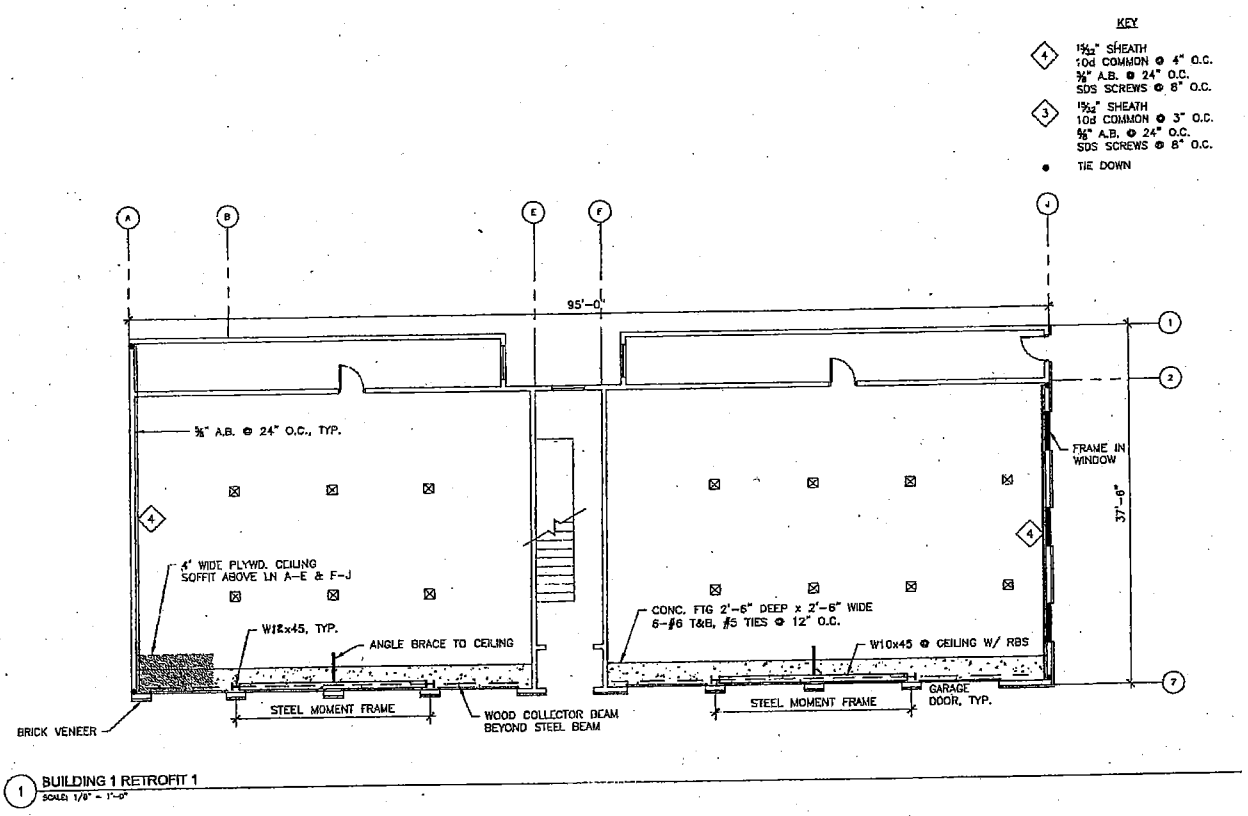


Figure 4-13 Conceptual Retrofit 1, Index Building 1.

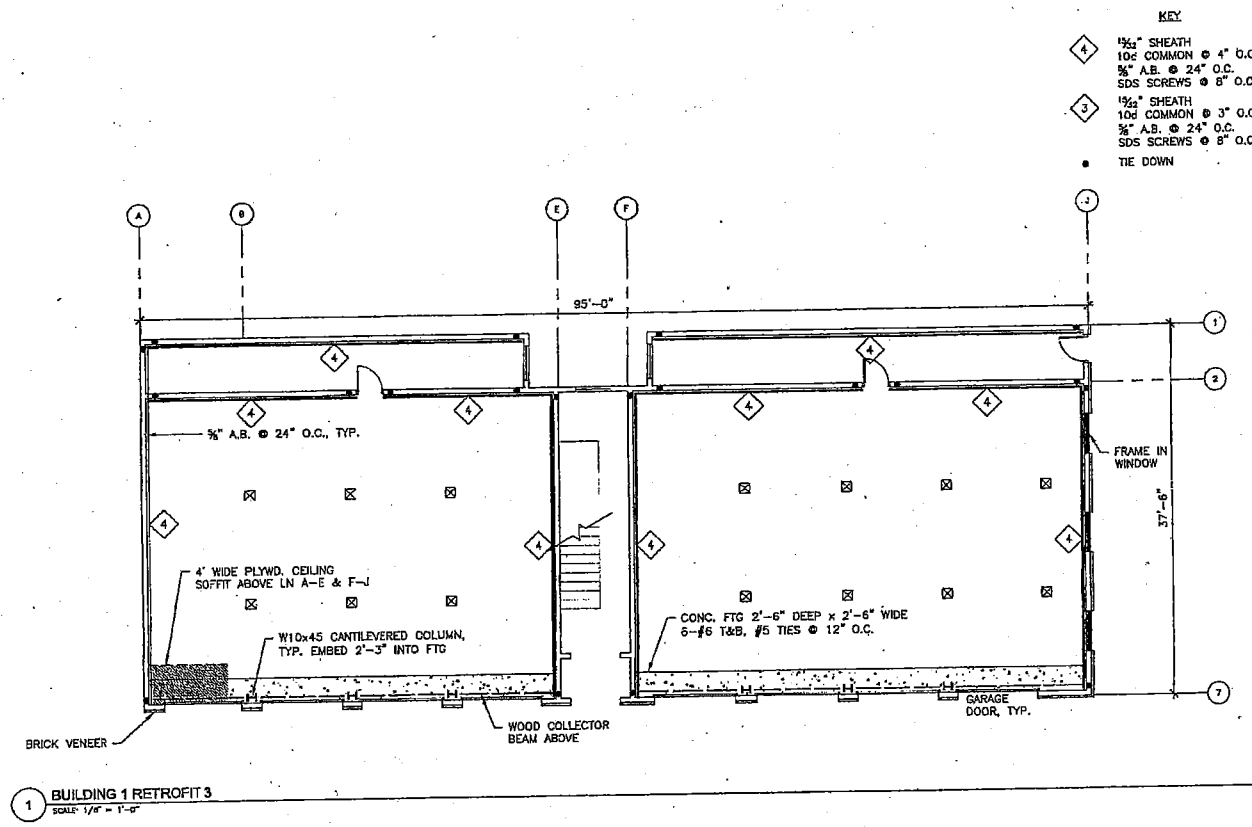


Figure 4-14 Conceptual Retrofit 3, Index Building 1.

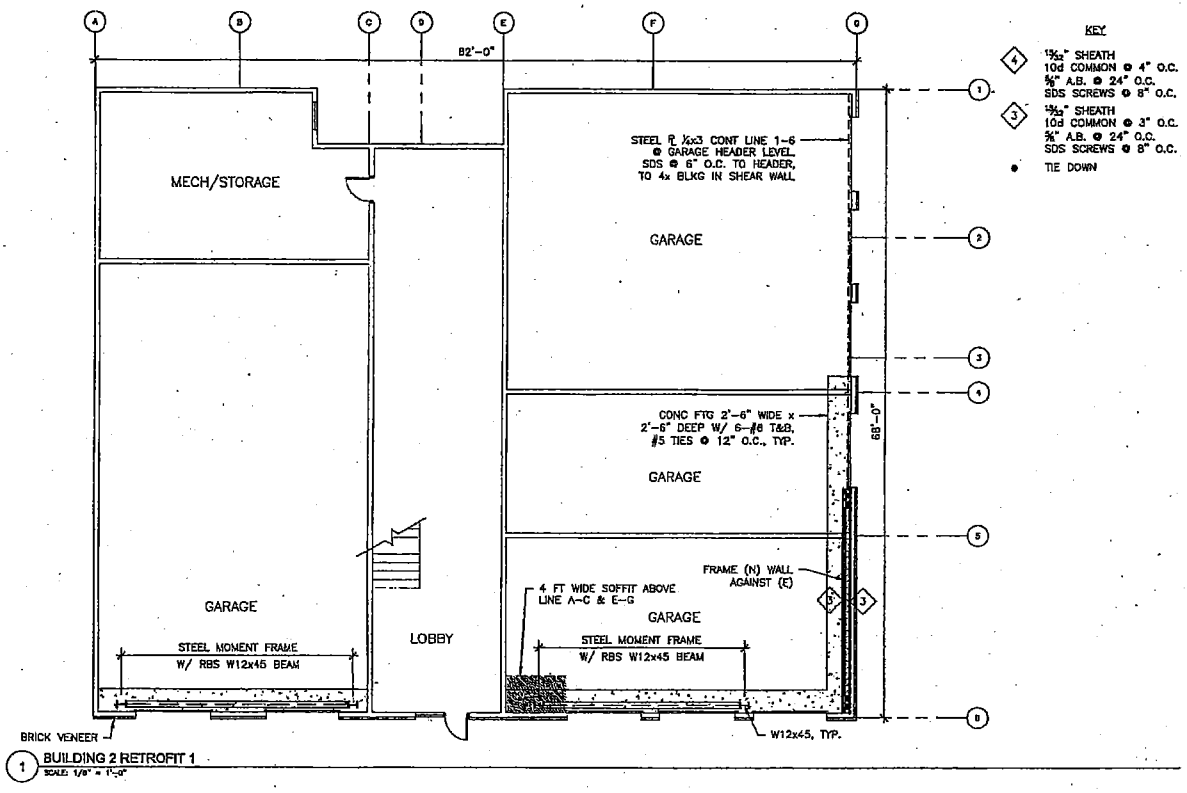


Figure 4-15 Conceptual Retrofit 1, Index Building 2.

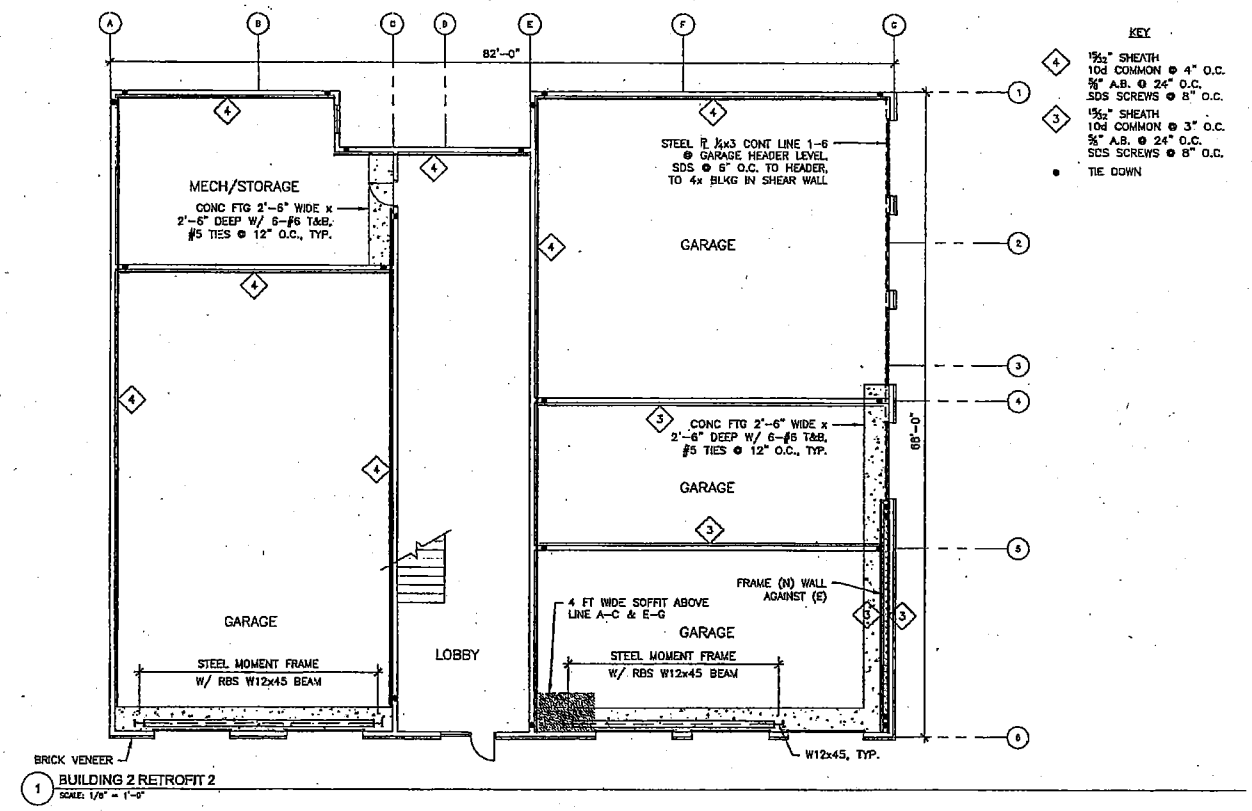


Figure 4-16 Conceptual Retrofit 2, Index Building 2.

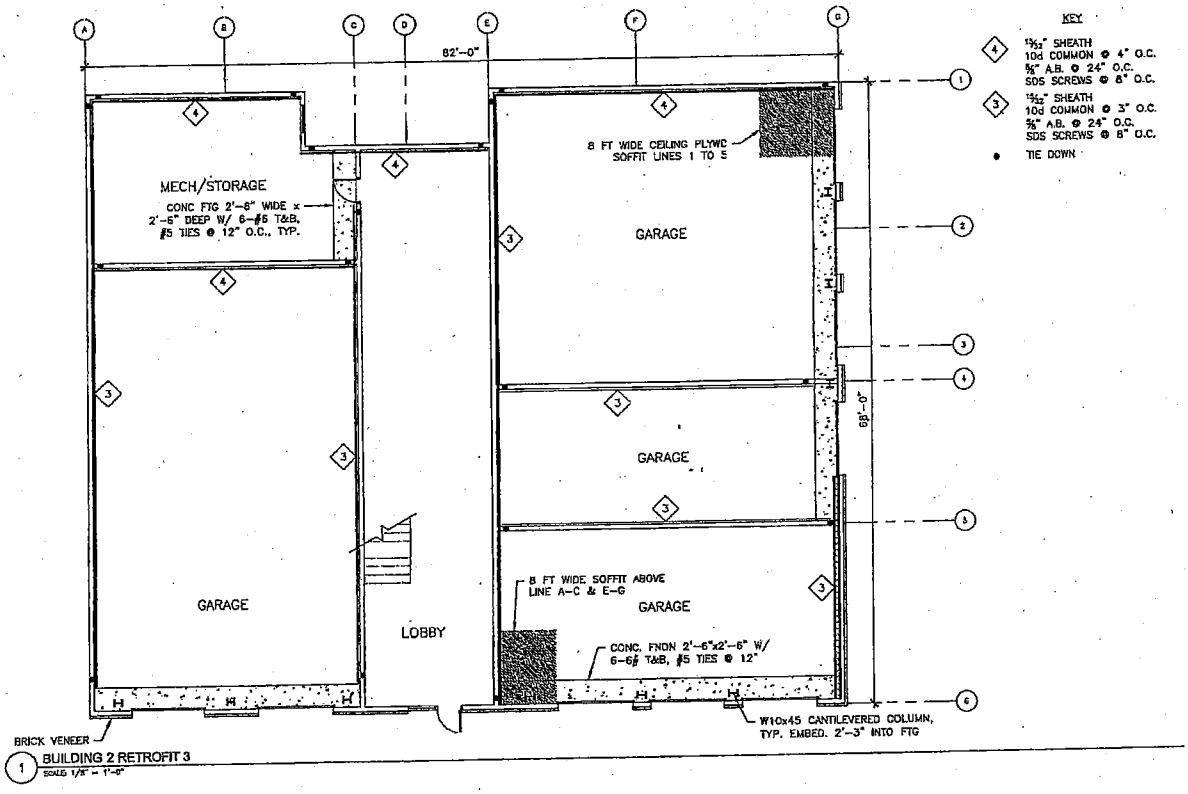


Figure 4-17 Conceptual Retrofit 3, Index Building 2.

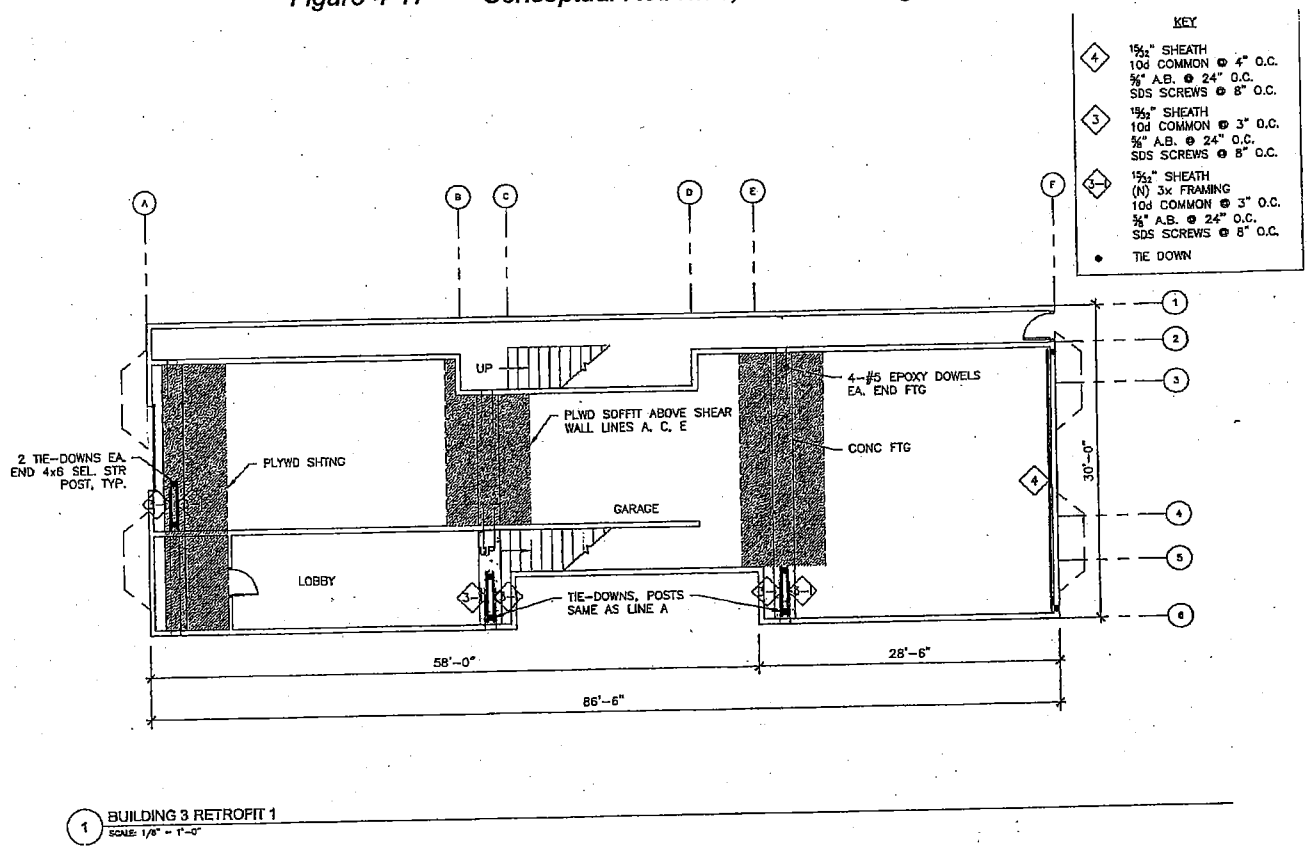
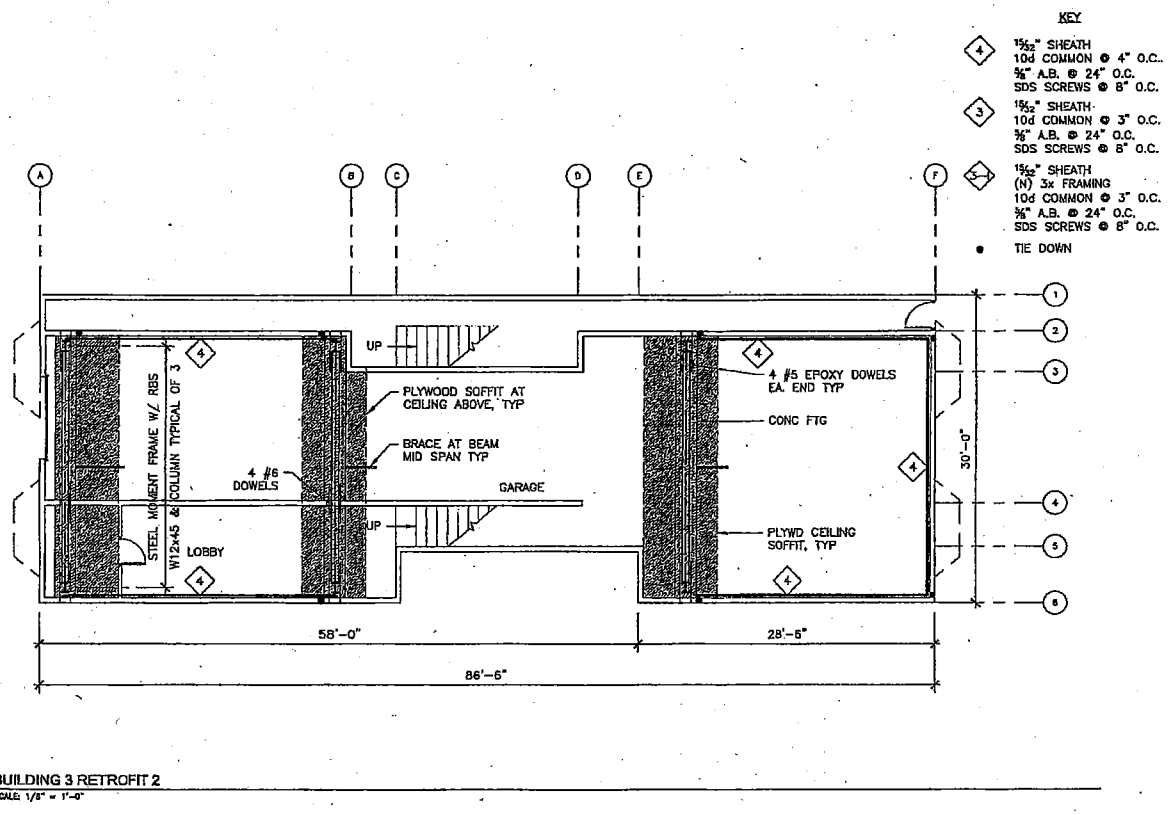
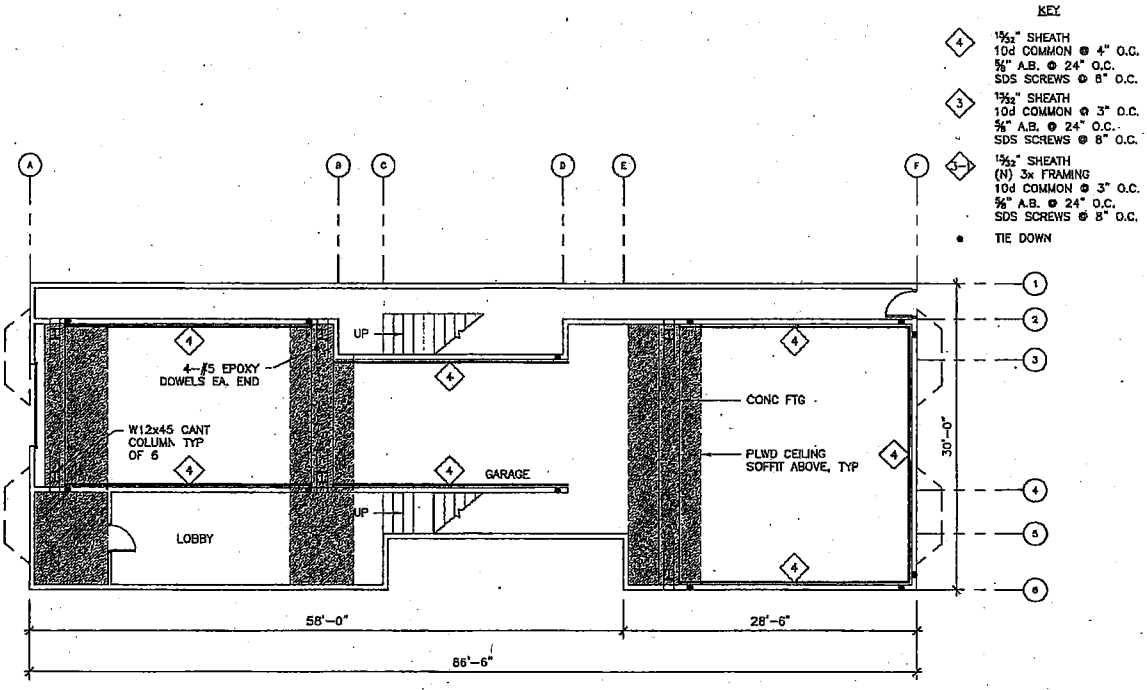


Figure 4-18 Conceptual Retrofit 1, Index Building 3.



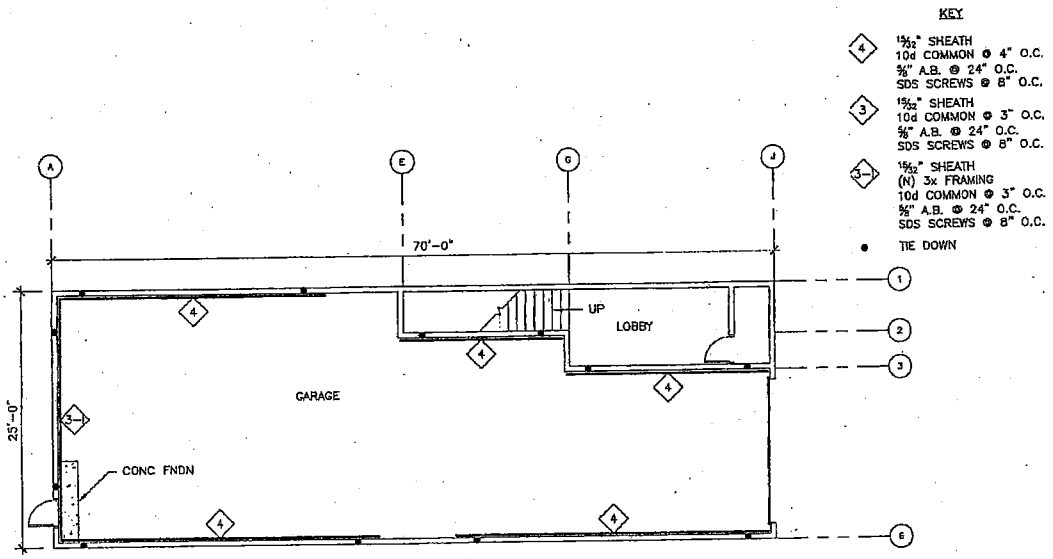
1 BUILDING 3 RETROFIT 2
SCALE: 1/8" = 1'-0"

Figure 4-19 Conceptual Retrofit 2, Index Building 3.



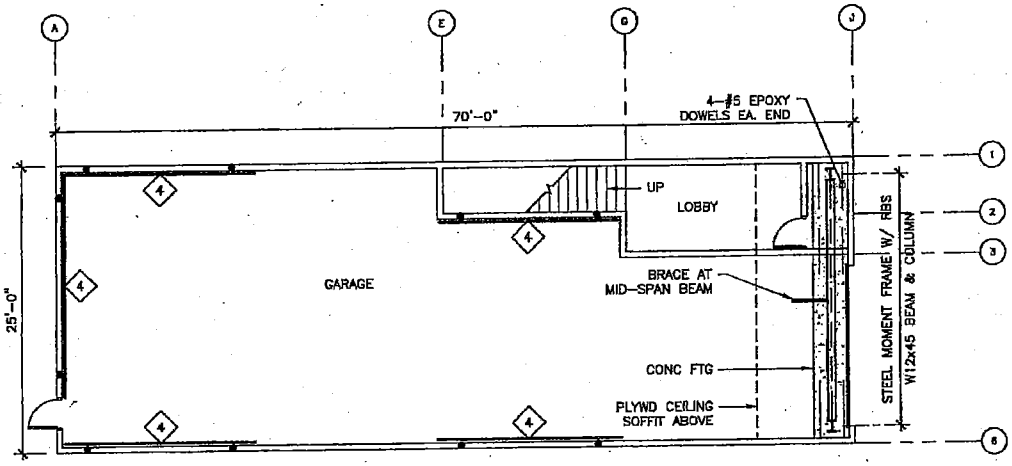
1 BUILDING 3 RETROFIT 3
SCALE: 1/8" = 1'-0"

Figure 4-20 Conceptual Retrofit 3, Index Building 3.



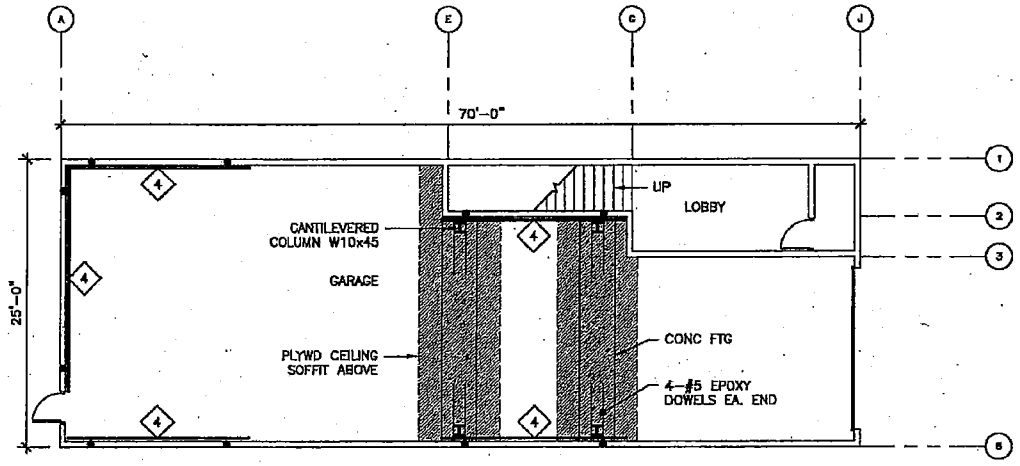
1 BUILDING 4 RETROFIT 1
SCALE: 1/8" = 1'-0"

Figure 4-21 Conceptual Retrofit 1, Index Building 4.



1 BUILDING 4 RETROFIT 2
SCALE: 1/8" = 1'-0"

Figure 4-22 Conceptual Retrofit 2, Index Building 4.



1 BUILDING 4 RETROFIT 3
SCALE: 1/8" = 1'-0"

Figure 4-23 Conceptual Retrofit 3, Index Building 4.

Building 1

$$S_a = \frac{F}{\alpha W} \qquad S_d = \frac{\Delta}{PF_N}$$

Weight of Building k 425

PF_N	0.8
α	1.3

Direction	Scheme		Force k	Displ in	Spectral Accel (S_a) g	Spectral Displ (S_d) in
Transverse Direction	No Retrofit				0	0
		Yield	26.5	0.63	0.078	0.48
		Ultimate	37.7	0.88	0.111	0.68
	Retrofit 1				0	0
		Yield	See No Retrofit			0.00
		Ultimate			0.000	0.00
	Retrofit 2				0	0
		Yield	77	0.65	0.226	0.50
		Ultimate	116	1.17	0.341	0.90
	Retrofit 3				0	0
		Yield	See Retrofit 2			0.00
		Ultimate			0.000	0.00
Longitudinal Direction	No Retrofit		0	0	0	0
		Yield	15.2	0.88	0.045	0.68
		Ultimate	19	1.1	0.056	0.85
	Retrofit 1				0	0
		Yield	31	1.3	0.091	1.00
		Ultimate	54	3.8	0.159	2.92
	Retrofit 2				0	0
		Yield	81	0.3	0.238	0.23
		Ultimate	135	1.3	0.397	1.00
	Retrofit 3				0	0
		Yield	119	0.8	0.350	0.62
		Ultimate	147	1.7	0.432	1.31

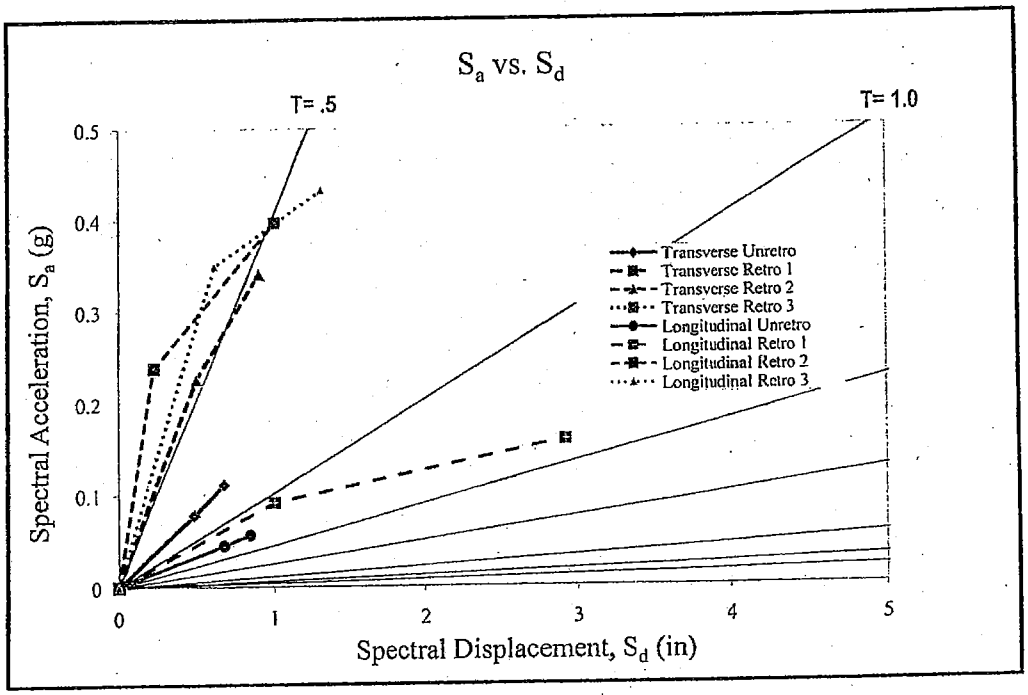


Figure 4-24 Index Building 1 capacity curves.

Building 2 .

$$S_a = \frac{F}{\alpha W} \qquad S_d = \frac{\Delta}{PF_x}$$

	Weight of Building	k	865		PF_N	0.8
					α	1.3

Direction	Scheme		Force k	Displ in	Spectral Accel (S_a) g	Spectral Displ (S_d) in
Transverse Direction	No Retrofit				0	0
		Yield	41	0.66	0.059	0.51
		Ultimate	47	0.92	0.068	0.71
	Retrofit 1				0	0
		Yield	71	0.82	0.103	0.63
		Ultimate	81	1.07	0.117	0.82
	Retrofit 2				0	0
		Yield	143	0.96	0.207	0.74
		Ultimate	223	2.17	0.322	1.67
	Retrofit 3				0	0
		Yield	146	1.18	0.211	0.91
		Ultimate	307	3.4	0.444	2.62
Longitudinal Direction	No Retrofit				0	0
		Yield	32	0.67	0.046	0.52
		Ultimate	37	0.92	0.053	0.71
	Retrofit 1				0	0
		Yield	80	0.96	0.116	0.74
		Ultimate	100	1.67	0.145	1.28
	Retrofit 2				0	0
		Yield	136	1.24	0.197	0.95
		Ultimate	209	3.4	0.302	2.62
	Retrofit 3				0	0
		Yield	167	1.41	0.241	1.08
		Ultimate	209	3.4	0.302	2.62

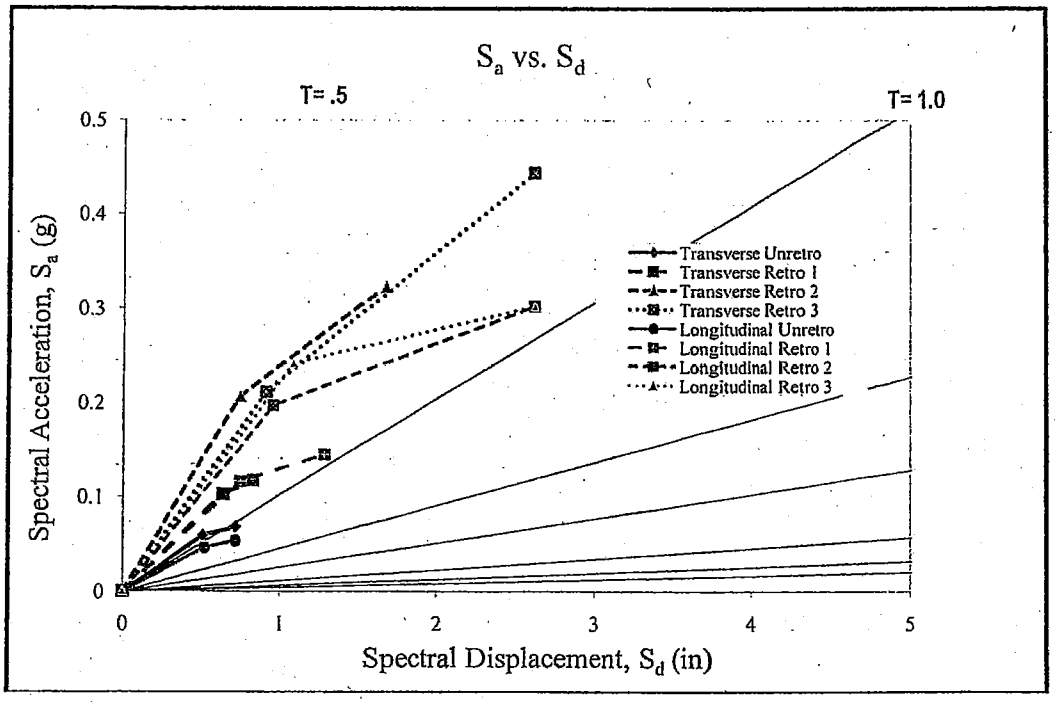


Figure 4-25 Index Building 2 capacity curves.

Building 3

$S_a = \frac{F}{\alpha W}$ $S_d = \frac{\Delta}{PF_x}$

Weight of Building k 412

PF_N	0.8
α	1.3

Direction	Scheme		Force k	Displ in	Spectral Accel (S_a) g	Spectral Displ (S_d) in
Transverse Direction	No Retrofit				0	0
		Yield	4	0.9	0.012	0.69
		Ultimate	5	3.1	0.015	2.38
	Retrofit 1				0	0
		Yield	43	1.4	0.130	1.08
		Ultimate	63	3.8	0.191	2.92
	Retrofit 2				0	0
		Yield	78	2	0.237	1.54
		Ultimate	89	2.4	0.270	1.85
	Retrofit 3				0	0
		Yield	78	1.5	0.237	1.15
		Ultimate	89	2.3	0.270	1.77
Longitudinal Direction	No Retrofit				0	0
		Yield	41	0.8	0.124	0.62
		Ultimate	56	1.1	0.170	0.85
	Retrofit 1				0	0
		Yield	41	0.8	0.124	0.62
		Ultimate	56	1.1	0.170	0.85
	Retrofit 2				0	0
		Yield	49	0.6	0.149	0.46
		Ultimate	74	1.8	0.225	1.38
	Retrofit 3				0	0
		Yield	74	0.8	0.225	0.62
		Ultimate	111	2.1	0.337	1.62

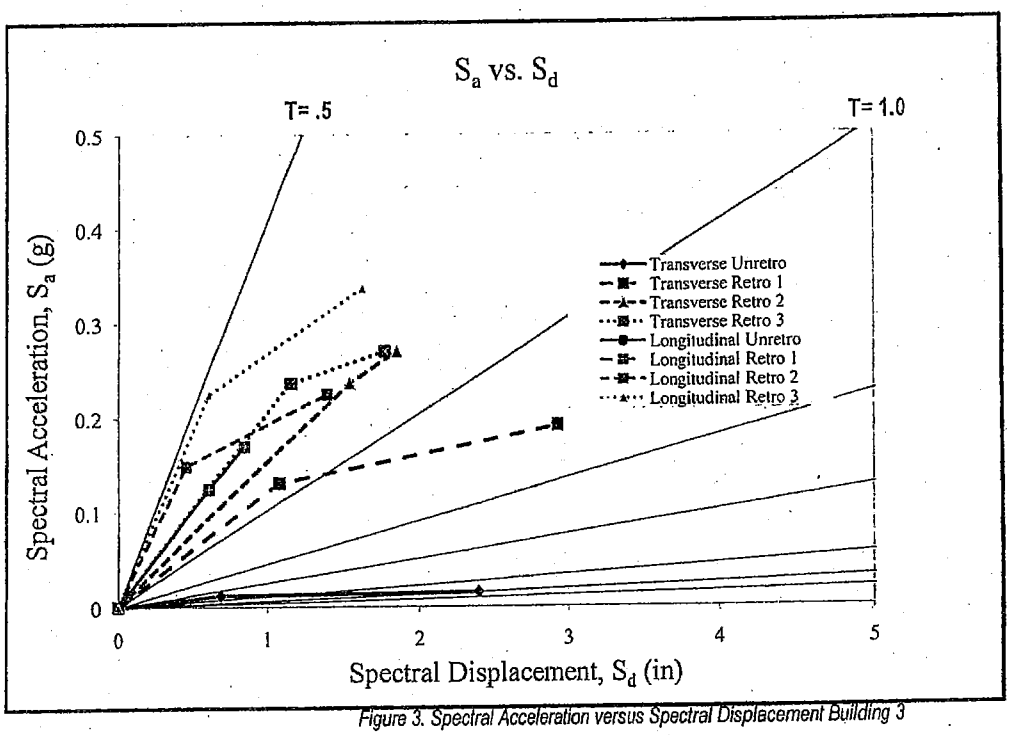


Figure 3. Spectral Acceleration versus Spectral Displacement Building 3

Figure 4-26 Index Building 3 capacity curves.

Building 4

$$S_a = \frac{F}{\alpha W} \qquad S_d = \frac{\Delta}{PF_N}$$

Weight of Building	k	155	PF_N	0.8
			α	1.3

Direction	Scheme		Force k	Displ in	Spectral Accel (S_a) g	Spectral Displ (S_d) in
Transverse Direction	No Retrofit				0	0
		Yield	1	0.1	0.008	0.08
		Ultimate	4	2	0.032	1.54
	Retrofit 1				0	0
		Yield	9	0.7	0.073	0.54
		Ultimate	15	1.4	0.121	1.08
	Retrofit 2				0	0
		Yield	9	0.3	0.073	0.23
		Ultimate	15	0.9	0.121	0.69
	Retrofit 3				0	0
		Yield	9	0.3	0.073	0.23
		Ultimate	15	0.9	0.121	0.69
Longitudinal Direction	No Retrofit				0	0
		Yield	6	0.2	0.048	0.15
		Ultimate	14	0.6	0.113	0.46
	Retrofit 1				0	0
		Yield	19	0.2	0.153	0.15
		Ultimate	29	0.7	0.234	0.54
	Retrofit 2				0	0
		Yield	19	0.3	0.153	0.23
		Ultimate	29	0.8	0.234	0.62
	Retrofit 3				0	0
		Yield	19	0.3	0.153	0.23
		Ultimate	29	0.8	0.234	0.62

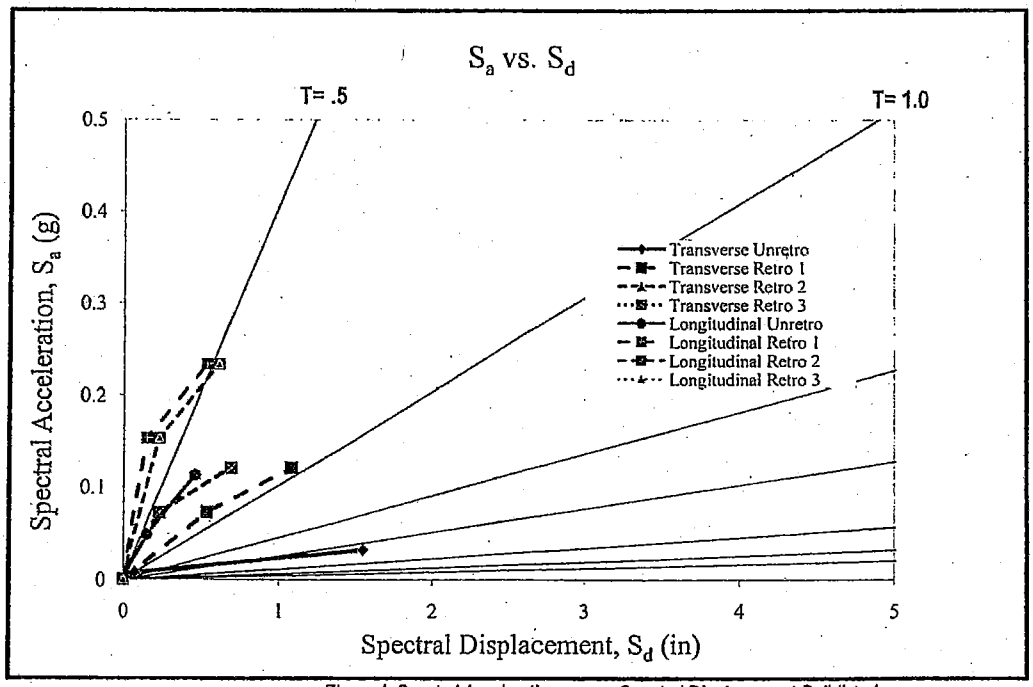
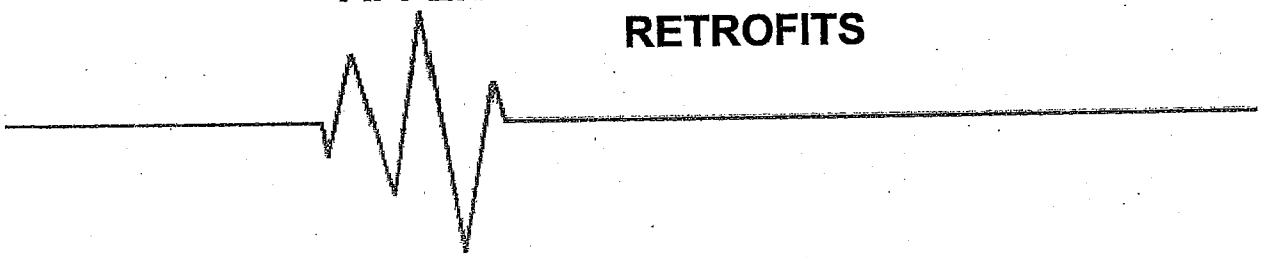


Figure 4. Spectral Acceleration versus Spectral Displacement Building 4

Figure 4-27 Index Building 4 capacity curves.

APPENDIX 5: COST ESTIMATES FOR RETROFITS



This section presents detailed construction cost estimates for retrofitting the four prototype buildings described in Appendix 4. Cost estimates are presented in Tables 5-1 through 5-16 for each of the three retrofit schemes developed for each prototype (index) building. These costs were estimated in November 2008.

These are complete cost estimates for direct construction costs only. They include labor, materials, equipment, permit fees, a contingency fee, and an overhead and profit fee. They do not include the following costs:

- complex finish work;
- engineering or architectural design fees;
- any triggered code upgrades;
- ADA upgrades for commercial properties; or
- relocation of conflicting utilities.

Table 5-1 Building 1: Summary of Cost Estimates for All Schemes

Division	Description	Scheme 1: Moment Frames & Limited Shear Walls		Scheme 2: Moment Frames & Greater Shear Walls		Scheme 3: Cantilevered Columns & Greater Shear Walls	
		Subtotal	Total	Subtotal	Total	Subtotal	Total
1	**General Conditions**		**$9,905**		**$12,349**		**$11,549**
	Personnel	4,000		5,000		5,000	
	Small Tools	500		500		500	
	Temporary Utilities	125		125		125	
	Clean - Up	1,400		1,525		1,525	
	Debris Removal	1,150		1,725		1,725	
	Testing & Inspections	2,730		3,474		2,674	
2	**Sitework**		**$9,070**		**$12,670**		**$12,670**
	Demolition	5,750		9,350		9,350	
	Structural Excavation	3,320		3,320		3,320	
3	**Concrete**		**$11,600**		**$11,600**		**$11,600**
	Reinforcing Steel	4,420		4,420		4,420	
	Concrete Footing	6,920		6,920		6,920	
	Finish Slab	260		260		260	
4	**Masonry**						
	None						
5	**Metals**		**$11,700**		**$11,700**		**$8,220**
	Structural Steel	11,700		11,700		8,220	
6	**Carpentry**		**$8,442**		**$25,602**		**$25,952**
	Rough Carpentry	7,762		24,922		25,272	
	Finish Carpentry	680		680		680	
7	**Moisture Protection**						
	None						
8	**Doors, Windows, & Glass**						
	None						
9	**Finishes**		**$3,188**		**$7,374**		**$7,374**
	Lath & Plaster	1,500		2,250		2,250	
	Drywall	918		4,104		4,104	
	Painting	770		1,020		1,020	
10	**Specialties**						
	None						
11	**Equipment**						
	None						
12	**Furnishings**						
	None						
13	**Special Construction**						
	None						
14	**Conveying Systems**						
	None						
15	**Mechanical**						
	None						
16	**Electrical**						
	None						
	Subtotal	53,905	**$53,905**	81,295	**$81,295**	77,365	**$77,365**
	Building Permit @ 2.4%		**$1,294**		**$1,951**		**$1,857**
	Contingency @ 15%		**$8,086**		**$12,194**		**$11,605**
	Subtotal		**$63,284**		**$95,440**		**$90,826**
	Overhead & Profit @ 25%		**$15,821**		**$23,860**		**$22,707**
	Total		**$79,106**		**$119,300**		**$113,533**

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-2 Building 1: Cost Estimate for Scheme 1

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
1	**General Conditions** Subtotal for Division: **$9,905**									
	Personnel:									
	Foreman w/truck & phone - 2 hours/day - 4 weeks	40	hours	$100	$4,000					$4,000
	Small Tools:	1	lump sum					$500	$500	$500
	Temporary Utilities:									
	Temporary Sanitation	1	months					$125	$125	$125
	Clean Up:									
	Daily Clean Up - 1 man, 1 hour/day	20	hours	$25	$500					$500
	Final Clean up	16	hours	$25	$400					$400
	Flagman	20	hours	$25	$500					$500
	Debris removal:									
	Debris box	2	each			$575	$1,150			$1,150
	Special Inspections:									
	Welding	1	lump sum					$1,200	$1,200	$1,200
	Concrete cylinders	1	lump sum					$600	$600	$600
	Epoxied dowels	6	hours					$93	$558	$558
	Shear panel nailing	4	hours					$93	$372	$372
2	**Sitework** Subtotal for Division: **$9,070**									
	Demolition:									
	Cut and remove 4' strip of ceiling plaster, 500 sf.	32	hours	$45	$1,440					$1,440
	Remove interior plaster from shear walls and intersecting walls, 720 sq. ft.	32	hours	$45	$1,440					$1,440
	Sawcut, load and haul 6" concrete floor slab, 168 lf. 5 cy.	1	lump sum						$2,870	$2,870
	Structural Excavation:									
	Excavate new footing at garage entries	26	cubic yard	$70	$1,820					$1,820
	Load dump truck (loader)	6	hours					$150	$900	$900
	Haul away dirt (dump truck)	8	hours					$75	$600	$600
3	**Concrete** Subtotal for Division: **$11,600**									
	Reinforcing steel:									
	6 ea #6's t&b w/#5 stirrups @ 12"oc. 84 lf. 2600#. Delivered cages.	1	lump sum					$3,700	$3,700	$3,700
	Place cages in footings	16	hours	$45	$720					$720
	Concrete footing:									
	Place concrete in 2'-6" x 2'-6" footing plus floor slab. 4x6x35/32. 84 lf.	32	cubic yard	$26	$840	$140	$4,480			$5,320
	Concrete pump	1						$1,600	$1,600	$1,600
	Finish slab on grade:									
	Smooth trowel finish concrete garage slab at top of footing. 3'	4	hours	$65	$260					$260
4	**Masonry** Subtotal for Division: **$0**									

Table 5-2 Building 1: Cost Estimate for Scheme 1 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
5	**Metals** Subtotal for Division: **$11,700**									
	Structural Steel: Steel moment frames, 8' x 20', 10WF45 w/RBS. 2 ea. Erected on anchor bolts in new concrete footings & field welded.	1	lump sum					$11,700	$11,700	$11,700
6	**Carpentry** Subtotal for Division: **$8,442**									
	Rough Carpentry:									
	• Additional studs @ shear wall plywood joints and misc framing @ windows. Material.	156	board ft.			$1	$148			$148
	• Additional studs @ shear wall plywood joints and misc framing @ windows. Labor.	4	hours	$60	$240					$240
	• Drill and epoxy anchor bolts.	35	each	$35	$1,225	$45	$1,575			$2,800
	• Drill and epoxy hold downs.	4	each	$35	$140	$110	$440			$580
	• Additional 4x4 posts and tie downs. 48 bf material @ $1.20/bf.	4	each	$30	$120	$15	$60			$180
	• Clips to framing above shear walls.	68	linear ft.	$4	$240	$5	$340			$580
	• Collector beam and connections to floor above @ door opening head. 2 ea 2x12, 168 bf.	168	board ft.			$2	$319			$319
	• Collector beam and connections to floor above @ door opening head. 2 ea 2x12, 42 lf.	16	hours	$60	$960					$960
	• Shear wall sheathing. 15/32 plywood.	612	sq. ft.	$1	$765	$1	$490			$1,255
	• Set anchor bolts for steel frames	4	hours	$75	$300					$300
	• Set anchor bolts for steel frames	4	each			$100	$400			$400
	Finish Carpentry • Exterior siding in 3 ea 4x4 windows	8	hours	$60	$480		$200			$680
7	**Moisture Protection** Subtotal for Division: **$0**									
8	**Doors, Windows, & Glass** Subtotal for Division: **$0**									

Table 5-2 Building 1: Cost Estimate for Scheme 1 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
9	**Finishes** Subtotal for Division: **$3,188**									
	Plaster:									
	Patch openings in ceilings.	500	sq. ft.					$3	$1,500	$1,500
	Drywall:									
	Cover shear walls, 5/8 type x, fire taped.	612	sq. ft.					$2	$918	$918
	Painting:									
	Plaster soffit, seal and 2 coats.	500	sq. ft.					$1	$500	$500
	Steel beams, 10" WF.	72	linear ft.					$2	$144	$144
	2 ea 2x12 collector beams	84	linear ft.					$2	$126	$126
10	**Specialties** Subtotal for Division: **$0**									
11	**Equipment** Subtotal for Division: **$0**									
12	**Furnishings** Subtotal for Division: **$0**									
13	**Special Construction** Subtotal for Division: **$0**									
14	**Conveying Systems** Subtotal for Division: **$0**									
15	**Mechanical** Subtotal for Division: **$0**									
16	**Electrical** Subtotal for Division: **$0**									
			Subtotal:		$16,390		$9,602		$27,913	$53,905
			Subtotal Check:		$53,905		Permits @ 2.4%			$1,294
							Contingency @ 15%			$8,086
			Division Subtotal Check:		$53,905		Subtotal			$63,284
							Overhead & Profit @ 25%			$15,821
							TOTAL			**$79,106**

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-3 Building 1: Cost Estimate for Scheme 2

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
1	**General Conditions** Subtotal for Division: **$ 12,349**									
	Personnel:									
	Foreman w/truck & phone. 2 hours/day - 5 weeks	50	hours	$100	$5,000					$5,000
	Small Tools:		lump sum						$500	$500
	Temporary Utilities:									
	Temp. Sanitation	1	months					$125	$125	$125
	Clean - Up:									
	Daily Clean up - 1 man, 1 hr/d	25	hours	$25	$625					$625
	Final Clean up	16	hours	$25	$400					$400
	Flagman	20	hours	$25	$500					$500
	Debris removal:									
	Debris box	3	each			$575	$1,725			$1,725
	Special Inspections:									
	Welding	1	lump sum					$1,200	$1,200	$1,200
	Concrete cylinders	1	lump sum					$600	$600	$600
	Epoxied dowels	12	hours					$93	$1,116	$1,116
	Shear panel nailing	6	hours					$93	$558	$558
2	**Sitework** Subtotal for Division: **$ 12,670**									
	Demolition:									
	Cut and remove 4' strip of ceiling plaster. 734 sq. ft.	48	hours	$45	$2,160					$2,160
	Remove interior plaster from shear walls and intersecting walls. 2850 sf.	96	hours	$45	$4,320					$4,320
	Sawcut, load and haul 6" concrete floor slab. 168 lf. 5	1	lump sum						$2,870	$2,870
	Structural Excavation:									
	Excavate new footing at garage entries.	26	cubic yards	$70	$1,820					$1,820
	Load dump truck (loader)	6	hours					$150	$900	$900
	Haul away dirt (dump truck).	8	hours					$75	$600	$600
3	**Concrete** Subtotal for Division: **$ 11,600**									
	Reinforcing steel:									
	6 ea #6's t&b w/#5 stirrups @ 12"oc. 84 lf. 2600#. Delivered cages.	1	lump sum					$3,700	$3,700	$3,700
	Place cages in footings	16	hours	$45	$720					$720
	Concrete footing:									
	Place concrete in 2'-6" x 2'-6" footing plus floor slab. 4x6x35/32. 84 lf.	32	cubic yard	$26	$840	$140	$4,480			$5,320
	Concrete pump	1						$1,600	$1,600	$1,600
	Finish slab on grade:									
	Smooth trowel finish concrete garage slab at top of footing. 3' x84'.	4	hours	$65	$260					$260

Table 5-3 Building 1: Cost Estimate for Scheme 2 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
4	**Masonry** Subtotal for Division: **$ 0.00**									
5	**Metals** Subtotal for Division: **$ 11,700**									
	Structural Steel: Steel moment frames, 8' x 20', 10WF45 w/RBS. 2 ea. Erected on anchor bolts in new concrete footings with field welding.	1	lump sum					$11,700	$11,700	$11,700
6	**Carpentry** Subtotal for Division: **$ 25,602**									
	Rough Carpentry:									
	• Additional studs @ shear wall plywood joints and misc framing @ windows. Material.	492	board ft.			$1	$246			$246
	• Additional studs @ shear wall plywood joints and misc framing @ windows. Labor.	12	hours	$60	$720					$720
	• Drill and epoxy anchor bolts.	135	each	$35	$4,725	$45	$6,075			$10,800
	• Drill and epoxy hold downs.	17	each	$35	$595	$110	$1,870			$2,465
	• Additional 4x4 posts and tie downs. 48 bf material @ $1.20/bf.	17	each	$15	$255	$15	$255			$510
	• Clips to framing above shear walls.	304	linear ft.	$4	$1,073	$5	$1,520			$2,593
	• Collector beam and connections to floor above @ door opening head. 2 ea 2x12, 168 bf.	168	board ft.			$2	$319			$319
	• Collector beam and connections to floor above @ door opening head. 2 ea 2x12, 42 lf.	16	hours	$60	$960					$960
	• Shear wall sheathing. 15/32 plywood.	2,736	sq. ft.	$1	$3,420	$1	$2,189			$5,609
	• Set anchor bolts for steel frames. Labor.	4	hours	$75	$300					$300
	• Set anchor bolts for steel frames. Material.	4	each			$100	$400			$400
	Finish Carpentry Exterior siding in 3 ea 4x4 windows	8	hours	$60	$480		$200			$680
7	**Moisture Protection** Subtotal for Division: **$ 0.00**									

Table 5-3 Building 1: Cost Estimate for Scheme 2 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
8	**Doors, Windows, & Glass** Subtotal for Division: **$ 0.00**									
9	**Finishes** Subtotal for Division: **$ 7,374**									
	Plaster:									
	Patch openings in ceilings.	750	sq. ft.					$3	$2,250	$2,250
	Drywall:									
	Cover shear walls, 5/8 type x, fire taped.	2,736	sq. ft.					$2	$4,104	$4,104
	Painting:									
	Plaster soffit, seal and 2	750	sq. ft.					$1	$750	$750
	Steel beams, 10" WF.	72	linear ft.					$2	$144	$144
	2 ea 2x12 collector beams	84	linear ft.					$2	$126	$126
10	**Specialties** Subtotal for Division: **$ 0.00**									
11	**Equipment** Subtotal for Division: **$ 0.00**									
12	**Furnishings** Subtotal for Division: **$ 0.00**									
13	**Special Construction** Subtotal for Division: **$ 0.00**									
14	**Conveying Systems** Subtotal for Division: **$0**									
15	**Mechanical** Subtotal for Division: **$ 0.00**									
16	**Electrical** Subtotal for Division: **$ 0.00**									
				Subtotal:	$29,173		$19,279		$32,843	$81,295
				Subtotal Check:	$81,295		Permits @ 2.4%			$1,951
							Contingency @ 15%			$12,194
				Division Subtotal Check:	$81,295		Subtotal			$95,440
							Overhead & Profit @ 25%			$23,860
							TOTAL			**$119,300**

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-4 Building 1: Cost Estimate for Scheme 3

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
1	**General Conditions** Subtotal for Division: **$11,549**									
	Personnel:									
	Foreman w/truck & phone.	50	hours	$100	$5,000					$5,000
	2 hours/day - 5 weeks	1	lump sum					$500	$500	$500
	Small Tools:									
	Temporary Utilities:									
	Temp. Sanitation	1	months					$125	$125	$125
	Clean - Up:									
	Daily Clean up - 1 hour/day	25	hours	$25	$625					$625
	Final Clean up	16	hours	$25	$400					$400
	Flagman	20	hours	$25	$500					$500
	Debris removal:									
	Debris box	3	each			$575	$1,725			$1,725
	Special Inspections:									
	Welding	1	lump sum					$400	$400	$400
	Concrete cylinders	1	lump sum					$600	$600	$600
	Epoxied dowels	12	hours					$93	$1,116	$1,116
	Shear panel nailing	6	hours					$93	$558	$558
2	**Sitework** Subtotal for Division: **$12,670**									
	Demolition:									
	Cut and remove 4' strip of ceiling plaster. 734 sf.	48	hours	$45	$2,160					$2,160
	Remove interior plaster from shear walls and intersecting walls. 2850 sf.	96	hours	$45	$4,320					$4,320
	Sawcut, load and haul 6" concrete floor slab. 168 lf. 5 cy.	1	lump sum						$2,870	$2,870
	Structural Excavation:									
	Excavate new footing at garage entries.	26	cubic yd.	$70	$1,820					$1,820
	Load dump truck (loader)	6	hours					$150	$900	$900
	Haul away dirt (debris box)	8	each					$75	$600	$600
3	**Concrete** Subtotal for Division: **$11,600**									
	Reinforcing steel:									
	6 ea #6's t&b w/#5 stirrups @ 12"oc. 84 lf. 2600#. Delivered cages.	1	lump sum					$3,700	$3,700	$3,700
	Place cages in footings	16	hours	$45	$720					$720
	Concrete footing:									
	Place concrete in 2'-6" x 2'-6" footing plus floor slab. 4x6x35/32. 84 lf.	32	cubic yd.	$26	$840	$140	$4,480			$5,320
	Concrete pump	1	lump sum					$1,600	$1,600	$1,600
	Finish slab on grade:									
	Smooth trowel finish concrete garage slab at top of footing. 252 sf.	4	hours	$65	$260					$260

Table 5-4 Building 1: Cost Estimate for Scheme 3 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
4	**Masonry** Subtotal for Division: **$0**									
5	**Metals** Subtotal for Division: **$8,220**									
	Structural Steel:									
	Steel moment cantilevered columns, 10', 10WF45. 6 ea. Delivered.	1	lump sum					$6,100	$6,100	$6,100
	Hang 6 ea steel columns ready for embedment in footing.	32	hours	$60	$1,920		$200			$2,120
6	**Carpentry** Subtotal for Division: **$25,952**									
	Rough Carpentry:									
	• Additional studs @ shear wall plywood joints and misc framing @ windows. Material.	492	board ft.			$1	$246			$246
	• Additional studs @ shear wall plywood joints and misc framing @ windows. Labor.	12	hours	$60	$720					$720
	• Drill and epoxy anchor bolts.	135	each	$35	$4,725	$45	$6,075			$10,800
	• Drill and epoxy hold downs.	17	each	$35	$595	$110	$1,870			$2,465
	• Additional 4x4 posts and tie downs. 48 bf material @ $1.20/bf.	17	each	$15	$255	$15	$255			$510
	• Clips to framing above shear walls.	304	linear ft.	$4	$1,073	$5	$1,520			$2,593
	• Collector beam and connections to floor above @ door opening head. 2 ea 2x12, 168 bf.	168	board ft.			$2	$319			$319
	• Collector beam and connections to floor above @ door opening head. 2 ea 2x12, 42 lf.	16	hours	$60	$960					$960
	• Shear wall sheathing. 15/32 plywood.	2,736	sq. ft.	$1	$3,420	$1	$2,189			$5,609
	• Set anchor bolts for steel frames. Labor.	6	hours	$75	$450					$450
	• Set anchor bolts for steel frames. Material.	6	each			$100	$600			$600
	Finish Carpentry									
	Exterior siding in 3 ea 4x4 windows	8	hours	$60	$480		$200			$680
7	**Moisture Protection** Subtotal for Division: **$0**									

Table 5-4 Building 1: Cost Estimate for Scheme 3 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
8	**Doors, Windows, & Glass** Subtotal for Division: $0									
9	**Finishes** Subtotal for Division: $7,374									
	Plaster: Patch openings in ceilings.	750	sq. ft.					$3	$2,250	$2,250
	Drywall: Cover shear walls, 5/8 type x, fire taped.	2,736	sq. ft.					$2	$4,104	$4,104
	Painting: Plaster soffit, seal and 2 coats.	750	sq. ft.					$1	$750	$750
	Steel beams, 10" WF.	72	linear ft.					$2	$144	$144
	2 ea 2x12 collector beams	84	linear ft.					$2	$126	$126
10	**Specialties** Subtotal for Division: $0									
11	**Equipment** Subtotal for Division: $0									
12	**Furnishings** Subtotal for Division: $0									
13	**Special Construction** Subtotal for Division: $0									
14	**Conveying Systems** Subtotal for Division: $0									
15	**Mechanical** Subtotal for Division: $0									
16	**Electrical** Subtotal for Division: $0									
				Subtotal:	$31,243		$19,679		$26,443	$77,365
				Subtotal Check:	$77,365		Permits @ 2.4%			$1,857
							Contingency @ 15%			$11,605
				Division Subtotal Check:	$77,365		Subtotal			$90,826
							Overhead & Profit @ 25%			$22,707
							TOTAL			**$113,533**

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-5 Building 2: Summary of Cost Estimates for All Schemes

Division	Description	Scheme 1: Moment Frames & Limited Shear Walls		Scheme 2: Moment Frames & Greater Shear Walls		Scheme 3: Cantilevered Columns & Greater Shear Walls	
		Subtotal	Total	Subtotal	Total	Subtotal	Total
1	**General Conditions**		**$9,516**		**$12,535**		**$11,235**
	Personnel	4,000		5,000		5,000	
	Small Tools	500		500		500	
	Temporary Utilities	125		125		125	
	Clean - Up	1,400		1,525		1,025	
	Debris Removal	575		1,725		1,725	
	Testing & Inspections	2,916		3,660		2,860	
2	**Sitework**		**$8,317**		**$15,057**		**$12,820**
	Demolition	4,857		11,387		8,640	
	Structural Excavation	3,460		3,670		4,180	
3	**Concrete**		**$12,165**		**$13,685**		**$13,685**
	Reinforcing Steel	5,125		6,013		5,125	
	Concrete Footing	6,780		7,281		8,040	
	Finish Slab	260		390		520	
4	**Masonry**						
	None						
5	**Metals**		**$12,675**		**$12,675**		**$12,030**
	Structural Steel	12,675		12,675		12,030	
6	**Carpentry**		**$4,809**		**$22,353**		**$10,495**
	Rough Carpentry	4,809		22,353		10,495	
7	**Moisture Protection**						
	None						
8	**Doors, Windows, & Glass**						
	None						
9	**Finishes**		**$1,164**		**$13,666**		**$11,827**
	Lath & Plaster	432		4,872		4,872	
	Drywall	432		6,696		5,022	
	Painting	300		2,098		1,933	
10	**Specialties**						
	None						
11	**Equipment**						
	None						
12	**Furnishings**						
	None						
13	**Special Construction**						
	None						
14	**Conveying Systems**						
	None						
15	**Mechanical**						
	None						
16	**Electrical**						
	None						
	Subtotal	48,645	**$48,645**	89,970	**$89,970**	72,091	**$72,091**
	Building Permit @ 2.4%		**$1,167**		**$2,159**		**$1,730**
	Contingency @ 15%		**$7,297**		**$13,496**		**$10,814**
	Subtotal		**$57,110**		**$105,625**		**$84,635**
	Overhead & Profit @ 25%		**$14,277**		**$26,406**		**$21,159**
	Total		**$71,387**		**$132,031**		**$105,794**

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-6 Building 2: Cost Estimate for Scheme 1

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
1	**General Conditions** Subtotal for Division: **$9,516**									
	Personnel:									
	Foreman w/truck & phone. 2 hrs/d - 4 wks.	40	hours	$100	$4,000					$4,000
	Small Tools:	1	lump sum					$500	$500	$500
	Temporary Utilities:									
	Temp. Sanitation	1	months					$125	$125	$125
	Clean - Up:									
	Daily Clean up - 1 man, 1 hr/d	20	hours	$25	$500					$500
	Final Clean up	16	hours	$25	$400					$400
	Flagman	20	hours	$25	$500					$500
	Debris removal:									
	Debris box	1	each			$575	$575			$575
	Special Inspections:									
	Welding	1	lump sum					$1,200	$1,200	$1,200
	Concrete cylinders	1	lump sum					$600	$600	$600
	Epoxied dowels	6	hours					$93	$558	$558
	Shear panel nailing	6	hours					$93	$558	$558
2	**Sitework** Subtotal for Division: **$8,317**									
	Demolition:									
	Cut and remove 4' strip of ceiling plaster. 88 lf, 352 sf.	24	hours	$45	$1,080					$1,080
	Remove interior plaster from shear walls and intersecting walls. 24 x 9 =216 sf.	8	hours	$45	$360					$360
	Sawcut, load and haul 6" concrete floor slab. 200 lf. 5 cy.	1	lump sum					$3,417	$3,417	$3,417
	Structural Excavation:									
	Excavate new footing at garage entries.	28	cubic yd.	$70	$1,960					$1,960
	Load dump truck (loader)	6	hrs					$150	$900	$900
	Haul away dirt (dump truck).	8	hrs					$75	$600	$600
3	**Concrete** Subtotal for Division: **$12,165**									
	Reinforcing steel:									
	6 ea #6's t&b w/#5 stirrups @ 12"oc. 100 lf. 3100#. Delivered cages.	1	lump sum					$4,405	$4,405	$4,405
	Place cages in footings	16	hours	$45	$720					$720
	Concrete footing:									
	Place concrete in 2'-6" x 2'-6" footing plus floor slab. 4x6x35/31. 100 lf.	31	cubic yd.	$27	$840	$140	$4,340			$5,180
	Concrete pump	1	each					$1,600	$1,600	$1,600
	Finish slab on grade:									
	Smooth trowel finish concrete garage slab at top of footing. 3' x84'.	4	hours	$65	$260					$260

Table 5-6 Building 2: Cost Estimate for Scheme 1 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
4	**Masonry** Subtotal for Division: **$0**									
5	**Metals** Subtotal for Division: **$12,675**									
	Structural Steel: Steel moment frames, 2 ea. (8'x22' & 8'x24'), 12WF45 w/RBS. Erected on anchor bolts in new concrete footings & field welded.	1	lump sum					$12,675	$12,675	$12,675
6	**Carpentry** Subtotal for Division: **$ $4,809**									
	Rough Carpentry:									
	New wall framing with 3"oc shear nailing in 1/2' ply on both sides.	24	linear ft.	$60	$1,440	$20	$480			$1,920
	• Anchor bolts.	11	each	$10	$110	$15	$165			$275
	• Tie downs.	4	each	$10	$40	$25	$100			$140
	• Clips to framing above shear walls.	24	linear ft.	$4	$85	$5	$120			$205
	• Collector and connections to floor above @ moment frames. 2 ea.	64	linear ft.	$9	$560	$4	$256			$816
	• Plywood soffit, 1/2" on existing floor joists.	264	sq. ft.	$2	$462	$1	$211			$673
	• Collector plate, 1/4" x 3" x 66 lf	1	each	$280	$280	$100	$100			$380
	• Set anchor bolts for steel frames	4	each	$75	$300	$25	$100			$400
7	**Moisture Protection** Subtotal for Division: **$0**									
8	**Doors, Windows, & Glass** Subtotal for Division: **$0**									

Table 5-6 Building 2: Cost Estimate for Scheme 1 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
9	**Finishes** Subtotal for Division: **$1,164**									
	Plaster: Patch openings in ceilings.	144	sq. ft.					$3	$432	$432
	Drywall: Cover shear walls, 5/8 type x, fire taped.	216	sq. ft.					$2	$432	$432
	Painting: Plaster soffit, seal and 2 coats.	144	sq. ft.					$1	$144	$144
	Steel beams, 10" WF.	78	linear ft.					$2	$156	$156
10	**Specialties** Subtotal for Division: **$0**									
11	**Equipment** Subtotal for Division: **$0**									
12	**Furnishings** Subtotal for Division: **$0**									
13	**Special Construction** Subtotal for Division: **$0**									
14	**Conveying Systems** Subtotal for Division: **$0**									
15	**Mechanical** Subtotal for Division: **$0**									
16	**Electrical** Subtotal for Division: **$0**									
				Subtotal:	$13,897		$6,447		$28,301	$48,645
				Subtotal Check:	$48,645		Permits @ 2.4%			$1,167
							Contingency @ 15%			$7,297
				Division Subtotal Check:	$48,645		Subtotal			$57,110
							Overhead & Profit @ 25%			$14,277
							TOTAL			$71,387

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-7 Building 2: Cost Estimate for Scheme 2

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
1	**General Conditions** Subtotal for Division: **$12,535**									
	Personnel:									
	Foreman w/truck & phone. 2 hours/day - 5 weeks	50	hours	$100	$5,000					$5,000
	Small Tools:	1	lump sum					$500	$500	$500
	Temporary Utilities:									
	Temp. Sanitation	1	months					$125	$125	$125
	Clean - Up:									
	Daily Clean up - 1 man, 1 hr/d	25	hours	$25	$625					$625
	Final Clean up	16	hours	$25	$400					$400
	Flagman	20	hours	$25	$500					$500
	Debris removal:									
	Debris box	3	each			$575	$1,725			$1,725
	Special Inspections:									
	Welding	1	lump sum					$1,200	$1,200	$1,200
	Concrete cylinders	1	lump sum					$600	$600	$600
	Epoxied dowels	12	hours					$93	$1,116	$1,116
	Shear panel nailing	8	hours					$93	$744	$744
2	**Sitework** Subtotal for Division: **$15,057**									
	Demolition:									
	Cut and remove 4' strip of ceiling plaster. 396 lf, 1200 sf.	56	hours	$45	$2,520					$2,520
	Remove interior plaster from shear walls and intersecting walls. 400 x 9 =3600 sf.	112	hours	$45	$5,040					$5,040
	Sawcut, load and haul 6" concrete floor slab. 224 lf. 5 cy.	1	lump sum					$3,827	$3,827	$3,827
	Structural Excavation:									
	Excavate new footing at garage entries.	31	cubic yd.	$70	$2,170					$2,170
	Load dump truck (loader)	6	hours					$150	$900	$900
	Haul away dirt (dump truck).	8	hours					$75	$600	$600
3	**Concrete** Subtotal for Division: **$13,685**									
	Reinforcing steel:									
	6 ea #6's t&b w/#5 stirrups @ 12"oc. 112 lf. 3400#. Delivered cages.	1	lump sum					$4,933	$4,933	$4,933
	Place cages in footings	24	hours	$45	$1,080					$1,080
	Concrete footing:									
	Place concrete in 2'-6" x 2'-6" footing plus floor slab. 4x6x35/31. 100 lf.	34	cubic yd.	$27	$921	$140	$4,760			$5,681
	Concrete pump	1	each					$1,600	$1,600	$1,600
	Finish slab on grade:									
	Smooth trowel finish concrete garage slab at top of footing. 3' x84'.	6	hours	$65	$390					$390

Table 5-7 Building 2: Cost Estimate for Scheme 2 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
4	**Masonry** Subtotal for Division: **$0**									
5	**Metals** Subtotal for Division: **$12,675**									
	Structural Steel: Steel moment frames, 2 ea. (8'x22' & 8'x24'), 12WF45 w/RBS. Erected on anchor bolts in new concrete footings & field welded.	1	lump sum					$12,675	$12,675	$12,675
6	**Carpentry** Subtotal for Division: **$22,353**									
	Rough Carpentry:									
	New wall framing with 3"oc shear nailing in 1/2' ply on both sides.	24	linear ft.	$60	$1,440	$20	$480			$1,920
	• Drill and epoxy anchor bolts.	164	each	$10	$1,640	$15	$2,460			$4,100
	• Drill and epoxy tie downs, add 4x4.	22	each	$10	$220	$25	$550			$770
	• Clips to framing above shear walls.	372	linear ft.	$1	$480	$3	$1,116			$1,596
	• Add studs @ shear panel joints.	1,116	board ft.	$0	$240	$0	$502			$742
	• Shear wall sheathing on existing studs, 15/32 plywood.	3,348	sq. ft.	$1	$4,185	$1	$2,678			$6,863
	• Collector and connections to floor above @ cantilevered columns. 2 ea 2x12, 110 lf.	110	linear ft.	$8	$880	$4	$440			$1,320
	• Plywood soffit, 1/2" on existing floor joists.	1,624	sq. ft.	$2	$2,842	$1	$1,299			$4,141
	• Set anchor bolts for steel cols.	9	each	$75	$675	$25	$225			$900
7	**Moisture Protection** Subtotal for Division: **$0**									
8	**Doors, Windows, & Glass** Subtotal for Division: **$0**									

Table 5-7 Building 2: Cost Estimate for Scheme 2 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
9	**Finishes** Subtotal for Division: **$13,666**									
	Plaster:									
	Patch openings in ceilings.	1,624	sq. ft.					$3	$4,872	$4,872
	Drywall:									
	Cover shear walls, 5/8 type x, fire taped. 372 lf x 9 = 3564 sf.	3,348	sq. ft.					$2	$6,696	$6,696
	Painting:									
	Plaster soffit, seal and 2 coats.	1,624	sq. ft.					$1	$1,624	$1,624
	Steel beams, 10" WF.	72	linear ft.					$2	$144	$144
	Collector beams	110	linear ft.					$3	$330	$330
10	**Specialties** Subtotal for Division: **$0**									
11	**Equipment** Subtotal for Division: **$0**									
12	**Furnishings** Subtotal for Division: **$0**									
13	**Special Construction** Subtotal for Division: **$0**									
14	**Conveying Systems** Subtotal for Division: **$0**									
15	**Mechanical** Subtotal for Division: **$0**									
16	**Electrical** Subtotal for Division: **$0**									
			Subtotal:		$31,248		$16,236		$42,486	$89,970
			Subtotal Check:		$89,970		Permits @ 2.4%			$2,159
							Contingency @ 15%			$13,496
			Division Subtotal Check:		$89,970		Subtotal			$105,625
							Overhead & Profit @ 25%			$26,406
							TOTAL			$132,031

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-8 Building 2: Cost Estimate for Scheme 3

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
1	**General Conditions** Subtotal for Division: **$11,235**									
	Personnel:									
	Foreman w/truck & phone. 2 hrs/d - 5 wks.	50	hours	$100	$5,000					$5,000
	Small Tools:	1	lump sum					$500	$500	$500
	Temporary Utilities:									
	Temp. Sanitation	1	months					$125	$125	$125
	Clean Up:									
	Daily Clean Up - 1 hour/day	25	hours	$25	$625					$625
	Final Clean Up	16	hours	$25	$400					$400
	Flagman	20	hours	$25						$0
	Debris removal:									
	Debris box	3	each			$575	$1,725			$1,725
	Special Inspections:									
	Welding	1	lump sum					$400	$400	$400
	Concrete cylinders	1	lump sum					$600	$600	$600
	Epoxied dowels	12	hours					$93	$1,116	$1,116
	Shear panel nailing	8	hours					$93	$744	$744
2	**Sitework** Subtotal for Division: **$12,820**									
	Demolition:									
	Cut and remove 4' strip of ceiling plaster. 480 lf, 1624 sf.	80	hours	$45	$3,600					$3,600
	Remove interior plaster from shear walls and intersecting walls. 400 x 9 =3600 sf.	112	hours	$45	$5,040					$5,040
	Sawcut, load and haul 6" concrete floor slab. 200 lf. 5 cy.	1	lump sum					$3,417	$273,333	$0
	Structural Excavation:									
	Excavate new footing at garage entries.	34	cubic yd.	$70	$2,380					$2,380
	Load dump truck (loader)	8	hours					$150	$1,200	$1,200
	Haul away dirt (dump truck).	8	hours					$75	$600	$600
3	**Concrete** Subtotal for Division: **$13,685**									
	Reinforcing steel:									
	6 ea #6's t&b w/#5 stirrups @ 12"oc. 100 lf. 2600#. Delivered cages.	1	lump sum					$4,405	$4,405	$4,405
	Place cages in footings	16	hours	$45	$720					$720
	Concrete footing:									
	Place concrete in 2'-6" x 2'-6" footing plus floor slab. 4x8x35/38.	38	cubic yd.	$29	$1,120	$140	$5,320			$6,440
	Concrete pump	1	lump sum					$1,600	$1,600	$1,600
	Finish slab on grade:									
	Smooth trowel finish concrete garage slab at top of footing. 366 sf	8	hours	$65	$520					$520

Table 5-8 Building 2: Cost Estimate for Scheme 3 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
4	**Masonry** Subtotal for Division: **$0**									
5	**Metals** Subtotal for Division: **$12,030**									
	Structural Steel:									
	Steel moment cantilevered columns, 10', 10WF45. 9 ea. Delivered.	1	lump sum					$9,150	$9,150	$9,150
	Hang 9 ea steel columns ready for embedment in footing.	48	hours	$60	$2,880					$2,880
6	**Carpentry** Subtotal for Division: **$10,495**									
	Rough Carpentry:									
	• Drill and epoxy anchor bolts.	11	each	$10	$110	$15	$165			$275
	• Drill and epoxy tie downs, add 4x4.	4	each	$10	$40	$25	$100			$140
	• Clips to framing above shear walls.	24	linear ft.	$4	$85	$5	$120			$205
	• Add studs @ shear panel joints.	1,116	board ft.	$0	$240	$0	$502			$742
	• Shear wall sheathing on existing studs, 15/32 plywood.	3,348	sq. ft.	$1	$4,185	$1	$2,678			$6,863
	• Collector and connections to floor above @ moment frames. 2 ea.	64	linear ft.	$9	$560	$4	$256			$816
	• Plywood soffit, 1/2" on existing floor joists.	264	sq. ft.	$2	$462	$1	$211			$673
	• Collector plate, 1/4" x 3" x 66 lf	1	each	$280	$280	$100	$100			$380
	• Set anchor bolts for steel frames	4	each	$75	$300	$25	$100			$400
	• Collector beam and connections to floor above @ door opening head. 2 ea 2x12, 168 bf.		bf			$2	$0			$0
	• Collector beam and connections to floor above @ door opening head. 2 ea 2x12, 42 lf.		hours	$60	$0					$0
	• Shear wall sheathing. 15/32 plywood.		sq. ft.	$1	$0	$1	$0			$0
	• Set anchor bolts for steel frames. Labor.		hours	$75	$0					$0
	• Set anchor bolts for steel frames. Material.		each			$100	$0			$0
	Finish Carpentry									
	Exterior siding in 3 ea 4x4 windows		hours	$60	$0					$0
7	**Moisture Protection** Subtotal for Division: **$0**									

Table 5-8 Building 2: Cost Estimate for Scheme 3 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
8	**Doors, Windows, & Glass** Subtotal for Division: $0									
9	**Finishes** Subtotal for Division: $11,827									
	Plaster:									
	Patch openings in ceilings.	1,624	sq. ft.					$3	$4,872	$4,872
	Drywall:									
	Cover shear walls, 5/8 type x, fire taped.	3,348	sq. ft.					$2	$5,022	$5,022
	Painting:									
	Plaster soffit, seal and 2 coats.	1,624	sq. ft.					$1	$1,624	$1,624
	Steel beams, 10" WF.	72	linear ft.					$2	$144	$144
	2 ea 2x12 collector beams	110	linear ft.					$2	$165	$165
10	**Specialties** Subtotal for Division: $0									
11	**Equipment** Subtotal for Division: $0									
12	**Furnishings** Subtotal for Division: $0									
13	**Special Construction** Subtotal for Division: $0									
14	**Conveying Systems** Subtotal for Division: $0									
15	**Mechanical** Subtotal for Division: $0									
16	**Electrical** Subtotal for Division: $0									
			Subtotal:		$28,547		$11,278		$305,600	$72,091
			Subtotal Check:		$345,425		Permits @ 2.4%			$1,730
							Contingency @ 15%			$10,814
			Division Subtotal Check:		$72,091		Subtotal			$84,635
							Overhead & Profit @ 25%			$21,159
							TOTAL			**$105,794**

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-9 Building 3: Summary of Cost Estimates for All Schemes

Division	Description	SCHEME 1 Shear Walls Only		SCHEME 2 Moment Frames & Shear Walls		SCHEME 3 Cantilevered Columns & Shear Walls	
		Subtotal	Total	Subtotal	Total	Subtotal	Total
1	**General Conditions**		**$8,502**		**$11,713**		**$11,488**
	Personnel	4,000		5,000		5,000	
	Small Tools	500		500		500	
	Temporary Utilities	125		250		250	
	Clean - Up	1,400		1,525		1,525	
	Debris Removal	575		1,150		1,725	
	Testing & Inspections	1,902		3,288		2,488	
2	**Sitework**		**$7,403**		**$9,833**		**$9,731**
	Demolition	4,653		7,083		7,463	
	Structural Excavation	2,750		2,750		2,268	
3	**Concrete**		**$10,264**		**$10,264**		**$8,462**
	Reinforcing Steel	4,064		4,064		3,102	
	Concrete Footing	5,940		5,940		5,100	
	Finish Slab	260		260		260	
4	**Masonry**						
	None						
5	**Metals**		**$0**		**$20,475**		**$8,220**
	Structural Steel	0		20,475		8,220	
6	**Carpentry**		**$11,021**		**$16,846**		**$19,945**
	Rough Carpentry	11,021		16,846		19,945	
7	**Moisture Protection**		**$351**		**$1,701**		**$2,349**
	Insulation	351		1,701		2,349	
8	**Doors, Windows, & Glass**						
	None.						
9	**Finishes**		**$2,733**		**$4,253**		**$5,093**
	Lath & Plaster	1,422		1,914		2,058	
	Drywall	837		1,701		2,349	
	Painting	474		638		686	
10	**Specialties**						
	None						
11	**Equipment**						
	None						
12	**Furnishings**						
	None						
13	**Special Construction**						
	None						
14	**Conveying Systems**						
	None						
15	**Mechanical**						
	None						
16	**Electrical**						
	None						
	Subtotal	40,274	**$40,274**	75,085	**$75,085**	65,287	**$65,287**
	Building Permit @ 2.4%		**$967**		**$1,802**		**$1,567**
	Contingency @ 15%		**$6,041**		**$11,263**		**$9,793**
	Subtotal		**$47,282**		**$88,150**		**$76,647**
	Overhead & Profit @ 25%		**$11,820**		**$22,038**		**$19,162**
	Total		**$59,102**		**$110,188**		**$95,809**

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-10 Building 3: Cost Estimate for Scheme 1

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Materia	Unit Cost	Subcontractor	
1	**General Conditions** Subtotal for Division: **$8,502**									
	Personnel:									
	Foreman w/truck & phone. 2 hours/day - 4 weeks	40	hours	$100	$4,000					$4,000
	Small Tools:	1	lump sum					$500	$500	$500
	Temporary Utilities:									
	Temporary Sanitation	1	months					$125	$125	$125
	Clean - Up:									
	Daily Clean up - 1 man, 1 hr/d	20	hours	$25	$500					$500
	Final Clean up	16	hours	$25	$400					$400
	Flagman	20	hours	$25	$500					$500
	Debris removal:									
	Debris box	1	each			$575	$575			$575
	Special Inspections:									
	Concrete cylinders	1	lump sum					$600	$600	$600
	Epoxied dowels	6	hours					$93	$558	$558
	Shear panel nailing	8	hours					$93	$744	$744
2	**Sitework** Subtotal for Division: **$7,403**									
	Demolition:									
	Cut and remove 1' strip of ceiling plaster @ walls plus removed soffit. 474 sf.	36	hours	$45	$1,620					$1,620
	Remove interior plaster from shear walls and intersecting walls. 26 x 9 = 234 sf.	10	hours	$45	$450					$450
	Sawcut, load and haul 6" concrete floor slab. 152 lf. 4 cy.	1	lump sum						$2,583	$2,583
	Structural Excavation:									
	Excavate new footing at garage entries.	20	cubic yd.	$70	$1,400					$1,400
	Load dump truck (loader)	6	hours					$150	$900	$900
	Haul away dirt (dump truck).	6	hours					$75	$450	$450
3	**Concrete** Subtotal for Division: **$10,264**									
	Reinforcing steel:									
	6 ea #6's t&b w/#5 stirrups @ 12"oc. 76 lf. 2350#. Delivered cages.	1	lump sum					$3,344	$3,344	$3,344
	Place cages in footings	16	hours	$45	$720					$720
	Concrete footing:									
	Place concrete in 2'-6" x 2'-6" footing plus floor slab. 25 cy. 76 lf.	25	cubic yd.	$34	$840	$140	$3,500			$4,340
	Concrete pump	1	lump sum					$1,600	$1,600	$1,600
	Finish slab on grade:									
	Smooth trowel finish concrete garage slab at top of footing. 3' x 76'.	4	hours	$65	$260					$260

Table 5-10 Building 3: Cost Estimate for Scheme 1 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Materia	Unit Cost	Subcontractor	
4	**Masonry** Subtotal for Division: **$0**									
5	**Metals** Subtotal for Division: **$0**									
	None.									
6	**Carpentry** Subtotal for Division: **$11,021**									
	Rough Carpentry:									
	• Framing @ shear wall plywood joints and new shear walls. Material.	284	board ft.			$1	$298			$298
	• Framing @ shear wall plywood joints and new shear walls. Labor.	8	hours	$60	$480					$480
	• Shear wall sheathing. Struc 1 plywood.	558	sq. ft.	$1	$698	$1	$502			$1,200
	• Soffit sheathing. Struc 1 plywood.	448	sq. ft.	$2	$672	$1	$403			$1,075
	• Collector beam and connections to floor above @ door opening head. 2 ea 2x12, 76 lf.	304	board ft.			$2	$578			$578
	• Collector beam and connections to floor above @ door opening head. Labor	24	hours	$60	$1,440					$1,440
	• Drill and epoxy anchor bolts & rebar dowels.	54	each	$35	$1,890	$45	$2,430			$4,320
	• Drill and epoxy hold downs w/4x6 post	2	each	$70	$140	$110	$220			$360
	• Set hold downs w/4x6 post	6	each	$35	$210	$100	$600			$810
	• Clips to framing above shear walls.	44	linear ft.	$5	$240	$5	$220			$460
7	**Moisture Protection** Subtotal for Division: **$351**									
	Insulation: Batt insulation in new exterior shear walls.	234	sq. ft.	$1	$117	$1	$234			$351
8	**Doors, Windows, & Glass** Subtotal for Division: **$0**									

Table 5-10 Building 3: Cost Estimate for Scheme 1 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
9	**Finishes** Subtotal for Division: **$2,733**									
	Plaster: Patch openings in ceilings.	474	sq. ft.					$3	$1,422	$1,422
	Drywall: Cover shear walls, 5/8 type x, fire taped.	558	sq. ft.					$2	$837	$837
	Painting: Plaster soffit, seal and 2 coats.	474	sq. ft.					$1	$474	$474
10	**Specialties** Subtotal for Division: **$0**									
11	**Equipment** Subtotal for Division: **$0**									
12	**Furnishings** Subtotal for Division: **$0**									
13	**Special Construction** Subtotal for Division: **$0**									
14	**Conveying Systems** Subtotal for Division: **$0**									
15	**Mechanical** Subtotal for Division: **$0**									
16	**Electrical** Subtotal for Division: **$0**									
			Subtotal:		$16,577		$9,560		$14,137	$40,274
			Subtotal Check:		$40,274		Permits @ 2.4%			$967
							Contingency @ 15%			$6,041
			Division Subtotal Check:		$40,274		Subtotal			$47,282
							Overhead & Profit @ 25%			$11,820
							TOTAL			$59,102

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-11 Building 3: Cost Estimate for Scheme 2

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
1	**General Conditions** Subtotal for Division: **$11,713**									
	Personnel:									
	Foreman w/truck & phone. 2 hours/day - 5 weeks	50	hours	$100	$5,000					$5,000
	Small Tools:	1	lump sum					$500	$500	$500
	Temporary Utilities:									
	Temp. Sanitation	2	months					$125	$250	$250
	Clean - Up:									
	Daily Clean up - 1 man, 1 hr/d	25	hours	$25	$625					$625
	Final Clean up	16	hours	$25	$400					$400
	Flagman	20	hours	$25	$500					$500
	Debris removal:									
	Debris box	2	each			$575	$1,150			$1,150
	Special Inspections:									
	Welding	1	lump sum					$1,200	$1,200	$1,200
	Concrete cylinders	1	lump sum					$600	$600	$600
	Epoxied dowels	6	lump sum					$93	$558	$558
	Shear panel nailing	10	hours					$93	$930	$930
2	**Sitework** Subtotal for Division: **$9,833**									
	Demolition:									
	Cut and remove 1' strip of ceiling plaster @ walls plus removed soffit. 638 sf.	52	hours	$45	$2,340					$2,340
	Remove interior plaster from shear walls and intersecting walls. 126 x 9 = 1134 sf.	48	hours	$45	$2,160					$2,160
	Sawcut, load and haul 6" concrete floor slab. 152 lf. 4 cy.	1	lump sum						$2,583	$2,583
	Structural Excavation:									
	Excavate new footing at garage entries.	20	cubic yd.	$70	$1,400					$1,400
	Load dump truck (loader)	6	hours					$150	$900	$900
	Haul away dirt (dump truck).	6	hours					$75	$450	$450
3	**Concrete** Subtotal for Division: **$10,264**									
	Reinforcing steel:									
	6 ea #6's t&b w/#5 stirrups @ 12"oc. 76 lf. 2350#. Delivered cages.	1	lump sum					$3,344	$3,344	$3,344
	Place cages in footings	16	hours	$45	$720					$720
	Concrete footing:									
	Place concrete in 2'-6" x 2'-6" footing plus floor slab. 25 cy. 76 lf.	25	cubic yd.	$34	$840	$140	$3,500			$4,340
	Concrete pump	1						$1,600	$1,600	$1,600
	Finish slab on grade:									
	Smooth trowel finish concrete garage slab at top of footing. 3' x 76'.	4	hours	$65	$260					$260

Table 5-11 Building 3: Cost Estimate for Scheme 2 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
4	**Masonry** Subtotal for Division: **$0**									
5	**Metals** Subtotal for Division: **$20,475**									
	Structural Steel: Steel moment frames, 8' x 26' W12x45 w/RBS. 3 ea. Erected on anchor bolts in new concrete footings with field welding. Braced at midpoint to diaphragm above.	1	lump sum					$20,475	$20,475	$20,475
6	**Carpentry** Subtotal for Division: **$16,846**									
	Rough Carpentry:									
	• Framing @ shear wall plywood joints. Material.	192	board ft.			$1	$202			$202
	• Framing @ shear wall plywood joints. Labor.	6	hours	$60	$360					$360
	• Shear wall sheathing. Struc 1 plywood.	1,134	sq. ft.	$1	$1,418	$1	$1,021			$2,438
	• Collector beam and connections to floor above @ door opening head. 2 ea 2x12, 76 lf.	304	board ft.			$2	$578			$578
	• Collector beam and connections to floor above @ door opening head. Labor	24	hours	$60	$1,440					$1,440
	• Soffit sheathing. Struc 1 plywood.	512	sq. ft.	$2	$768	$1	$461			$1,229
	• Drill and epoxy anchor bolts & rebar dowels.	104	each	$35	$3,640	$45	$4,680			$8,320
	• Drill and epoxy hold downs w/4x6 post	2	each	$70	$140	$110	$220			$360
	• Set hold downs w/4x6 post	6	each	$35	$210	$100	$600			$810
	• Clips to framing above shear walls.	126	linear ft.	$4	$480	$5	$630			$1,110
7	**Moisture Protection** Subtotal for Division: **$1,701**									
	Insulation: Batt insulation in new exterior shear walls.	1,134	sq. ft.	$1	$567	$1	$1,134			$1,701
8	**Doors, Windows, & Glass** Subtotal for Division: **$0**									

Table 5-11 Building 3: Cost Estimate for Scheme 2 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
9	**Finishes** Subtotal for Division: **$4,253**									
	Plaster: Patch openings in ceilings.	638	sq. ft.					$3	$1,914	$1,914
	Drywall: Cover shear walls, 5/8 type x, fire taped.	1,134	sq. ft.					$2	$1,701	$1,701
	Painting: Plaster soffit, seal and 2 coats.	638	sq. ft.					$1	$638	$638
10	**Specialties** Subtotal for Division: **$0**									
11	**Equipment** Subtotal for Division: **$0**									
12	**Furnishings** Subtotal for Division: **$0**									
13	**Special Construction** Subtotal for Division: **$ $0**									
14	**Conveying Systems** Subtotal for Division: **$0**									
15	**Mechanical** Subtotal for Division: **$0**									
16	**Electrical** Subtotal for Division: **$0**									
				Subtotal:	$23,268		$14,175		$37,643	$75,085
				Subtotal Check:	$75,085		Permits @ 2.4%			$1,802
							Contingency @ 15%			$11,263
				Division Subtotal Check:	$75,085		Subtotal			$88,150
							Overhead & Profit @ 25%			$22,038
							TOTAL			**$110,188**

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-12 Building 3: Cost Estimate for Scheme 3

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
1	**General Conditions** Subtotal for Division: **$11,488**									
	Personnel:									
	Foreman w/truck & phone. 2 hrs/d - 5 wks.	50	hours	$100	$5,000					$5,000
	Small Tools:	1	lump sum					$500	$500	$500
	Temporary Utilities:									
	Temp. Sanitation	2	month					$125	$250	$250
	Clean - Up:									
	Daily Clean up - 1 man, 1 hr/d	25	hours	$25	$625					$625
	Final Clean up	16	hours	$25	$400					$400
	Flagman	20	hours	$25	$500					$500
	Debris removal:									
	Debris box	3	each			$575	$1,725			$1,725
	Special Inspections:									
	Welding	1	lump sum					$400	$400	$400
	Concrete cylinders	1	lump sum					$600	$600	$600
	Epoxied dowels	6	hours					$93	$558	$558
	Shear panel nailing	10	hours					$93	$930	$930
2	**Sitework** Subtotal for Division: **$9,731**									
	Demolition:									
	Cut and remove 1' strip of ceiling plaster @ walls plus removed soffit. 686 sf.	54	hours	$45	$2,430					$2,430
	Remove interior plaster from shear walls and intersecting walls. 174 x 9 = 1566 sf.	64	hours	$45	$2,880					$2,880
	Sawcut, load and haul 6" concrete floor slab. 116 lf. 3 cy.	1	lump sum						$2,153	$2,153
	Structural Excavation:									
	Excavate new footing at garage entries.	15	cubic yd.	$70	$1,068					$1,068
	Load dump truck (loader)	6	hours					$150	$900	$900
	Haul away dirt (dump truck).	4	hours					$75	$300	$300
3	**Concrete** Subtotal for Division: **$8,462**									
	Reinforcing steel:									
	6 ea #6's t&b w/#5 stirrups @ 12"oc. 58 lf. 1800#. Delivered cages.	1	lump sum					$2,562	$2,562	$2,562
	Place cages in footings	12	hours	$45	$540					$540
	Concrete footing:									
	Place concrete in 2'-6" x 2'-6" footing plus floor slab. 58 lf.	19	cubic yd.	$44	$840	$140	$2,660			$3,500
	Concrete pump	1						$1,600	$1,600	$1,600
	Finish slab on grade:									
	Smooth trowel finish concrete garage slab at top of footing. 3' x 58'.	4	hours	$65	$260					$260

Table 5-12 Building 3: Cost Estimate for Scheme 3 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
4	**Masonry** Subtotal for Division: $0									
5	**Metals** Subtotal for Division: $8,220									
	Structural Steel: Steel moment cantilevered columns, 10', 12WF45. 6ea. Delivered.	1	lump sum					$6,100	$6,100	$6,100
	Hang 6 ea steel columns ready for embedment in footings.	32	hours	$60	$1,920		$200			$2,120
6	**Carpentry** Subtotal for Division: $19,945									
	Rough Carpentry:									
	• Framing @ shear wall plywood joints. Material.	265	board ft.			$1	$278			$278
	• Framing @ shear wall plywood joints. Labor.	8	hours	$60	$480					$480
	• Shear wall sheathing. Struc 1 plywood.	1,566	sq. ft.	$1	$1,958	$1	$1,409			$3,367
	• Soffit sheathing. Struc 1 plywood.	512	sq. ft.	$2	$768	$1	$461			$1,229
	• Collector beam and connections to floor above @ door opening head. 2 ea 2x12, 58 lf.	232	board ft.			$2	$441			$441
	• Collector beam and connections to floor above @ door opening head. Labor	20	hours	$60	$1,200					$1,200
	• Drill and epoxy anchor bolts & rebar dowels.	112	each	$35	$3,920	$45	$5,040			$8,960
	• Drill and epoxy hold downs w/4x6 post	14	each	$70	$980	$110	$1,540			$2,520
	• Clips to framing above shear walls.	174	linear ft.	$3	$600	$5	$870			$1,470
7	**Moisture Protection** Subtotal for Division: $2,349									
	Insulation: Batt insulation in new exterior shear walls.	1,566	sq. ft.	$1	$783	$1	$1,566			$2,349
8	**Doors, Windows, & Glass** Subtotal for Division: $ $0									

Table 5-12 Building 3: Cost Estimate for Scheme 3 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
9	**Finishes** Subtotal for Division: **$5,093**									
	Plaster: Patch openings in ceilings.	686	sq. ft.					$3	$2,058	$2,058
	Drywall: Cover shear walls, 5/8 type x, fire taped.	1,566	sq. ft.					$2	$2,349	$2,349
	Painting: Plaster soffit, seal and 2 coats.	686	sq. ft.					$1	$686	$686
10	**Specialties** Subtotal for Division: **$0**									
11	**Equipment** Subtotal for Division: **$0**									
12	**Furnishings** Subtotal for Division: **$0**									
13	**Special Construction** Subtotal for Division: **$0**									
14	**Conveying Systems** Subtotal for Division: **$0**									
15	**Mechanical** Subtotal for Division: **$0**									
16	**Electrical** Subtotal for Division: **$0**									
			Subtotal:		$27,152		$16,190		$21,945	$65,287
			Subtotal Check:		$65,287		Permits @ 2.4%			$1,567
							Contingency @ 15%			$9,793
			Division Subtotal Check:		$65,287		Subtotal			$76,647
							Overhead & Profit @ 25%			$19,162
							TOTAL			**$95,809**

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-13 Building 4: Summary of Cost Estimates for All Schemes

Division	Description	SCHEME 1 Shear Walls Only		SCHEME 2 Moment Frames & Shear Walls		SCHEME 3 Cantilevered Columns & Shear Walls	
		Subtotal	Total	Subtotal	Total	Subtotal	Total
1	**General Conditions**		**$9,352**		**$10,091**		**$9,291**
	Personnel	4,000		4,000		4,000	
	Small Tools	500		500		500	
	Temporary Utilities	125		125		125	
	Clean - Up	1,400		1,400		1,400	
	Debris Removal	1,725		1,150		1,150	
	Testing & Inspections	1,602		2,916		2,116	
2	**Sitework**		**$4,854**		**$4,976**		**$6,774**
	Demolition	3,814		3,656		4,794	
	Structural Excavation	1,040		1,320		1,980	
3	**Concrete**		**$1,819**		**$4,953**		**$6,372**
	Reinforcing Steel	709		1,693		2,478	
	Concrete Footing	980		3,000		3,634	
	Finish Slab	130		260		260	
4	**Masonry**						
	None						
5	**Metals**		**$0**		**$7,475**		**$3,157**
	Structural Steel	0		7,475		3,157	
6	**Carpentry**		**$13,017**		**$9,475**		**$10,314**
	Rough Carpentry	13,017		9,475		10,314	
7	**Moisture Protection**		**$1,917**		**$1,134**		**$1,134**
	Insulation	1,917		1,134		1,134	
8	**Doors, Windows, & Glass**	-					
	None						
9	**Finishes**		**$2,493**		**$2,238**		**$2,750**
	Lath & Plaster	426		828		1,212	
	Drywall	1,917		1,134		1,134	
	Painting	150		276		404	
10	**Specialties**						
	None						
11	**Equipment**						
	None						
12	**Furnishings**						
	None						
13	**Special Construction**						
	None						
14	**Conveying Systems**						
	None						
15	**Mechanical**						
	None						
16	**Electrical**						
	None						
	Subtotal	33,451	**$33,451**	40,342	**$40,342**	39,792	**$39,792**
	Building Permit @ 2.4%		**$803**		**$968**		**$955**
	Contingency @ 15%		**$5,018**		**$6,051**		**$5,969**
	Subtotal		**$39,272**		**$47,362**		**$46,715**
	Overhead & Profit @ 25%		**$9,818**		**$11,840**		**$11,679**
	Total		**$49,090**		**$59,202**		**$58,394**

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-14 Building 4: Cost Estimate for Scheme 1

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
1	**General Conditions** Subtotal for Division: **$9,352**									
	Personnel:									
	Foreman w/truck & phone. 2 hours/day - 4 weeks.	40	hours	$100	$4,000					$4,000
	Small Tools:	1	lump sum					$500	$500	$500
	Temporary Utilities:									
	Temp. Sanitation	1	months					$125	$125	$125
	Clean - Up:									
	Daily Clean up - 1 man, 1 hr/d	20	hours	$25	$500					$500
	Final Clean up	16	hours	$25	$400					$400
	Flagman	20	hours	$25	$500					$500
	Debris removal:									
	Debris box	3	each			$575	$1,725			$1,725
	Special Inspections:									
	Concrete cylinders	1	lump sum					$300	$300	$300
	Epoxied dowels	6	hours					$93	$558	$558
	Shear panel nailing	8	hours					$93	$744	$744
2	**Sitework** Subtotal for Division: **$4,854**									
	Demolition:									
	Cut and remove 1' strip of ceiling plaster @ walls. 142 sf.	16	hours	$45	$720					$720
	Remove interior plaster from shear walls and intersecting walls. 150 x 9 = 1350 sf.	56	hours	$45	$2,520					$2,520
	Sawcut, load and haul 6" concrete floor slab. 16 lf. 0.5 cy.	1	lump sum					$574	$574	$574
	Structural Excavation:									
	Excavate new footing at garage entries.	2	cubic yd.	$70	$140					$140
	Load dump truck (loader)	4	hours					$150	$600	$600
	Haul away dirt (dump truck).	4	hours					$75	$300	$300
3	**Concrete** Subtotal for Division: **$1,819**									
	Reinforcing steel:									
	6 ea #6's t&b w/#5 stirrups @ 12"oc. 8 lf. 250#. Delivered cage.	1	lump sum					$529	$529	$529
	Place cages in footings	4	hours	$45	$180					$180
	Concrete footing:									
	Place concrete in 2'-6" x 2'-6" footing plus floor slab w/o pump. 8 lf.	3	cubic yd.	$187	$560	$140	$420			$980
	Finish slab on grade:									
	Smooth trowel finish concrete garage slab at top of footing. 3' x 8'.	2	hours	$65	$130					$130

Table 5-14 Building 4: Cost Estimate for Scheme 1 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
4	**Masonry** Subtotal for Division: **$0**									
5	**Metals** Subtotal for Division: **$0**									
	None.									
6	**Carpentry** Subtotal for Division: **$13,017**									
	Rough Carpentry:									
	• Framing @ shear wall plywood joints and new shear walls. Material.	342	board ft.			$1	$359			$359
	• Framing @ shear wall plywood joints and new shear walls. Labor.	8	hours	$60	$480					$480
	• Shear wall sheathing. Struc 1 plywood.	1,278	sq. ft.	$1	$1,598	$1	$1,150			$2,748
	• Drill and epoxy anchor bolts & rebar dowels.	76	each	$35	$2,660	$45	$3,420			$6,080
	• Drill and epoxy hold downs w/4x6 post	12	each	$70	$840	$110	$1,320			$2,160
	• Clips to framing above shear walls.	142	linear ft.	$3	$480	$5	$710			$1,190
7	**Moisture Protection** Subtotal for Division: **$1,917**									
	Insulation:									
	Batt insulation in new exterior shear walls.	1,278	sq. ft.	$1	$639	$1	$1,278			$1,917
8	**Doors, Windows, & Glass** Subtotal for Division: **$0**									
9	**Finishes** Subtotal for Division: **$2,493**									
	Plaster:									
	Patch openings in ceilings.	142	sq. ft.					$3	$426	$426
	Drywall:									
	Cover shear walls, 5/8 type x, fire taped.	1,278	sq. ft.					$2	$1,917	$1,917
	Painting:									
	Plaster soffit, seal and 2 coats.	150	sq. ft.					$1	$150	$150

Table 5-14 Building 4: Cost Estimate for Scheme 1 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
10	**Specialties** Subtotal for Division: $0									
11	**Equipment** Subtotal for Division: $0									
12	**Furnishings** Subtotal for Division: $0									
13	**Special Construction** Subtotal for Division: $0									
14	**Conveying Systems** Subtotal for Division: $0									
15	**Mechanical** Subtotal for Division: $0									
16	**Electrical** Subtotal for Division: $0									
			Subtotal:		$16,347		$10,382		$6,723	$33,451
			Subtotal Check:		$33,451		Permits @ 2.4%			$803
							Contingency @ 15%			$5,018
			Division Subtotal Check:		$33,451		Subtotal			$39,272
							Overhead & Profit @ 25%			$9,818
							TOTAL			**$49,090**

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-15 Building 4: Cost Estimate for Scheme 2

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
1	**General Conditions** Subtotal for Division: **$10,091**									
	Personnel:									
	Foreman w/truck & phone. 2 hrs/d - 4 wks.	40	hours	$100	$4,000					$4,000
	Small Tools:	1	lump sum					$500	$500	$500
	Temporary Utilities:									
	Temp. Sanitation	1	mounths					$125	$125	$125
	Clean - Up:									
	Daily Clean up - 1 man, 1 hr/d	20	hours	$25	$500					$500
	Final Clean up	16	hours	$25	$400					$400
	Flagman	20	hours	$25	$500					$500
	Debris removal:									
	Debris box	2	each			$575	$1,150			$1,150
	Special Inspections:									
	Welding	1	lump sum					$1,200	$1,200	$1,200
	Concrete cylinders	1	lump sum					$600	$600	$600
	Epoxied dowels	6	hours					$93	$558	$558
	Shear panel nailing	6	hours					$93	$558	$558
2	**Sitework** Subtotal for Division: **$4,976**									
	Demolition:									
	Cut and remove 1' strip of ceiling plaster @ walls plus removed soffit. 276 sf.	28	hours	$45	$1,260					$1,260
	Remove interior plaster from shear walls and intersecting walls. 90 x 9 = 810 sf.	32	hours	$45	$1,440					$1,440
	Sawcut, load and haul 6" concrete floor slab. 48 lf. 1 cy.	1	lump sum					$956	$956	$956
	Structural Excavation:									
	Excavate new footing at garage entries.	6	cubic yd.	$70	$420					$420
	Load dump truck (loader)	4	hours					$150	$600	$600
	Haul away dirt (dump truck).	4	hours					$75	$300	$300
3	**Concrete** Subtotal for Division: **$4,953**									
	Reinforcing steel:									
	6 ea #6's t&b w/#5 stirrups @ 12"oc. 24 lf. 750#. Delivered cages.	1	lump sum					$1,423	$1,423	$1,423
	Place cages in footings	6	hours	$45	$270					$270
	Concrete footing:									
	Place concrete in 2'-6" x 2'-6" footing plus floor slab. 24'.	7	cubic yd.	$60	$420	$140	$980			$1,400
	Concrete pump	1	lump sum					$1,600	$1,600	$1,600
	Finish slab on grade:									
	Smooth trowel finish concrete garage slab at top of footing. 3' x 24'.	4	lump sum	$65	$260					$260

Table 5-15 Building 4: Cost Estimate for Scheme 2 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
4	**Masonry** Subtotal for Division: **$0**									
5	**Metals** Subtotal for Division: **$7,475**									
	Structural Steel: Steel moment frame, 8' x 24' W12x45 w/RBS. 1 ea. Erected on anchor bolts in new concrete footings with field welding. Braced at midpoint to diaphram above.	1	lump sum					$7,475	$7,475	$7,475
6	**Carpentry** Subtotal for Division: **$9,475**									
	Rough Carpentry:									
	• Framing @ shear wall plywood joints. Material.	216	board ft.			$1	$227			$227
	• Framing @ shear wall plywood joints. Labor.	6	hours	$60	$360					$360
	• Shear wall sheathing. Struc 1 plywood.	756	sq. ft.	$1	$945	$1	$680			$1,625
	• Soffit sheathing. Struc 1 plywood.	192	sq. ft.	$2	$288	$1	$173			$461
	• Collector beam and connections to floor above @ door opening head. 2 ea 2x12, 24 lf.	96	board ft.			$2	$182			$182
	• Collector beam and connections to floor above @ door opening head. Labor	8	hours	$60	$480					$480
	• Drill and epoxy anchor bolts & rebar dowels.	46	each	$35	$1,610	$45	$2,070			$3,680
	• Drill and epoxy hold downs w/4x6 post	10	each	$70	$700	$110	$1,100			$1,800
	• Clips to framing above shear walls.	84	linear ft.	$3	$240	$5	$420			$660
7	**Moisture Protection** Subtotal for Division: **$1,134**									
	Insulation: Batt insulation in new exterior shear walls.	756	sq. ft.	$1	$378	$1	$756			$1,134
8	**Doors, Windows, & Glass** Subtotal for Division: **$0**									

Table 5-15 Building 4: Cost Estimate for Scheme 2 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
9	**Finishes** Subtotal for Division: **$2,238**									
	Plaster:									
	Patch openings in ceilings.	276	sq. ft.					$3	$828	$828
	Drywall:									
	Cover shear walls, 5/8 type x, fire taped.	756	sq. ft.					$2	$1,134	$1,134
	Painting:									
	Plaster soffit, seal and 2 coats.	276	sq. ft.					$1	$276	$276
10	**Specialties** Subtotal for Division: **$0**									
11	**Equipment** Subtotal for Division: **$0**									
12	**Furnishings** Subtotal for Division: **$0**									
13	**Special Construction** Subtotal for Division: **$0**									
14	**Conveying Systems** Subtotal for Division: **$0**									
15	**Mechanical** Subtotal for Division: **$0**									
16	**Electrical** Subtotal for Division: **$0**									
			Subtotal:		$14,471		$7,738		$18,133	$40,342
			Subtotal Check:		$40,342		Permits @ 2.4%			$968
							Contingency @ 15%			$6,051
			Division Subtotal Check:		$40,342		Subtotal			$47,362
							Overhead & Profit @ 25%			$11,840
							TOTAL			**$59,202**

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

Table 5-16 Building 4: Cost Estimate for Scheme 3

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
1	**General Conditions** Subtotal for Division: **$9,291**									
	Personnel:									
	Foreman w/truck & phone. 2 hours/day - 5 weeks.	40	hours	$100	$4,000					$4,000
	Small Tools:	1	lump sum					$500	$500	$500
	Temporary Utilities:									
	Temporary Sanitation	1	months					$125	$125	$125
	Clean - Up:									$500
	Daily Clean up - 1 man, 1 hr/d	20	hours	$25	$500					$400
	Final Clean up	16	hours	$25	$400					$500
	Flagman	20	hours	$25	$500					
	Debris removal:									
	Debris box	2	each			$575	$1,150			$1,150
	Special Inspections:									
	Welding	1	lump sum					$400	$400	$400
	Concrete cylinders	1	lump sum					$600	$600	$600
	Epoxied dowels	6	hours					$93	$558	$558
	Shear panel nailing	6	hours					$93	$558	$558
2	**Sitework** Subtotal for Division: **$6,774**									
	Demolition:									
	Cut and remove 1' strip of ceiling plaster @ walls plus removed soffit. 404 sf.	32	hours	$45	$1,440					$1,440
	Remove interior plaster from shear walls and intersecting walls. 90 x 9 = 810 sf.	32	hours	$45	$1,440					$1,440
	Sawcut, load and haul 6" concrete floor slab. 80 lf. 2 cy.	1	lump sum					$1,914	$1,914	$1,914
	Structural Excavation:									
	Excavate new footing at garage entries.	9	cubic yd.	$70	$630					$630
	Load dump truck (loader)	6	hours					$150	$900	$900
	Haul away dirt (dump truck).	6	hours					$75	$450	$450
3	**Concrete** Subtotal for Division: **$6,372**									
	Reinforcing steel:									
	6 ea #6's t&b w/#5 stirrups @ 12"oc. 40 lf. 1240#. Delivered cages.	1	lump sum					$1,938	$1,938	$1,938
	Place cages in footings	12	hours	$45	$540					$540
	Concrete footing:									
	Place concrete in 2'-6" x 2'-6" footing plus floor slab. 40 lf.	12	cubic yd.	$29	$354	$140	$1,680			$2,034
	Concrete pump	1						$1,600	$1,600	$1,600
	Finish slab on grade:									
	Smooth trowel finish concrete garage slab at top of footing. 3' x 40'.	4	hours	$65	$260					$260

Table 5-16 Building 4: Cost Estimate for Scheme 3 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
4	**Masonry** Subtotal for Division: **$0**									
5	**Metals** Subtotal for Division: **$3,157**									
	Structural Steel:									
	Steel moment cantilevered columns, 10', 12WF45. 2ea. Delivered.	1	lump sum					$2,237	$2,237	$2,237
	Hang 6 ea steel columns ready for embedment in footings.	12	hours	$60	$720		$200			$920
6	**Carpentry** Subtotal for Division: **$10,314**									
	Rough Carpentry:									
	• Framing @ shear wall plywood joints. Material.	216	board ft.			$1	$227			$227
	• Framing @ shear wall plywood joints. Labor.	6	hours	$60	$360					$360
	• Shear wall sheathing. Struc 1 plywood.	756	sq. ft.	$1	$945	$1	$680			$1,625
	• Soffit sheathing. Struc 1 plywood.	320	sq. ft.	$2	$480	$1	$288			$768
	• Collector beam and connections to floor above @ door opening head. 2 ea 2x12, 40 lf.	160	board ft.			$2	$304			$304
	• Collector beam and connections to floor above @ door opening head. Labor	14	hours	$60	$840					$840
	• Drill and epoxy anchor bolts & rebar dowels.	46	each	$35	$1,610	$45	$2,070			$3,680
	• Drill and epoxy hold downs w/4x6 post	10	each	$70	$700	$110	$1,100			$1,800
	• Clips to framing above shear walls.	84	linear ft.	$3	$290	$5	$420			$710
7	**Moisture Protection** Subtotal for Division: **$1,134**									
	Insulation:									
	Batt insulation in new exterior shear walls.	756	sq. ft.	$1	$378	$1	$756			$1,134
8	**Doors, Windows, & Glass** Subtotal for Division: **$0**									

Table 5-16 Building 4: Cost Estimate for Scheme 3 (continued)

Division	Description	Quantity	Unit	Labor		Material		Subcontractor		Total
				Unit Cost	Labor	Unit Cost	Material	Unit Cost	Subcontractor	
9	**Finishes** Subtotal for Division: **$2,750**									
	Plaster: Patch openings in ceilings.	404	sq. ft.					$3	$1,212	$1,212
	Drywall: Cover shear walls, 5/8 type x, fire taped.	756	sq. ft.					$2	$1,134	$1,134
	Painting: Plaster soffit, seal and 2 coats.	404	sq. ft.					$1	$404	$404
10	**Specialties** Subtotal for Division: **$0**									
11	**Equipment** Subtotal for Division: **$0**									
12	**Furnishings** Subtotal for Division: **$0**									
13	**Special Construction** Subtotal for Division: **$0**									
14	**Conveying Systems** Subtotal for Division: **$0**									
15	**Mechanical** Subtotal for Division: **$0**									
16	**Electrical** Subtotal for Division: **$0**									
				Subtotal:	$16,386		$8,875		$14,530	$39,792
				Subtotal Check:	$39,792		Permits @ 2.4%			$955
							Contingency @ 15%			$5,969
				Division Subtotal Check:	$39,792		Subtotal			$46,715
							Overhead & Profit @ 25%			$11,679
							TOTAL			**$58,394**

Items not included in estimates:

- relocating any conflicting utilities
- painting new shear walls: walls are not painted, but instead are covered with 5/8" Type X sheetrock and fire taped
- clearing garages of cars and tenants' possessions before construction
- no code upgrade construction for remainder of building
- costs are current for November, 2008; there is no allowance for inflation

APPENDIX 6: PROCEDURES TO EVALUATE SEISMIC HAZARDS

6.1 Seismic Setting

San Francisco is in the Coast Ranges geomorphic province that is characterized by northwest-southeast trending faults. San Francisco lies between the San Andreas fault zone to the west and the Hayward fault zone to the east, as shown on Figure 6-1. The major active faults near San Francisco are the San Andreas, Hayward, San Gregorio, Rodgers Creek and Calaveras faults. In 1999, the Working Group on California Earthquake Probabilities (WGCEP) at the U.S. Geologic Survey (USGS) predicted a 70-percent probability of a magnitude 6.7 or greater earthquake occurring in the San Francisco Bay Area by the year 2030. More specific estimates of the probabilities for different faults in the Bay Area are presented in Table 6-1.

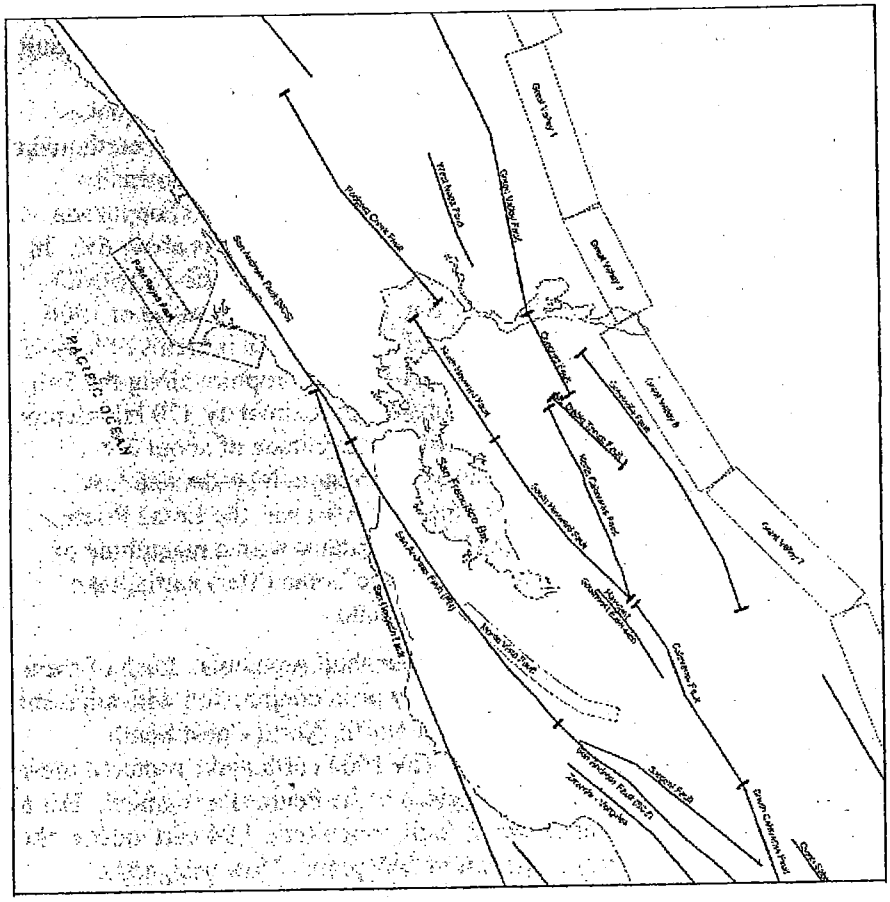

PACIFIC OCEAN
San Andreas Fault (1906)
San Andreas Fault (Peninsula)
San Gregorio Fault
Point Reyes Fault
Tomales Point Fault
Rodgers Creek Fault
Green Valley Fault
Concord Fault
Clayton Fault
Calaveras Fault
Hayward (Southeast Extension)
Hayward (Southeast Extension)
Hayward (Southeast Extension)
San Francisco Bay
Northern Hayward Fault
Southern Hayward Fault
Southern Calaveras Fault
Northern Calaveras Fault
Concord Valley
Clayton Valley
Southern Green Valley Fault
Northern Green Valley Fault
Northern Concord Fault
Southern Concord Fault
Northern Calaveras Fault
Southern Calaveras Fault
Northern Hayward Fault (1868)
Southern Hayward Fault (1868)
Seismicity
Seismicity
Seismicity

Table 6-1 WGCEP (1999) Estimates of 30-Year Probability (2000 to 2030) of a Magnitude 6.7 or Greater Earthquake

Fault	Probability (percent)
Hayward-Rodgers Creek	32
San Andreas	21
Calaveras	18
San Gregorio	10
Concord-Green Valley	6
Greenville	6

The Hayward, San Andreas and Calaveras fault systems have the highest probabilities of generating a magnitude 6.7 or greater earthquake before 2030. Because the San Andreas and Hayward fault systems are closer to San Francisco and have the highest probabilities, these faults pose greatest threat in terms of levels of ground shaking in San Francisco.

6.2 San Andreas Fault System

The dominant fault structure in the coastal California region is the San Andreas fault system. The San Andreas fault extends from the Mendocino Coast in Northern California to the Gulf of California, Mexico. Since 1800, four major earthquakes have been recorded on the San Andreas fault in the Bay Area. In 1836 an earthquake with an estimated maximum intensity of VII on the Modified Mercalli Intensity (MMI) scale occurred east of Monterey Bay on the San Andreas fault (Toppozada and Borchardt, 1998). The estimated magnitude for this earthquake is about 6¼. In 1838, an earthquake occurred with an estimated intensity of about VIII-IX (MMI), corresponding to a magnitude of about 7½. The San Francisco earthquake of 1906 caused the most significant damage in the history of the Bay Area in terms of loss of lives and property damage. This earthquake created a surface rupture along the San Andreas fault from Shelter Cove to San Juan Bautista, approximately 470 kilometers in length. It had a maximum intensity of XI (MMI), a magnitude of about 7.9 (Wallace, 1990), and was felt 560 kilometers away in Oregon, Nevada, and Los Angeles. The most recent earthquake to affect the Bay Area was the Loma Prieta earthquake of October 17, 1989, in the Santa Cruz Mountains with a magnitude of 6.9. Although there is some debate as to which fault the Loma Prieta earthquake occurred on, it possibly occurred on the San Andreas fault.

The northern San Andreas fault is subdivided into four fault segments. Each of these segments is capable of rupturing either independently or in conjunction with adjacent segments. These segments include the North Coast North, North Coast South, Peninsula and the San Cruz Mountains segment. The 1906 earthquake ruptured these four segments. The closest segment to San Francisco is the Peninsula segment. For a repeat of a 1906-type event on the San Andreas fault, magnitude 7.94 earthquake, the WGCEP (1999) calculated a recurrence interval of 361 years. They assigned a maximum magnitude earthquake of 7.2 to the Peninsula segment, with a 21 percent probability of a magnitude 6.7 or larger earthquake in the time period from 2000 to 2030 on this segment of the San Andreas fault.

6.3 Hayward Fault

The Hayward fault extends from Mount Misery, east of San Jose, to Point Pinole on San Pablo Bay. It is divided into two segments: the northern and southern Hayward fault. They are 35 and 52 km in length, respectively. The Rodgers Creek fault is the northern continuation of the Hayward fault. In 1868 an earthquake with an estimated maximum intensity of X on the MMI scale occurred on the southern segment (between San Leandro and Fremont) of the Hayward fault. The estimated magnitude for the earthquake is 6.9.

The WGCEP (1999) estimated the highest probability of the next magnitude 6.7 or greater earthquake in the Bay Area on the Hayward-Rodgers Creek fault system, with a 32 percent probability in the time period from 2000 to 2030. The WGCEP has assigned a maximum magnitude of 6.63 and 6.88, with corresponding recurrence periods of 387 and 371 years to the northern and southern segments, respectively. The WGCEP also assigned a maximum magnitude of 7.1 for a rupture of the total Hayward fault (north and south segments) with a recurrence time of 523 years.

6.4 Estimation of Ground Motions

To estimate the ground motion during an earthquake at each intersection in San Francisco, a deterministic analysis was performed using four scenario earthquakes. The closest distance from the site to the fault rupture was calculated. The coordinates for the faults were obtained from California Division of Mine and Geology (CDMG, 1996). For a given scenario event, median estimates of the spectral acceleration for periods of 0.0 (peak ground acceleration), 0.2 and 1.0 seconds were made using three attenuation relationships. The effects of local soil amplification were also taken into account.

6.5 Scenario Earthquakes

The four scenario earthquakes considered in this study are:

1. A moment magnitude 7.9 on the San Andreas fault, which is a repeat of the 1906 earthquake. This is the largest known earthquake to have occurred in Northern California on the San Andreas fault. It has an estimated recurrence rate of 361 years (WGCEP, 1999). For comparison, the 1998 *San Francisco Building Code* definition of Design Basis Earthquake is 10 percent probability of exceedance in 50 years, which is equivalent to a 475-year return period.
2. A moment magnitude 7.2 on the Peninsula segment of the San Andreas fault, which is the maximum postulated magnitude that could occur on the Peninsula segment (WGCEP, 1999).
3. A moment magnitude 6.5 on the Peninsula segment of the San Andreas fault. The WGECP estimates a 21 percent probability of a magnitude 6.7 or greater earthquake occurring on the San Andreas in the next 30 years.
4. A magnitude 6.9 on the Hayward fault.

6.6 Attenuation Relationships

We used three recent spectral attenuation relationships for estimating spectral accelerations in this study. They are:

- Abrahamson and Silva (1997);

- Campbell (1997); and
- Sadigh *et al.* (1997).

Each of these attenuation relationships provides estimates of spectral accelerations for rock and stiff soil conditions. Because Boore et al. (1997) is not valid for moment magnitudes greater than 7.5, this relationship was not included in this study, for the sake of consistency.

6.7 Amplification of Ground Shaking—Local Site Conditions

Amplification of ground shaking to account for local site conditions is based on the site classes and soil amplification factors proposed for the *1997 NEHRP Provisions for Seismic Regulations for New Buildings and Other Structures (NEHRP Provisions)*. The classification is based on the average shear wave velocity of the upper 30 meters of the local Geology, as shown in Table 6-2.

The United States Geological Survey (USGS) has developed a map of the San Francisco Bay Area, which delineates the site class types based on the NEHRP classification (ArcInfo files were downloaded from the USGS site at samoa.wr.usgs.gov). Figure 6-2 presents site classes for the City and County of San Francisco.

Table 6-2 Site Classes (from the 1997 *NEHRP Provisions for Seismic Regulations for New Buildings and Other Structures)*

Site Class	Site Class Description	Shear Wave Velocity (m/s)
A	Hard Rock (Eastern United States only)	At least 1,500
B	Rock	760 to 1,500
C	Very Dense Soil and Rock	360 to 760
D	Stiff Soils	180 to 360
E	Soft Soils, 10 feet or more of soft clay	Less than 180

Median estimates of spectral accelerations were calculated for site classes B and D, using the average of Abrahamson and Silva (1997), Campbell (1997) and Sadigh et al. (1997) attenuation relationships for rock and soil, respectively. Site class C represents an intermediate condition between rock (class B) and stiff soil (class D). Therefore, spectral accelerations for class C sites were developed using the average of rock and soil values obtained from the three proposed attenuation relationships. Because the three attenuation relationships proposed for use in this study do not provide estimates of spectral accelerations for soft soil sites (class E), spectral values for this class were estimated using a two step approach. First, rock spectral accelerations (class B) were estimated using the attenuation relationships; these values were then adjusted using the NEHRP soil amplification values for site class E, as presented in Table 6-3.

The *NEHRP Provisions* do not provide site class E amplification factors when $S_{AS} > 1$ or $S_{A1} > 0.4$. Values for these conditions were obtained from HAZUS®99-SR1 Technical Manual.

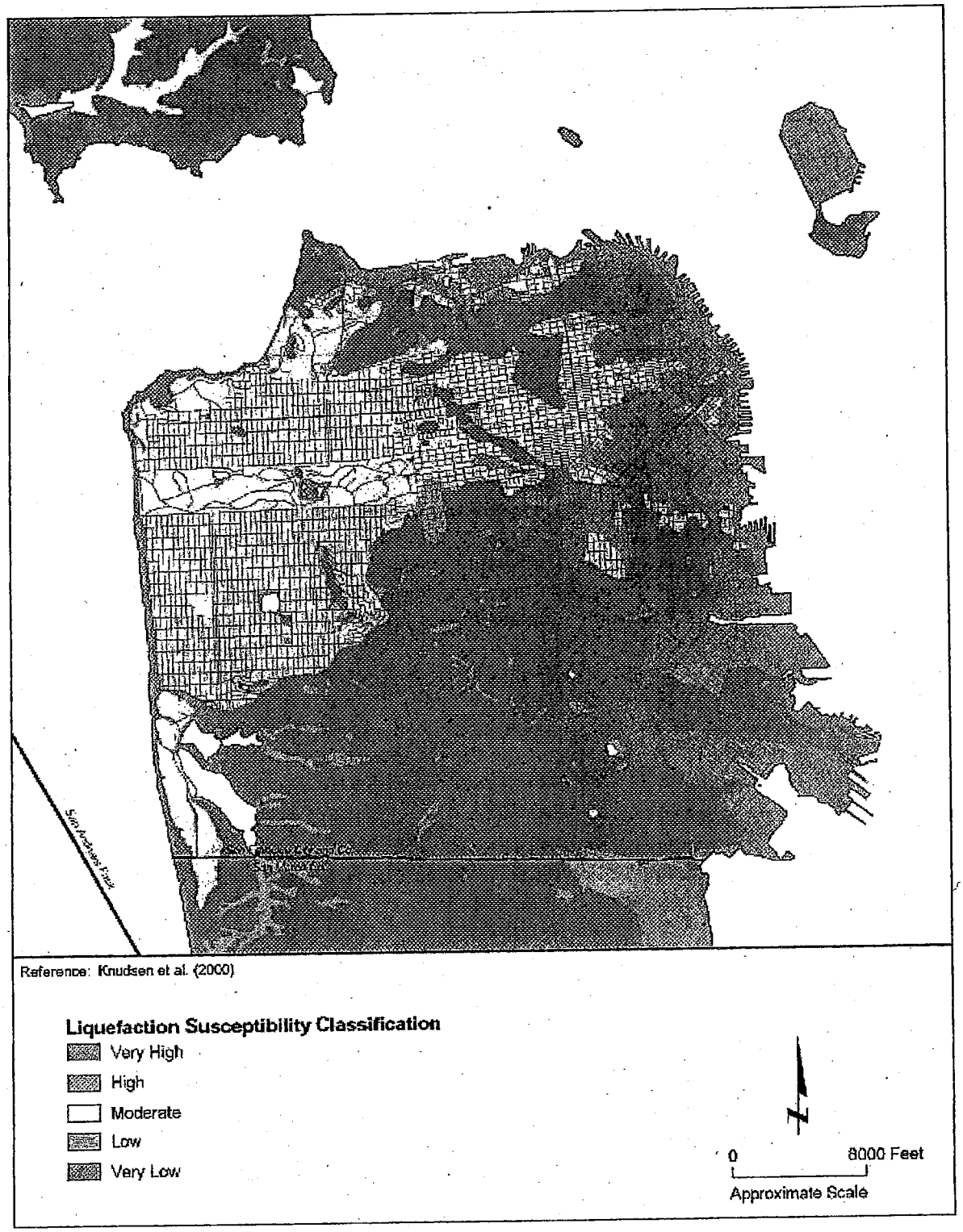


Figure 6-2 *Liquefaction susceptibility map of San Francisco (Source: Treadwell & Rollo).*

Table 6-3 NEHRP Soil Amplification Factors

Site Class B Spectral Acceleration	Site Class E Amplification Factor
Short Period, S_{AS} (g)	
≤0.25	2.5
0.50	1.7
0.75	1.2
1.0	0.9
≥1.25	0.8*
1-Second Period, S_{A1} (g)	
≤0.1	3.5
0.2	3.2
0.3	2.8
0.4	2.4
≥0.5	2.0*

6.8 Liquefaction Susceptibility

Liquefaction is a phenomenon in which loose, saturated, cohesionless soil experiences temporary reduction in strength during cyclic loading, such as that produced by earthquakes. Liquefaction can result in permanent ground displacements, such as lateral spreading, settlement and loss of bearing capacity. Knudsen et al. (2000) have addressed the liquefaction susceptibility of various types of soil deposits in the Bay Area by assigning a qualitative susceptibility rating based on general depositional environment and geologic ages of the deposit. The Knudsen et al. (2000) study assigned a relative liquefaction susceptibility rating (e.g., very low, low, moderate, high, and very high) to each soil deposit. These ratings are broad, and general classifications may vary within the deposit. Mapped areas characterized as rock are not considered to pose a liquefaction hazard.

Peak ground acceleration (PGA) value is used to evaluate liquefaction potential. We used a qualitative approach to evaluate liquefaction potential. Table 6-4 presents general estimates of the threshold PGA required to trigger liquefaction for each of the liquefaction susceptibility ratings, as discussed by Knudsen et al. (2000). The PGA's that are presented in Table 6-4 are estimates only and are provided to indicate relative levels of shaking necessary to liquefy different geologic units. Figure 6-3 presents the liquefaction susceptibility map as developed by Knudsen *et al.* (2000).

Liquefaction potential for different areas within the City was evaluated by comparing the computed PGA's for each scenario earthquake to the threshold PGA. Where the computed PGA exceeds the threshold PGA, the area was designated as liquefiable. Considering the significant variations in subsurface conditions and lack of detailed knowledge about specific sites, this approach was intended to provide a qualitative evaluation of liquefaction susceptibility. Therefore, some judgment may be needed in designating certain areas of the City as liquefiable for a particular earthquake scenario.

Table 6-4 Threshold PGA Required to Trigger Liquefaction

Mapped Relative Susceptibility	Threshold PGA (g's)
Very High	0.1
High	0.2
Moderate	0.3
Low	0.5
Very Low	0.6

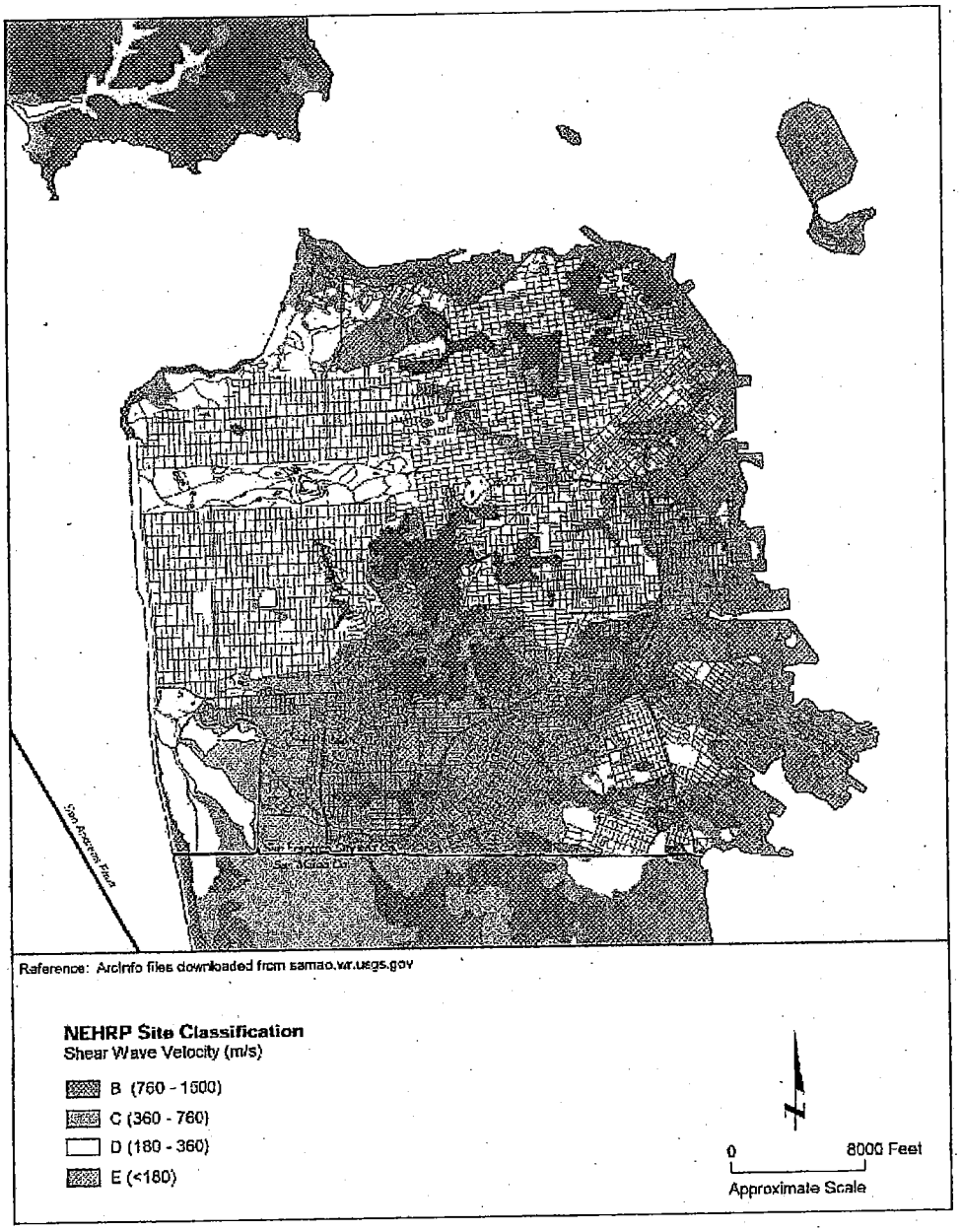


Figure 6-3 NEHRP site classification map of San Francisco. (Source: Treadwell & Rollo).

APPENDIX 7: COMPONENT FRAGILITY FUNCTIONS FOR OLDER WOOD-FRAME CONSTRUCTION

7.1 Executive Summary

Fragility functions for older (pre-1940), large, soft-story wood-frame dwellings were developed based on laboratory tests and post-earthquake observations for use in a study for the City of San Francisco's Community Action Plan for Seismic Safety (CAPSS). The functions are expressed in terms of San Francisco Planning and Urban Research Association (SPUR) performance categories A, B, C, D, and E, which equate with ATC-20 post-earthquake safety evaluation (ATC-1989) green, yellow, and red tag (placard) colors and HAZUS®-MH damage states, as shown in Table 7-1. Drifts associated with green and yellow tags were estimated using laboratory testing of common building components. The drift at which red-tagging occurs was estimated either from drift at which straight sheathing reaches ultimate strength (nails severely deformed), or from estimates by Deierlein (personal communication) of the transient drift (5%) at which wood-frame buildings experience 2% residual drift. Collapse was estimated using two approaches: (1) based on a fraction of square footage in the complete structural damage state (the HAZUS®-MH approach), or (2) based on a survey of corner apartment buildings in the Marina District by Harris and Egan (1992) after the 1989 Loma Prieta earthquake. For each damage state, Table 7-1 shows a range of median drift capacities interpreted from the evidence. Figure 7-1 illustrates fragility functions, estimated by different methods, for the various damage states shown in Table 7-1.

Table 7-1 Comparison of Various Damage State Characterizations and Estimates of Building Drift Capacities

Damage State				Spectral Displacement, Inches	
SPUR		ATC-20 tag	HAZUS®	Median S_d	β
A	Safe and operational	Green	Slight	0.06 - 0.4	1.0
B	Safe and usable during repair	Green	Moderate	0.4 - 1.5	1.0
C	Safe and usable after repair	Yellow	Extensive	1.5 - 3.0	1.0
D	Safe but not repairable	Red (no collapse)	Complete	3.0 - 5.0	1.0
E	Partial or complete collapse	Red (collapse)	Collapse	(a) - 13	0.6

Notes:
(a) lower-bound uses standard HAZUS®-MH approach for collapse

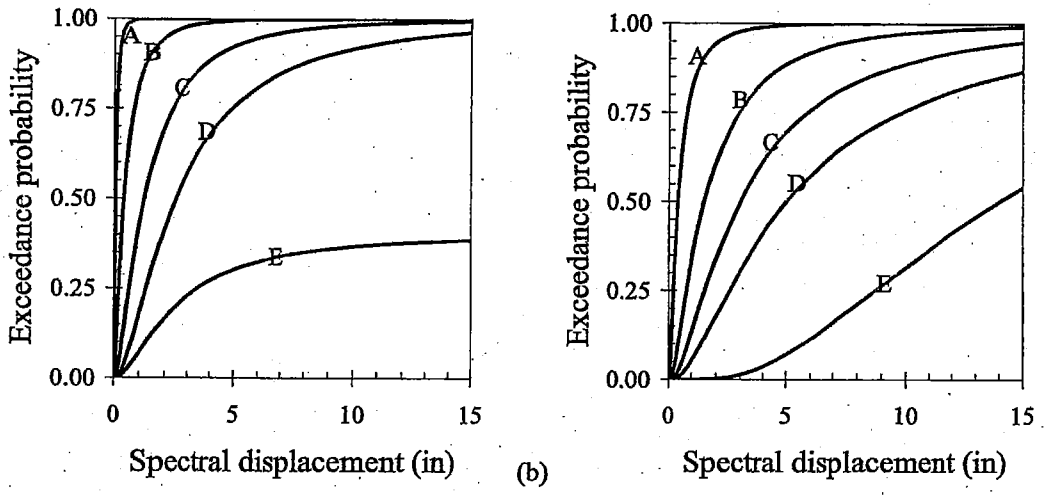


Figure 7-1 *CAPSS soft-story fragility functions (a) using the lower spectral displace, S_d, values interpreted from tests and a HAZUS®-MH approach to collapse, and (b) using the larger S_d values from tests and using earthquake evidence of collapse fragility. See Table 7-1 for definitions of A, B, C, D, and E.*

7.2 Objectives and Scope of Work

Soft-story wood-frame buildings in California have been observed to be particularly susceptible to collapse in earthquakes. This report proposes fragility information for use in estimating seismic risk to wood-frame, multifamily dwellings at least three stories tall, with at least five housing units and with soft-story conditions on the ground floor. This type of construction is of particular concern to the City of San Francisco. Several buildings of this type collapsed in the 1989 Loma Prieta earthquake, killing several people. Soft-story wood-frame buildings represent an ongoing concern, especially since a larger or closer rupture of the northern San Andreas fault could cause far greater damage than did the 1989 Loma Prieta earthquake, and it seems realistic to assume that these older, multifamily wood-frame dwellings with a soft-story at ground level would be particularly heavily damaged. Furthermore, there are so many buildings of this type in San Francisco that a larger or closer earthquake might eliminate a large fraction of San Francisco's housing.

CAPSS is estimating the risk posed by older soft-story wood-frame multifamily dwellings by creating models of four representative Index Buildings, and analyzing their seismic vulnerability as-is and under one or more practical seismic retrofit options. For various reasons, for this analysis of wood-frame buildings, the CAPSS project team is using the HAZUS®-MH methodology (FEMA 2003a) as encoded in the "Cracking an open safe" approach of Porter (2009c). This approach requires developing pushover curves and component fragility functions through the following tasks:

1. Identifying common building components of buildings constructed in this era and developing fragility functions for them, i.e., relationships between component forces or deformation and the probability of various levels of damage to those components;
2. Developing seismic vulnerability relationships for these buildings, i.e., relating overall repair cost as a fraction of replacement cost (new structure) to spectral acceleration response; and

3. Selecting or designing a loss-estimation methodology, performing the loss calculations, and presenting the methodology and results in meetings and in a written report.

The study described in this appendix addresses the first of these tasks.

7.3 Background on HAZUS®-MH

Like other second-generation performance-based earthquake engineering analyses, HAZUS®-MH (FEMA, 2003a) uses fragility functions for damageable building components as one important aspect of its assessment. These fragility functions relate the probability of various levels of physical damage to a structural response parameter, such as peak transient interstory drift or peak floor acceleration. In HAZUS®-MH and the ongoing FEMA-funded ATC-58 project, which seeks to bring second-generation performance-based earthquake engineering analyses to professional practice, such fragility functions are typically expressed in the form of lognormal cumulative distribution functions, i.e.,

$$P\left[D \geq d \middle| R = r\right] = \Phi\left(\frac{\ln(r/\theta)}{\beta}\right) \tag{1}$$

where D denotes a number that refers to the uncertain damage state of a given component; d denotes a particular value of D; R denotes the demand to which the component is subjected (generally a measure of structural response, i.e., a member force or deformation); r is a particular value of R; Φ is the cumulative standard normal (Gaussian) distribution function, and; θ and β are its parameters, referred to here as the median capacity and logarithmic standard deviation of capacity, respectively. A fragility function is completely defined by identifying the component to which it refers; defining the damage state in question, generally in terms of the repair efforts required to restore it to the undamaged state; defining the demand parameter R, and; by fixing the values of θ and β. Methods to derive these values from experimental data or other empirical observations are detailed in Porter et al. (2007).

HAZUS®-MH considers only two structural response parameters: spectral displacement (denoted by S_d) and spectral acceleration (S_a) at the performance point in a capacity-spectrum-method (pushover) structural analysis. The pushover curve in a HAZUS®-MH analysis has a linear part from the origin to yield (denoted by *Dy,Ay*), a perfectly plastic portion beyond the ultimate point (denoted by *Du,Au*), and an elliptical transition between the two, as illustrated in Figure 7-2. Beyond yield, hysteretic energy dissipation adds to elastic damping, so effective damping exceeds elastic. The point on the pushover curve where it intersects an idealized response spectrum (essentially a constant-acceleration segment and a constant-velocity segment) with the same effective damping ratio is the performance point, (D^*, A^*), for that earthquake. The parts of the building that are assumed to be primarily sensitive to displacement use D^* as the response parameter r in Equation (1); these parts are the structural components and parts of the nonstructural systems such as veneer, nonbearing walls, and partitions. The parts of the building that are assumed to be acceleration-sensitive use A^* as the parameter r: these parts include building contents, parapets, and most building service equipment.

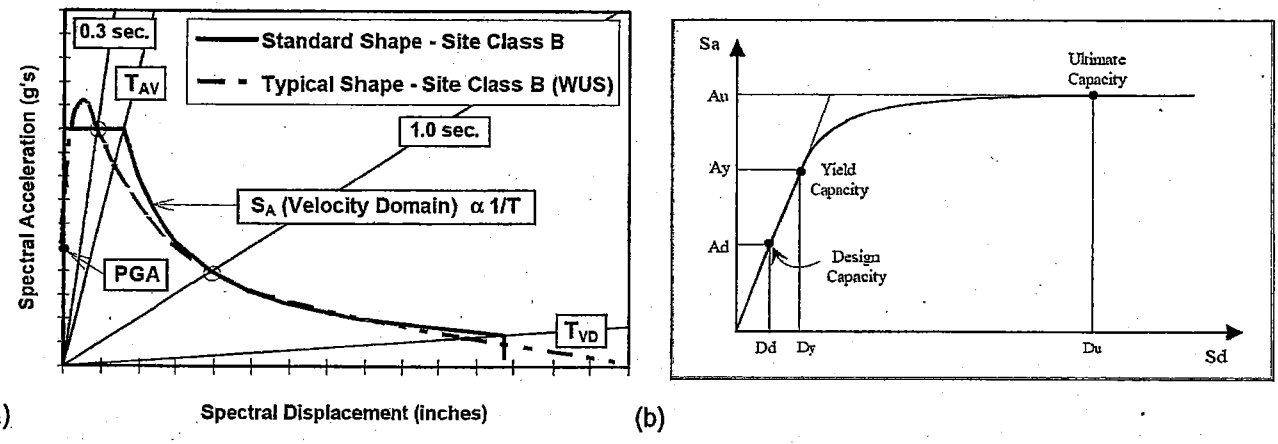


Figure 7-2 HAZUS®-MH standard response spectrum shape and capacity curve (FEMA, 2003a).

HAZUS®-MH considers only three aggregate components: the structural system (drift-sensitive), drift-sensitive nonstructural components, and acceleration-sensitive nonstructural components. Each of these components is taken as being in one of several damage states: slight, moderate, extensive, complete, and, for the structural component, collapse. The damage states are defined qualitatively but are associated with the mean damage factors (repair cost as a fraction of the total facility replacement cost) shown in Table 7-2. The three components need not be in the same damage state, so the sum and inferred range of the damage factors (shown in columns 5 and 6 of the table) simply gives a sense of the damage state; still, these sums and inferred ranges are useful for comparison with the damage states of ATC-13 (ATC, 1985), which give the damage factors for its damage states listed in Table 7-2. The table is significant, because it implies that HAZUS's "complete" damage state approximately equates with ATC-13's damage state 6, Major, while HAZUS collapse equates with ATC-13 damage state 7, Destroyed. These points will become relevant later.

Table 7-2 HAZUS®-MH and ATC-13 Damage States and Damage Factors

Damage State	Structural	Nonstructural Drift-Sensitive	Nonstructural Acceleration-Sensitive	Sum	Inferred Range	Equivalent ATC-13 Damage States	ATC-13 Range
Slight	0.003	0.009	0.008	0.02	0 - 0.05	2-3, Slight to Light	0 - 0.10
Moderate	0.014	0.043	0.043	0.10	0.05 - 0.20	3-4, Light to Moderate	0.01 - 0.30
Extensive	0.069	0.213	0.131	0.41	0.20 - 0.60	4-5, Moderate to Heavy	0.10 - 0.60
Complete	0.138	0.425	0.437	1.00	0.60 - 1.00	6. Major	0.60 - 1.00
Collapse	0.138	0.425	0.437	1.00	1.00	7. Destroyed	1.00

The probabilistic damage state of each component is estimated using fragility functions in the form of lognormal cumulative distribution functions, each involving two parameter values: median and logarithmic standard deviation of the distribution. The HAZUS®-MH documentation offers a library of fragility functions for these three components, for each of four to five damage states and each of 128 different

combinations of structure type and code era. That library is designed for societal-level risk assessment, rather than reflecting the detailed behavior of particular subcategories of dwellings. It treats all large wood-frame buildings (>5000 sq. ft., as in the typical large multifamily dwelling dealt with here) with four structure types: W2 pre-code, low code, moderate code, and high code. Most of the buildings examined here would be considered W2 pre-code. Thus, HAZUS®-MH may not provide adequate fragility information to distinguish the damageability of, for example, soft-story versus non-soft-story or brick-veneer vs. straight-sheathed buildings. The developers offer the Advanced Engineering Building Module (FEMA, 2003b) to handle such cases, but the user is required to provide the relevant fragility parameters.

Therefore, to ensure that the behavior of these particular buildings was modeled appropriately for this CAPSS study, it was necessary to develop new fragility functions that reflect the behavior of the components that probably dominate the building's force-deformation behavior, damage, and life-safety impacts. Considering the common features of this category of construction, and the likelihood that the wood-frame walls dominate the response, damage, and loss, it was necessary to create fragility functions for the categories of wall listed in Table 7-3.

Table 7-3 Wall Categories Examined in This Study

Type	Description
Straight Sheathed	2x4 full-sawn redwood studs @ 16 inches on center, toe-nailed to top and bottom plates, 1x12 horizontal straight sheathing, three 8d nail each board each stud
Stucco	Straight sheathed + 3/4-inch stucco
Brick Veneer	Straight sheathed + brick veneer (1 wythe of full bricks), flexible anchors
Wood Lath & Plaster	Wood lath and plaster interior sheathing

These wall categories needed to be associated with one of the three component categories of HAZUS®-MH. The straight sheathing is purely structural. The lath and plaster and the stucco might be considered either structural or nonstructural drift-sensitive. The brick veneer can be considered nonstructural drift-sensitive.

The fragility functions developed in this study needed to relate the spectral displacement to damage states expressed by SPUR (2008) for the post-earthquake condition of the building after the "expected" earthquake, i.e., an event producing shaking with 10% exceedance probability in 50 years. Table 7-4 provides the SPUR performance categories and descriptions.

7.4 Tests of Straight Sheathing

Little testing data that addresses the fragility of these components appears to exist, with three notable exceptions. Trayer (1956) reports on racking tests of various contemporary wood-frame wall specimens. Each specimen was approximately 9-feet high and 14-feet long, with 2x4 studs of No. 1 common well-seasoned southern yellow pine at 16-inch centers with 2x4 top and bottom plates of the same material and a double stud at each end. Each plate was connected to each stud with two 16d common nails through the plate into the ends of the studs. No vertical load was applied to the wall; to prevent overturning, hold-down rods connected the top plate to

Table 7-4 SPUR (2008) Performance Categories

Label	Description	Tag*
A	*Safe and Operational.* This defines a performance standard now in place and used for new essential facilities such as hospitals and emergency operations centers. Buildings will experience only very minor damage and will have energy power, gas, water, wastewater, and telecommunications systems to back-up any disruption to the normal utility services.	Green
B	*Safe and usable during repair.* This defines a new performance standard that is needed for buildings that will be used to shelter-in-place and for some emergency operations. Buildings will experience damage and disruption to their utility services, but no significant damage to the structural system. They may be occupied without restriction and are expected to receive a green tag (INSPECTED placard, building inspected and deemed safe for occupancy) after "expected" earthquake.	Green
C	*Safe and usable after repair.* This is the current minimum design standard for new, non-essential buildings. Buildings may experience significant structural damage that will require repairs prior to resuming unrestricted occupancy and therefore are expected to receive a yellow tag (RESTRICTED USE placard, building inspected and found to be damaged with restricted access) after "expected" earthquake.	Yellow
D	*Safe but not repairable.* This level of performance is below the standard accepted for new, non-essential buildings, but is often used as a performance goal for existing buildings undergoing voluntary rehabilitation. Buildings may experience extensive structural damage and may be on the verge of collapse. They will need to be demolished as soon as possible and therefore, are expected to receive a red tag (UNSAFE placard, building inspected, found to be seriously damaged and unsafe to occupy) after "expected" earthquake.	Red (No Collapse)
E	*Unsafe: Partial or complete collapse.* Damage that will likely lead to significant casualties in the event of an "expected" earthquake. These are the "killer" buildings that need to be addressed by a mandatory seismic mitigation program.	Red (Collapse)

* ATC-20 placard color

the testing floor on either side of the test specimen 1 to 2 feet from the end of the specimen. The specimen was subjected to in-plane, pseudostatic loading by a force applied along the axis of the upper plate (Figure 7-3). The manner of measuring the force is unclear. Displacement was measured by observing the displacement of the top plate relative to a fixed vertical line.

The author reports tests to 50 specimens with and without openings, and with various finishes, two of which are relevant here. One finish was horizontal straight sheathing on one side with square-edged 1x8, also of the same material, nailed with two 8d nails at each stud crossing. The author does not report any observations of physical damage to these specimens: for example, no mention of nail pullout, nail tear through, or splitting of framing members. There is no indication on the force-deformation curve of a sudden physical change, from which one might infer a particular damage state, and there are no observations related to unloading or residual displacement after unloading. The only indication of a particular damage state is the point of ultimate strength, where connections begin to lose strength. This is reported to occur at a drift of approximately 3 inches, or a drift ratio of 2.8%.

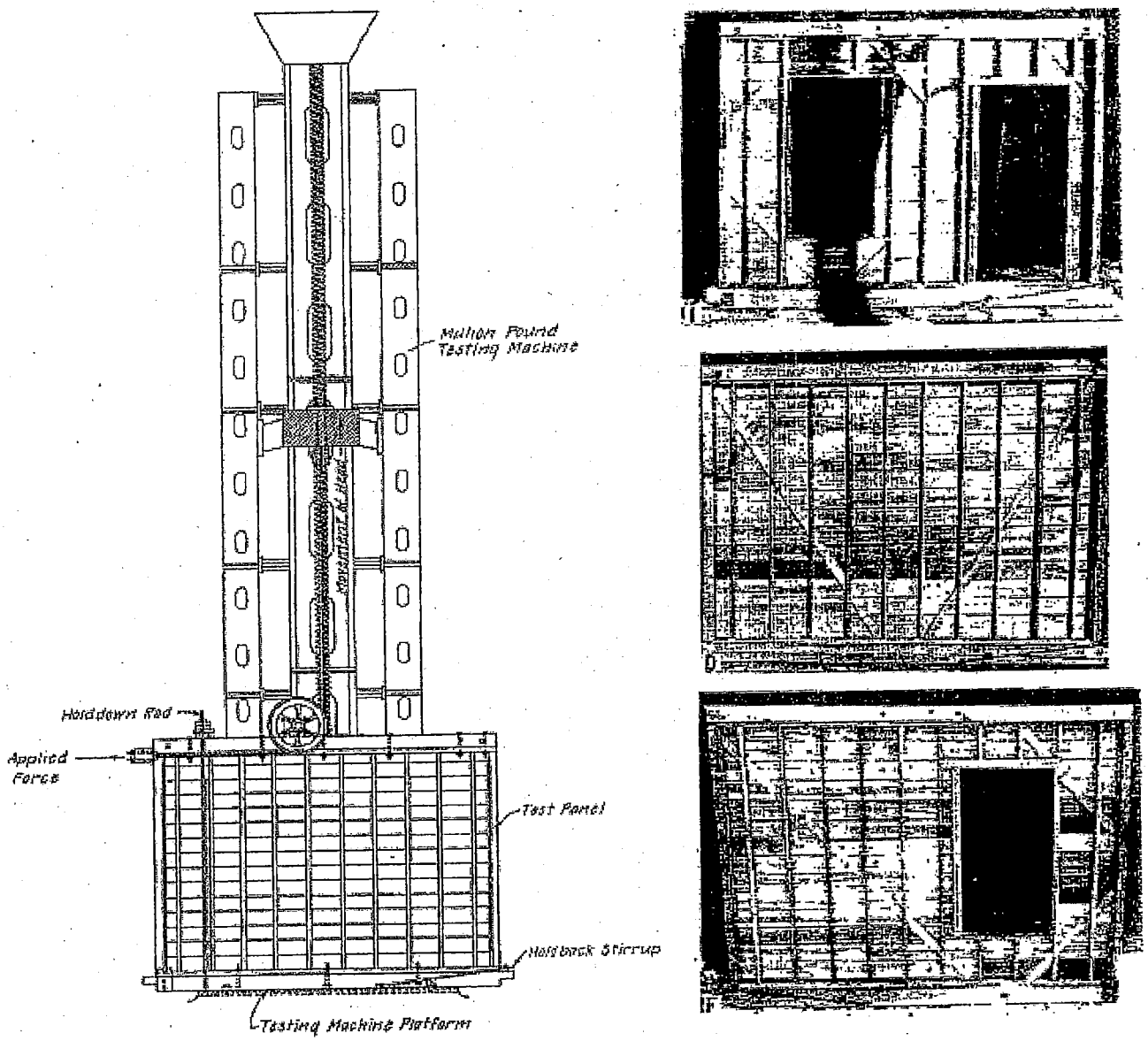


Figure 7-3 Test setup and some specimens discussed by Trayer (1956).

Trayer (1956) reports that the tests also included 6-inch straight sheathing, and 8-inch sheathing with three 8d nails at each board and stud crossing, and that both stiffness and strength were largely unchanged by these variations., He explains this by pointing out that it is the bending stiffness of the nail and the lever arm between the two adjacent nails that provide the wall's stiffness and strength. Adding a third nail in the middle of the board at the stud crossing adds neither to stiffness nor strength, as that is the neutral axis. Although with 6-inch boards, the lever arm between nails is reduced, there are proportionately more boards, and therefore more nails, for a given height of wall.

More recently, Elkhoraibi and Mosalam (2007a, b) report on full-scale dynamic tests of a two-story house and two wood-frame wall specimens with straight sheathing

(Figure 7-4). The former was tested on a shake table and the latter, by hybrid simulation and representing the lower-floor longitudinal walls of the prototype house. In hybrid simulation, the behavior of the rest of the (generally well-understood) building is computationally simulated, with force or displacements imposed dynamically on the physical substructure whose characteristics are of interest. The response of the real specimen is fed back into the computation model in real or near-real-time. The specimens are constructed of 2x4 studs at 16 inch centers, end-nailed to the double 2x4 top plate with 2-16d common nails and toe-nailed to a 3x6 sill plate with 3-16d common nails. The straight sheathing is 1x12 shiplap siding, with 3-8d common nails per board at each stud crossing. The walls are braced by V-shaped 2×4 diagonal blocking between studs (2–16d toe common nails). All lumber is Douglas Fir-Larch.

The authors' focus is not on specimen damageability but rather on a procedure for switching between force and deformation control for input to the real specimen. Limited damage data are presented. From a sample force-deformation plot that the authors provided (Figure 7-5), it appears that the combined specimens reach an ultimate-strength limit state near the end of the largest negative cycle, near 3 inches of drift (3% drift), similar to the 2.8% drift at ultimate observed by Trayer (1956) in tests of 1x8 straight-sheathed walls. They observed connection failure in the braces shown in Figure 7-6, and confirm that the deformation is accommodated by bending of the nail at the interface between the sheathing and framing.

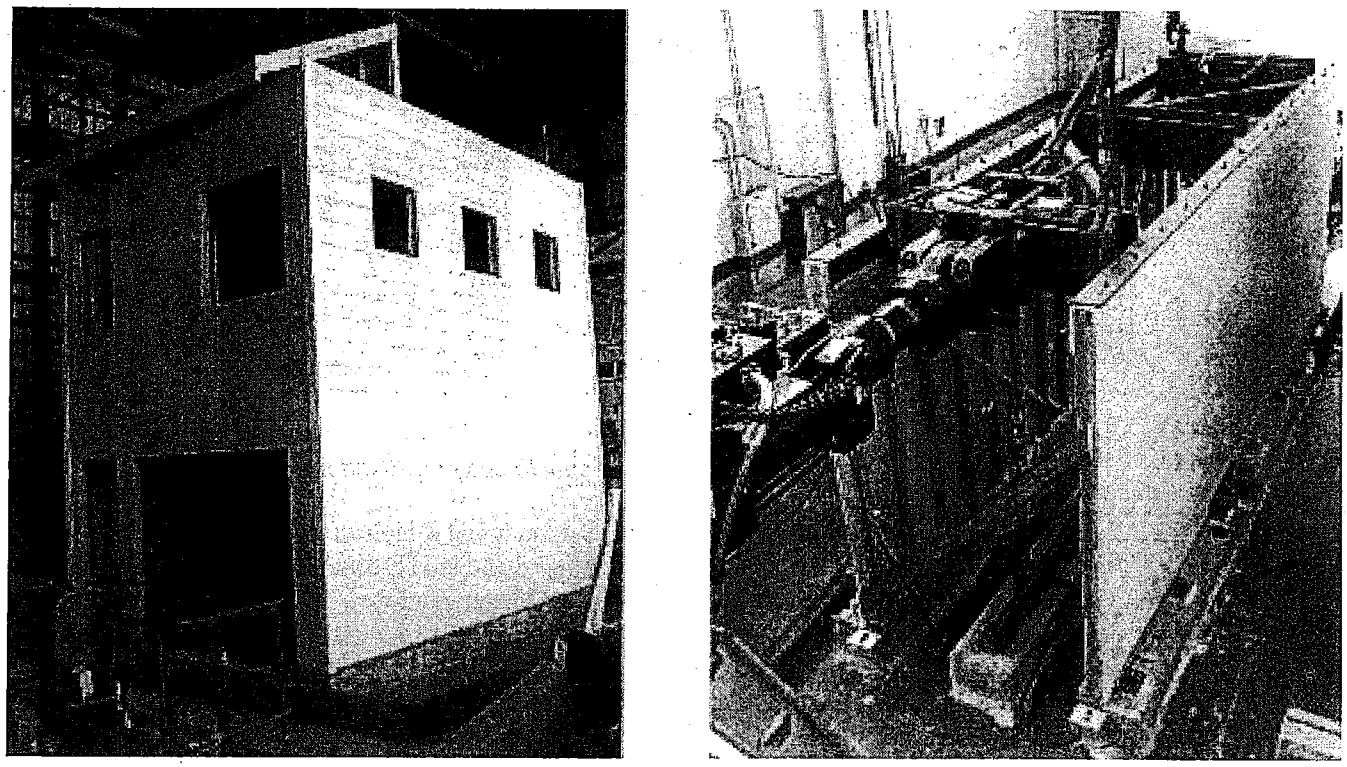


Figure 7-4 *Straight-sheathed house prototype and specimens representing the lower floor longitudinal wall tested in hybrid simulation by Elkhoraibi and Mosalam (2007).*

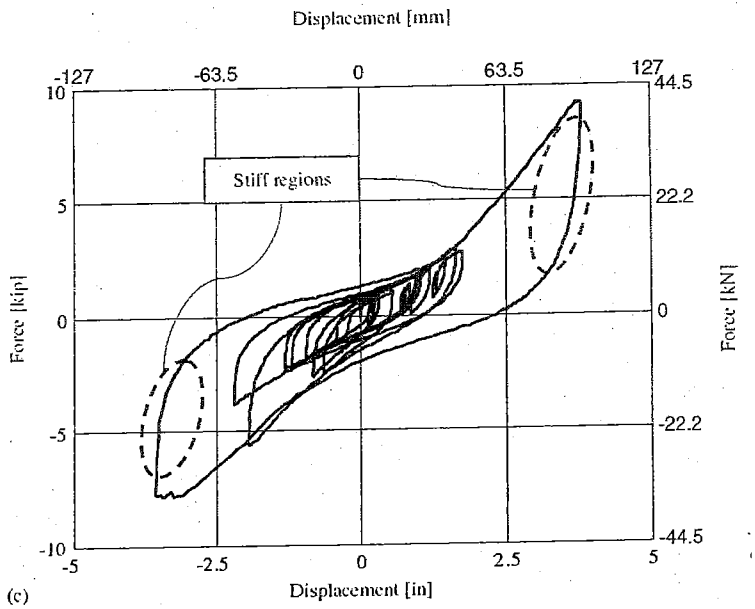


Figure 7-5 *Force deformation response from hybrid simulation of the specimen shown in Figure 7-4 (Elkhoraibi and Mosalam 2007).*

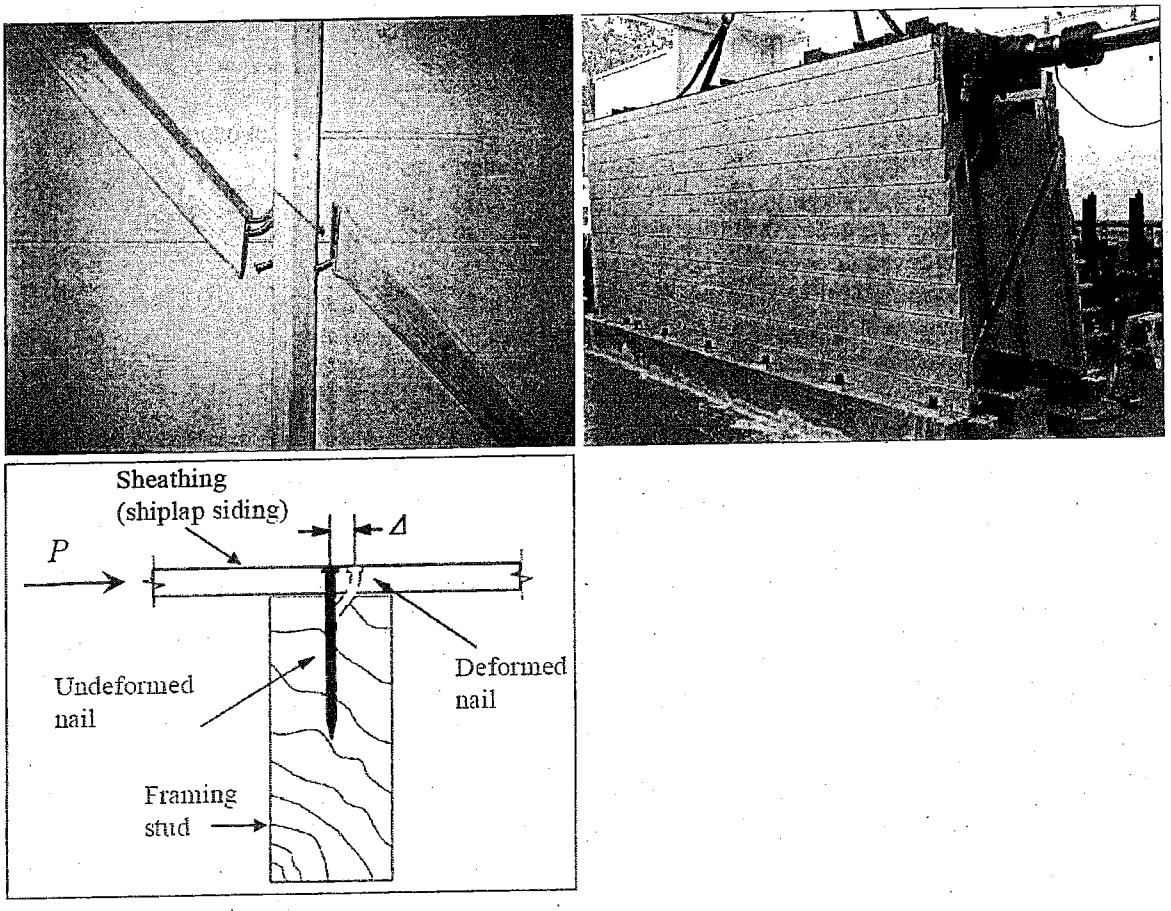


Figure 7-6 *Damage and deformed shape observed in hybrid simulation tests by Elkhoraibi and Mosalam (2007).*

7.5 Tests of Wood Lath and Plaster

Trayer (1956) also reports on the performance of wood lath and plaster: 4-foot horizontal boards nailed to studs with 3d nails and with a ¼-inch vertical gap between each lath course. A ¾-inch ground coat was applied, along with a finish coat of unspecified thickness. Wall testing was performed after one week of aging. Lath and plaster ceilings tend to crack after about 35 to 45 years and continue to deteriorate until they need replacement, after about 80 to 100 years, but lath and plaster walls are usually dependable for 100 to 120 years or more. Therefore, 1956 tests of new walls are probably appropriate to the fragility of 70-year-old walls.

Trayer (1956) reports that walls with openings tended to develop cracks at the corners of openings, when the drift reached "a few hundredths of an inch." This is consistent with the statement that cracks developed when in-plane loading reached 800 to 1300 lb in a specimen with an in-plane shear stiffness of 12.9 kip/in (secant stiffness measured at 0.1 in displacement), indicating cracking drift ratios between 0.057 to 0.093% peak transient drift. One could associate that damage state with the requirement to re-plaster corners of openings and to repaint the room. Another limit state is reported: a sudden drop in load as displacement increases, which occurs in the walls with openings at displacements of 0.75 to 1.5 in (0.69 to 1.39% drift). Also reported is that in panels with both plaster and wood sheathing, "The plaster was badly cracked under distortions of less than an inch."

In walls without openings, Trayer (1956) states that cracking initiated at drifts of 9.9 to 10.8 kip, which appears to relate to a peak transient drift of 0.4 to 0.6 in, or a drift ratio of 0.37 to 0.56%.

In another study, Schmid (1984) performed *in situ* in-plane cyclic racking tests of two lath and plaster wall specimens without openings in an existing Los Angeles building. Each specimen (Figure 7-7) was 8-foot by 8-foot, cut from the structure on its ends and top edge by removing a 1-foot-6-inch segment of wall at each end and a 1-foot-4-inch segment of the wall at the top edge below the girder above. Force was imposed by operating one of two calibrated hydraulic jacks inserted at the level of the top plate at each end of the specimen, reacting with the adjacent 8x8 column. Displacement was measured by observing dial indicators accurate to 0.001 inch. At least six load reversals were imposed, as illustrated in Figure 7-8.

Schmid (1984) reports that cracks appeared in the plaster of specimen 1 at displacements of 0.445 in and -0.407 in (0.46 and 0.42%, respectively), and in specimen 2 at displacements of 0.246 and -0.196 in (0.26 and 0.20%, respectively). Specimen 2 differed from specimen 1, in that it had an existing crack. Ultimate strength was reached in specimens 1 and 2 at 1.56 in and 1.30 in (1.62 and 1.35%), respectively. Readily available images of the specimens after testing are of poor quality, having been duplicated and scanned, but Figure 7-9, from Schmid (1984), should give a sense of the ultimate-strength limit state. Lath and plaster test results from Trayer (1956) and Schmid (1984) are recapped in Table 7-5.

7.6 Tests and Observations of Masonry Veneer

Figure 7-10 shows several instance of masonry veneer fallen from straight-sheathed wood-frame walls in various earthquakes. In each case, the masonry appears to have been self-supporting and anchored to the wall either by flexible metal connectors or by nails, with a gap of 1-2 inches between the sheathing and the wall.

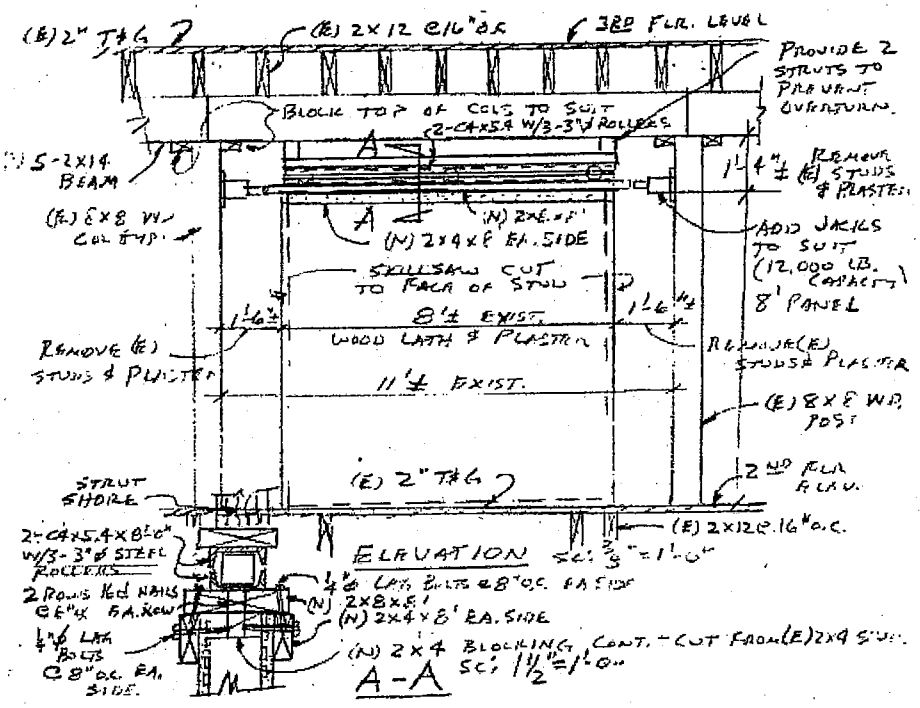


Figure 7-7 In situ testing of lath and plaster walls (Schmid, 1984).

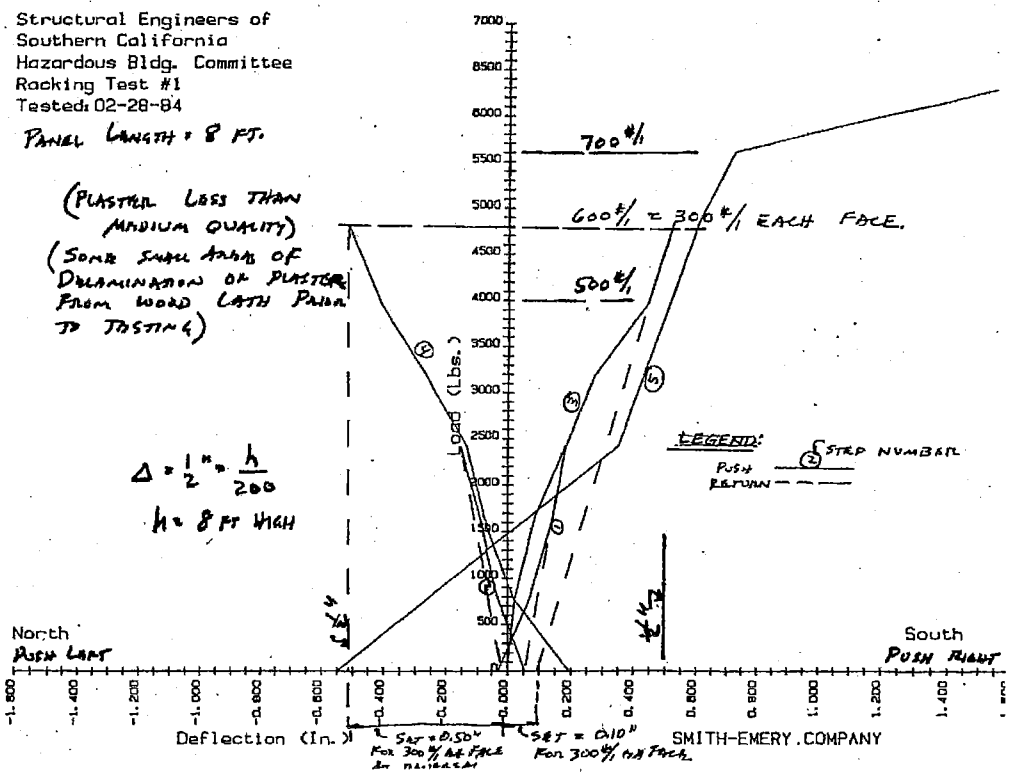


Figure 7-8 Loading history for an in situ test of a lath and plaster wall in a Los Angeles building (Schmid, 1984).

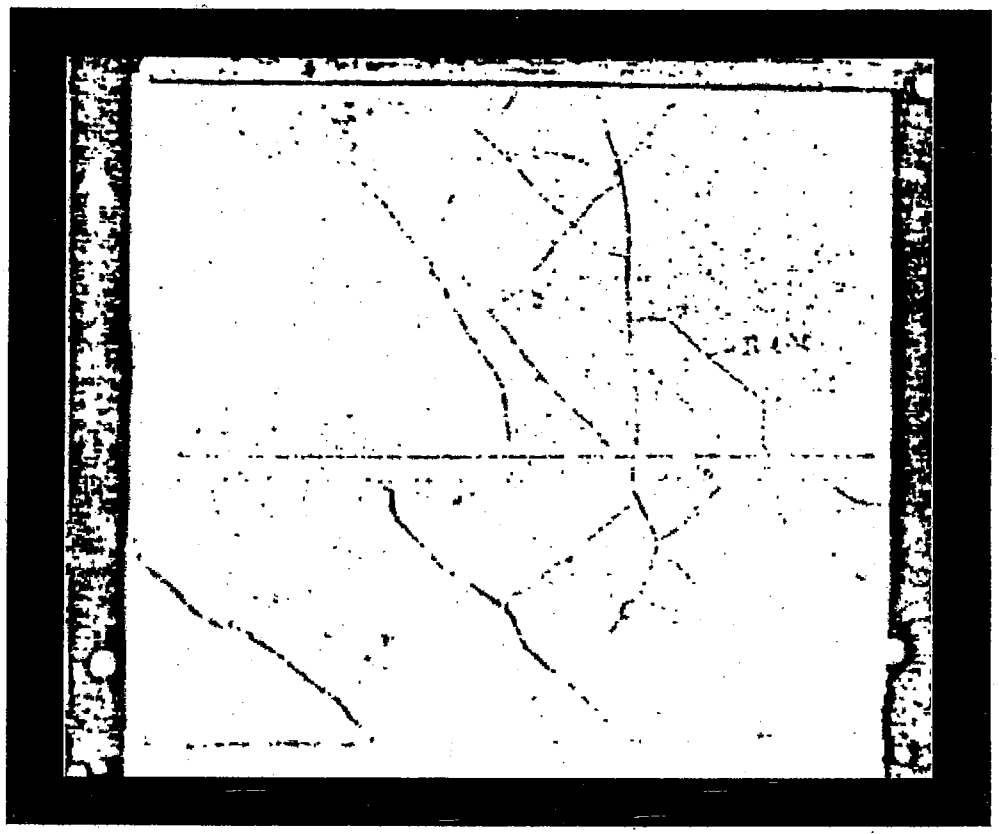


Figure 7-9 *In situ testing specimen of wall with lath and plaster finish, after testing (Schmid 1984).*

Table 7-5 Summary of Lath and Plaster Pseudostatic In-Plane Racking Tests

Id	Author	Lath And Plaster Wall Specimen	Limit State	Drift, %
1	Trayer (1956)	New wall with window, door openings	Cracks at openings	0.057
2	Ditto	Ditto	Ditto	0.093
3	Ditto	New wall without openings	Cracks appear	0.37
4	Ditto	Ditto	Ditto	0.56
5	Schmid (1984)	E wall 1 no prior cracks, + shear	Ditto	0.46
6	Ditto	Ditto, – shear	Ditto	0.42
7	Ditto	E wall 2 with prior cracks, + shear	New cracks appear	0.26
8	Ditto	Ditto, – shear	Ditto	0.20
9	Ditto	E wall 1 no prior cracks	Ultimate strength	1.62
10	Ditto	E wall 2 with prior cracks	Ditto	1.35

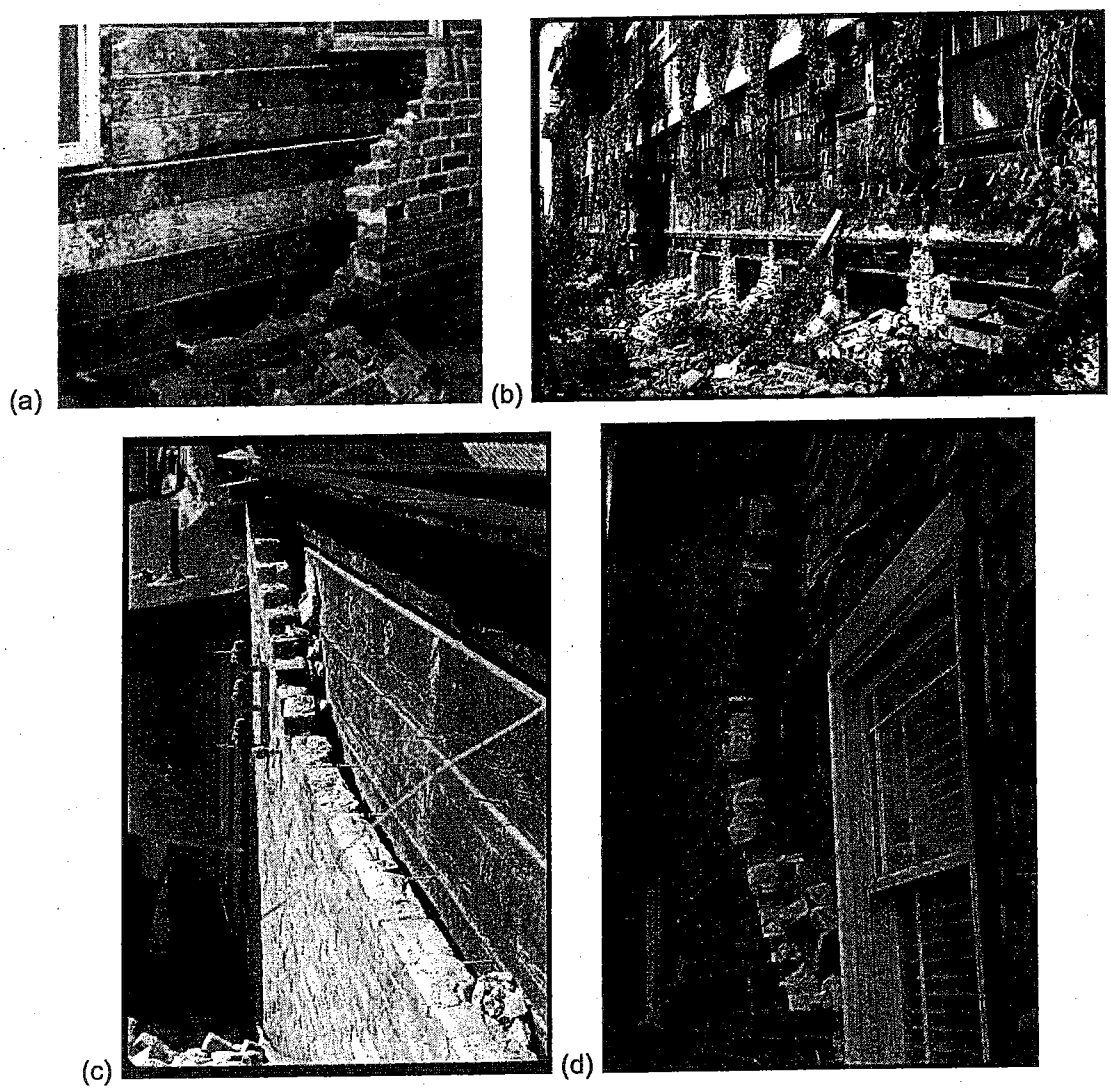


Figure 7-10 Damaged masonry veneer over straight-sheathed wood-frame walls in (a) 1994 Northridge earthquake (the Masonry Society, via Klingner 2003); (b) 1925 Santa Barbara earthquake (Huber, via Earthquake Engineering Online Archive); (c) 1961 Hollister earthquake (Steinbrugge via Earthquake Engineering Online Archive); (d) 1965 Puget Sound earthquake (Steinbrugge, via Earthquake Engineering Online Archive).

Klingner (2004) reports that in the 1994 Northridge and 2003 Mexico earthquakes, anchored masonry veneer "experienced a large fraction of the damage observed to modern masonry.... Anchored veneer was often attached using either corrugated ties fastened to the building, or corrugated dovetail ties, which were attached to channel slots fastened to the building. Veneer was damaged when ties or channel slots detached from the structure, or when the veneer detached from the ties. In no cases was actual tensile failure of the tie itself observed. Tie attachment failures show the need to connect ties with nails or screws to the structural system, and not just to the sheathing, and to control the deformation permitted by corrugated ties. Many ordinary nails, even correctly driven into wood, are not capable of developing the required anchoring forces."

Laboratory tests are still ongoing into the performance of masonry veneer. Okail *et al.* (2008) presented some results of in-progress Network for Earthquake Engineering Simulation (NEES) test research: shake-table test results of modern anchored brick masonry veneer with corrugated metal ties or rigid metal ties on wood stud walls, subjected to in-plane and out-of-plane shaking. Ten specimens of either 4-foot-wide x 8-foot-high blank panels or 8x8-foot panels with a 4x4-foot window opening were shaken with a 1.1g peak ground acceleration (PGA) Sylmar record or a 2g Tarzana record from the Northridge earthquake, with amplitudes scaled to achieve various levels of excitation of roughly 0.9, 1.4, and 2.6g peak ground acceleration. The tests did not impose deformation at the top edge, and there was no superimposed load. When the records were scaled so that each achieved first 0.9g and then 1.4g PGA, and the walls were subjected to them, they performed satisfactorily. Subjecting the walls to the records scaled to the maximum level caused complete damage to specimens, regardless of the type of anchor. Failure came in the form of collapse of the masonry above the window openings, or of the piers to either side of the window, or of the entire wall. (The results would therefore seem to be indicative of the effects of inertial forces on a single story of veneer, rather than strain incompatibility between veneer and framing. For reference, 0.9, 1.4, and 2.6g PGA for scaled versions of these two records is roughly equivalent to 1.3, 2.0, and 3.8g of 5%-damped spectral acceleration response at 0.3-sec period, or 0.8, 1.2, and 2.2g with 17.5% damping ratio, using the R_A factor offered by Newmark and Hall (1982).

The NEES researchers have found that in-plane behavior of the walls tested so far tended to be a combination of sliding and rocking of the veneer, and that out-of-plane behavior is governed by pullout from the framing of the nails connecting the anchor to the framing. In-plane excitation also caused nails connecting the anchors to the framing to pry loose or to extract from the framing. They observed diagonal cracking at the base of window corners, indicative of rocking of the pier beside the window. They also observed that ties ruptured and pulled out of the masonry and that ties deformed at the holes where screws connected them to the framing, allowing the screw to pull through the hole and remain attached to the framing, while the anchor became detached.

Jalil et al. (1992) studied the performance of the building at 2 Alhambra St, San Francisco, in the 1989 Loma Prieta earthquake (Figure 7-11). In the earthquake, this four-story corner apartment building in the San Francisco Marina District was observed to have lost all of its brick veneer sheathing at the bottom story on three facades. The authors performed an elastic response spectrum structural analysis of the building with and without masonry veneer, using a record from the nearby California Strong-Motion Instrumentation Program (CSMIP) Station 58222, modified to account for site soil. They find that in the likely fundamental period range of the building, 0.3 to 0.4 sec, the 5%-damped spectral acceleration response imposed on the building was approximately 150 in/sec^2, or approximately 0.4g. (Dividing by R_A value to account for wood frame elastic damping of perhaps 15-20% suggests a 17.5%-damped S_a of approximately 0.3g.) The authors do not offer an opinion of the deformation at which the veneer delaminated, although they do suggest that veneer fell off before the ground story drift reached 1%. Their analyses suggest that the ground story would have experienced drifts of 0.055 and 0.156 inch its orthogonal directions with the veneer (i.e., approximately 0.055 and 0.156%), and 0.78 and 0.98 inch without the veneer (0.78 and 0.98%).



Figure 7-11 Veneer damage to 2 Alhambra St, San Francisco, 1989 Loma Prieta earthquake (Jalil et al. 1992).

Thurston and Beattie (2008) also performed racking tests of a single-story, full-scale prototype house with modern brick veneer over wood frame, characteristic of construction in New Zealand. Piers were of various widths. The bricks had holes that the authors credited with improving the veneer's performance relative to solid clay bricks. Nonetheless, it may be noteworthy that, regardless of pier width, the authors estimate a substantial loss of stiffness occurs when the wood-frame wall deflects more than approximately 2 cm.

7.7 Literature on the Performance of Stucco Walls

Interpreting experimental testing by the CUREE-Caltech Wood-Frame Project, Porter et al. (2002) developed two fragility functions for stucco sheathing with metal lath: one for a cracking damage state repaired by patching and repainting, and a second for fracture of the connection between the framing or sheathing and the stucco, which must be repaired by demolishing and replacing the stucco. The former seems to dominate when metal lath is properly embedded in the stucco and connected to the framing; deformation is accommodated by cracking of the stucco. The latter seems to dominate when metal lath is not properly embedded in the stucco, and deformation is accommodated by delamination of the stucco from the lath. Stucco on wood lath (of special concern in this CAPSS study) would seem to be very different from stucco with well-embedded metal lath, akin to the difference between plain concrete and reinforced concrete, so the first failure mode addressed by the Porter et al. (2002) seems irrelevant. Loss of bond between the lath and stucco, however, seems perfectly relevant, so the second failure mode and associated fragility function might be applicable. The function was a lognormal fragility function with a median capacity of 1.2% drift and a logarithmic standard deviation of 0.5.

7.8 Observations of Red-Tagging and Structural Collapse

Red- tagging. ATC-20 (Applied Technology Council, 1989) is the *de facto* standard methodology for post-earthquake safety inspections of buildings. It suggests that if a

building has between 1 and 2 inches of residual drift after an earthquake (i.e., 1-2% drift ratio in the ground floor), then it is reasonable to post it as unsafe to enter or occupy. The larger number seems to be a better threshold for wood-frame construction, which can tolerate greater residual drift before its P-delta effects are likely to become a concern. Based on work for the ongoing ATC-58 project, Deierlein (person communication) suggests that approximately 5% transient drift in the ground floor of a wood-frame shear wall can result in 2% residual drift in that floor.

One retrofit considered in the CAPSS study is to add steel frames or cantilever columns, changing the lateral force resisting system on the ground story to a dual system of wood-frame shear wall and steel frame (see Appendix 4). Deierlein suggests that for a steel frame, the ratio of residual drift to transient drift is 4:7; this suggests that the 2-inch residual drift that is likely to trigger red-tagging would occur with 3.5% transient drift, or roughly 4.4 inches of spectral displacement. It is not clear which value should be used, but the figure for wood frame seems justified.

Deierlein indicates that there is significant uncertainty in this ratio of 5:2, with a logarithmic standard deviation of 0.8, so the values of 5 to 6 inches of transient drift producing 2 inches of residual drift are highly uncertain. One additional data point is provided in Figure 7-12, which shows safety inspection tag colors in the San Francisco Marina District, after the 1989 Loma Prieta earthquake. It shows, for example, that approximately 33 corner buildings were red tagged (including 6 that collapsed).

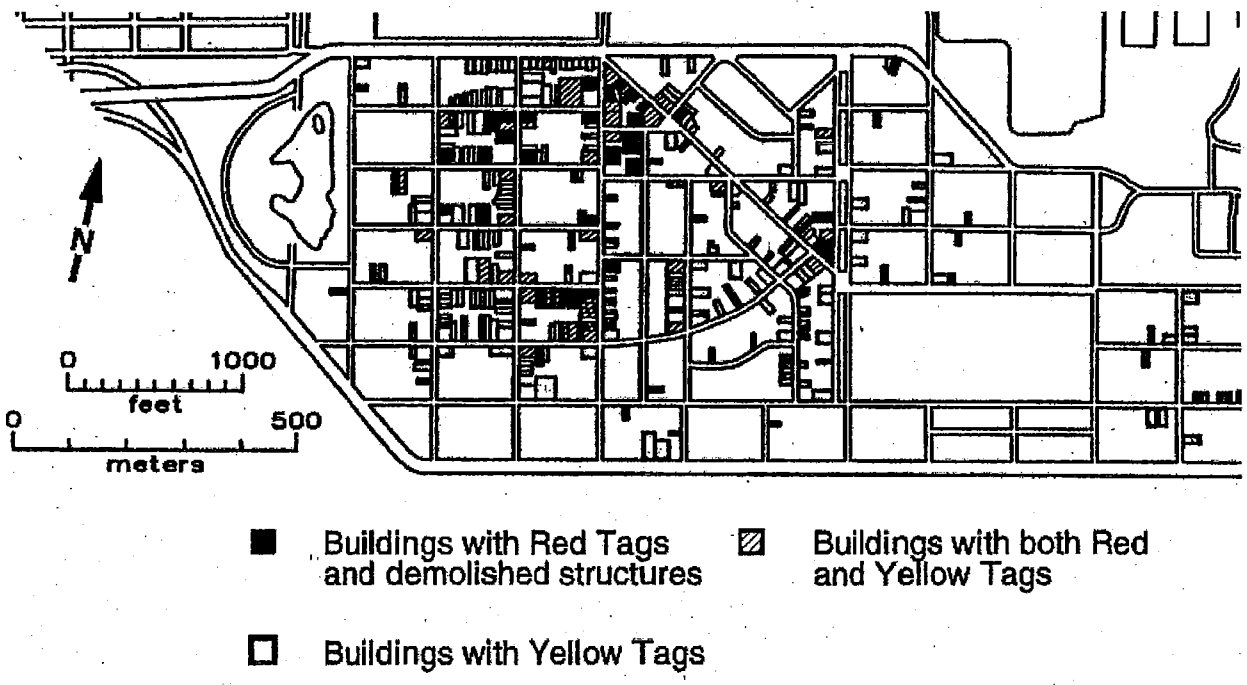
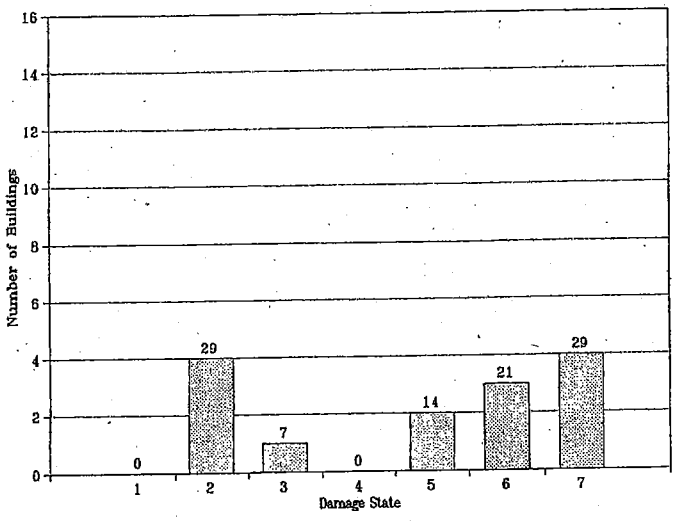


Figure 7-12 Safety tags in the San Francisco Marina District after the 1989 Loma Prieta earthquake (Seekins et al. 1990 via Scawthorn et al. 1992).

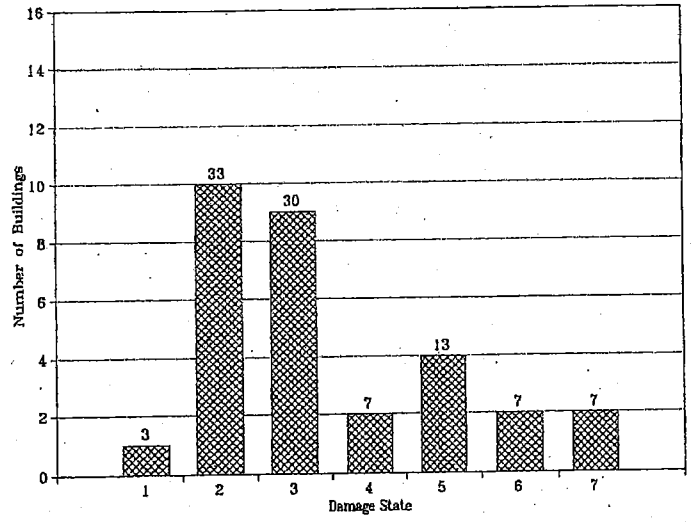
Collapse. The HAZUS®-MH methodology does not attempt to express collapse fragility functions and instead, estimates the building area that experiences collapse as a fraction of the building area that experiences the complete damage state; the fraction is denoted by P_c, which for ordinary W1 or W2 construction (FEMA, 2003a) take as 0.03. In the case of an n-story apartment building, collapse is likely to involve

the ground floor, or 1 n^{th} of the building area; therefore, the fraction of all buildings that collapse, given that they are in the complete damage state, would be n times P_c. Note that HAZUS®-MH assumes that the typical W1 is one story tall, and the typical W2 is two stories tall. P_c is given as 0.03 in both cases.

Harris and Egan (1992) offer some observations relevant to P_c of the performance of four-story corner apartment buildings in San Francisco Marina District after the 1989 Loma Prieta earthquake. They observed eleven such buildings to have experienced ATC-13 (ATC, 1985) damage states 6 or 7, where 6 indicates repair costing at least 60% of replacement cost, and 7 indicates collapse. As noted earlier, ATC-13 (ATC, 1985) damage state 6 (major), appears to equate in terms of damage factor with HAZUS's "complete" damage state, while 7 (destroyed) equates with HAZUS's "collapse."



(a) Figure 6.—Number of buildings in "soft"-soil-profile zone versus damage state. Most (64 percent of) buildings were assigned to damage states 5 (heavy) through 7 (destroyed). Numbers at top of bars indicate percentage of total.



(b) Figure 8.—Number of buildings in ground-failure zones versus damage state. Buildings are spread across all damage states but are concentrated at lower end. Numbers at top of bars indicate percentage of total.

Figure 7-13 Harris and Egan (1992) observed performance of 4-story wood-frame corner apartment buildings in the San Francisco Marina District: (a) buildings on soft soil; and (b) buildings on sites with ground failure.

Harris and Egan (1992) also provide some data relevant to a fragility approach to collapse. They estimate that in the 1989 Loma Prieta earthquake, of seven four-story corner apartment buildings on firm or soft (but not failed) soil that experienced $12 \leq S_d < 13$ in, three collapsed and four did not. In the range of $8 \leq S_d < 12$ inches, one of eleven collapsed. The data are shown in Figure 7-14. It is difficult to see three collapses at $S_d \approx 12$ inches in Figure 7-14a, but the total must sum to four, as in Figure 7-13a, so it is reasonable to conclude that there are three data points at 12 inch spectral displacement and 100% loss, and one at 9 inches. No buildings with $4 \leq S_d < 8$ inches collapsed.

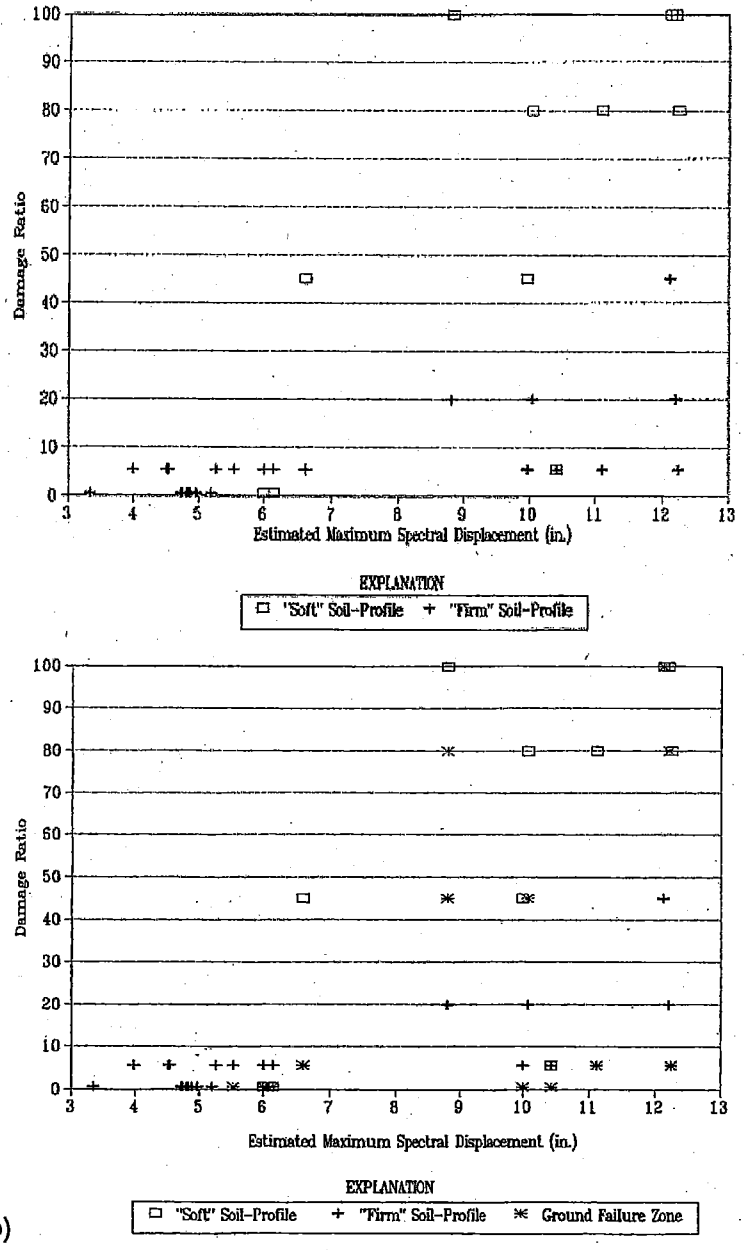


Figure 7-14 Collapse capacity of Marina District corner apartment buildings: performance of corner apartment buildings in the San Francisco Marina District in the1989 Loma Prieta earthquake on (a) soft or firm soil, (b) all soil profiles (Harris and Egan, 1992).

7.9 Component Fragility Analysis

With these tests and other observations in mind, consider now how to interpret them in terms of limit states at various levels of spectral displacement.

Straight sheathing. There appear to be two readily available observations of the drift at which straight sheathing experiences connection fracture: 2.8% and 3.0%, from Trayer (1956) and Elkhoraibi and Mosalam (2007a,b), respectively. The median capacity is therefore taken to be 2.9% peak transient drift at the story level of the wall, or roughly 2.9 inches for a 96-inch wall. To express this in terms of spectral displacement of the equivalent single-degree-of-freedom (SDOF) oscillator, one can calculate:

$$S_d = \Delta_1 \cdot \frac{(S_d/\Delta_r)}{(\Delta_1/\Delta_r)} \tag{2}$$

where Δ_1 denotes the drift (in inches) of the ground story, Δ_r denotes the roof displacement, and the ratio S_d/Δ_r denotes the modal factor denoted by α_2 in HAZUS®-MH (FEMA 2003a). Cobeen (personal communication) estimates the ratio Δ_1/Δ_r near ultimate to be 0.75 in index buildings 1 and 2 under as-is conditions, and 0.6 to 0.65 under seismic retrofit. The modal factor α_2 or S_d/Δ_r is estimated to be approximately 0.75 in FEMA (2003a). Thus, under as-is conditions, the spectral displacement equals the ground-floor displacement multiplied by 0.75/0.75, or unity. Under seismic retrofit, the factor is 0.75/0.60, or 1.25.

For example, Jalil et al. (1992), in their analysis of 2 Alhambra St., estimated that ground-floor displacement accounted for approximately 65-75% of the roof drift of the four-story apartment building, compared with the 25% it would have been if the deformed shape were linear: 70%/25% = 2.8. See Figure 7-15. Therefore the drift capacity of the siding, when measured in terms of the SDOF oscillator's drift ratio rather than the story drift ratio, will be taken as 2.9% divided by 2.8, or 1.0%. The height of the equivalent SDOF oscillator is taken to be 0.7 to 0.8 times the building height, which in the present case is on the order of 25 to 35 ft, so the oscillator is taken as having a height of 21 to 24 ft (30 ft x 0.7 to 0.8), or approximately 250 to 290 inches. To measure the capacity of the straight sheathing in terms of the spectral displacement of the oscillator, one multiplies the drift ratio of the oscillator by its height, e.g., 0.010 x 290 inches, or 2.9 inches. Thus, at roughly 3 inches of spectral displacement (in the HAZUS sense), one would expect the ground-floor sheathing to have experienced 2.9% peak transient drift, perhaps enough to require its demolition and replacement, though perhaps not enough to represent an immediate collapse risk, as will be discussed later. Under seismic retrofit, the ground story would experience 2.9 inches of drift at $S_d = 3.6$ inches.

Lath and plaster interior finish. The test results summarized in Table 7-5 can be interpreted to suggest three damage states: (1) a light damage state associated with cracks near window and door openings, repairable by patching and repainting; (2) a moderate damage state associated with cracks in walls without openings, repairable by more extensive patching and repainting; and (3) an ultimate-strength data state with heavy cracking that would seem to require demolition and replacement of the plaster with gypsum wallboard. The median for damage state 1 (using Test IDs 1 and 2 in Table 7-5) is taken as 0.073% peak transient drift in the story of interest, or roughly 0.073 inches, which would equate with $S_d = 0.073$ in under as-is conditions, or 0.09 under retrofitted conditions. For damage state 2, drawing on observations 3-8

in Table 7-5, the median capacity is 0.36% drift, equivalent to $S_d \approx 0.36$ inches under as-is conditions or 0.45 under retrofitted conditions. For damage state 3, from observations 9 and 10, the median drift capacity for ultimate strength (requiring demolition and replacement) is 1.5% drift, equivalent to $S_d = 1.5$ to 1.9 inches (as-is and retrofitted, respectively).

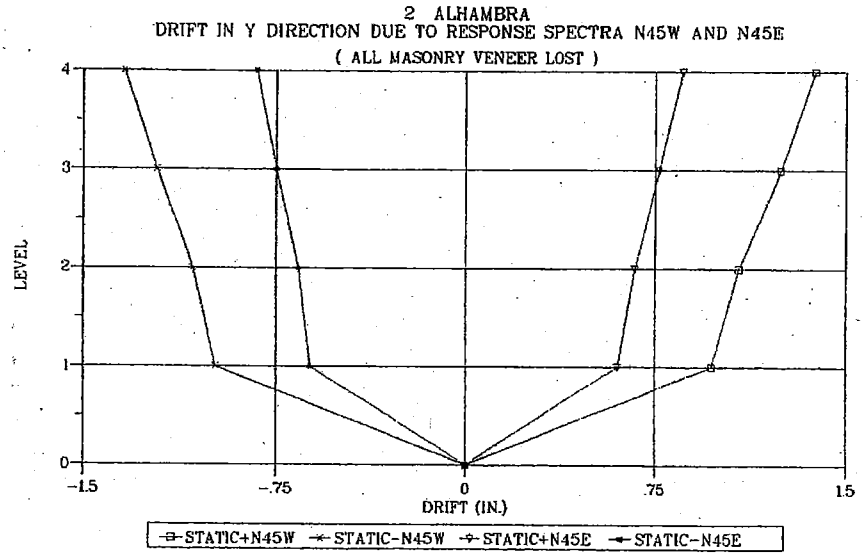


Figure 7-15 Estimated mode shape of 2 Alhambra after loss of masonry veneer (Jalil et al., 1992).

Brick veneer. There is little evidence on which to base a drift capacity associated with failure of brick veneer. As noted above, Jalil et al. (1992) estimated that the first story lost its brick veneer at drifts below 1%, and one might arbitrarily select a first-story drift of 0.4% as the median capacity, equivalent to $S_d = 0.4$ to 0.5 inch; this might be selected for simplicity, because it is the same range for S_d at which cracks appear throughout ground-floor stucco. Alternatively, if one believes that inertial forces are more strongly related to veneer failure, as seems to be the direction in which the NEES project is proceeding, then the capacity of the brick veneer is something less than $S_a = 0.3g$. The HAZUS developers suggest that brick veneer is drift-sensitive (FEMA, 2003a, Table 5.2), so for consistency's sake, a median capacity of the first-story veneer is somewhat arbitrarily assigned as 0.4 inch (as-is) or 0.5 inch (retrofitted).

Stucco. Consistent with the CUREE-Caltech Wood-Frame Project work, the median drift capacity of ground-story stucco is assigned as 1.2%, equivalent to $S_d = 1.2$ inches (as-is) 1.5 inches (retrofitted). This range is close enough to the drift at which lath and plaster exhibit large cracks that the drift level for stucco delaminating is taken as 1.5 to 1.9 inches

Red tagging. As previously described, Deierlein (personal communication) estimates that 5 inches of transient drift implies 2 inches of residual drift. Here, that would equate with a spectral displacement of perhaps 5 inches under as-is conditions or 6.2 inches under seismic retrofit. According to Harris and Egan's (1992) drift estimates (Figure 7-14b), there were perhaps 35 to 45 corner apartment buildings in the San Francisco Marina District in the 1989 Loma Prieta earthquake that experienced spectral displacements of 5 inches or more. The exact number is not known, because

the symbols in Figure 7-14b tend to overlap; nor is the safety tag color associated with each of the buildings represented in the figure known. However, the estimate of 35 to 45 buildings with $S_d \geq 5$ inches roughly equates with the approximately 33 red-tagged or collapsed corner buildings reported by Seekins *et al.* (1990; Figure 11), so together these two observations tend to support Deierlein's estimate.

It was the opinion of the CAPSS Project Engineering Panel in its January 2009 meeting that the retrofitted buildings could tolerate up to 8 inches of transient drift before triggering a red tag, as opposed to the 6.2 inches suggested above.

HAZUS®-MH approach to collapse. If we denote by N_4 the number of buildings in the HAZUS complete but not collapsed damage state, and by N_5 the number of buildings that experience collapse, then the fraction of buildings in the complete damage state that collapse can be taken as $N_5/(N_4 + N_5)$. If a four-story soft-story building collapses, typically it is the ground story that collapses, and the upper stories do not; therefore, only one-fourth the building area has collapsed. Letting P_c denote the fraction of building area that collapses given complete damage, for four-story buildings where collapse always means the collapse of the whole first story,

$$P_c \approx \frac{N_5}{4\left(N_4 + N_5\right)} \tag{3}$$

Recall the equivalence of HAZUS's complete damage state and ATC-13's major damage state, and the equivalence between HAZUS's collapse damage state and ATC-13's destroyed damage state. Recall also Harris and Egan's (1992) estimate of five corner apartment buildings in the ATC-13 major damage state, and six destroyed (Figure 7-13). No buildings on firm soil experienced either damage state, so they are ignored for purposes of calculating P_c. Thus, if all Marina District buildings are included for purposes of evaluating Equation (3), $N_4 = 5$ and $N_5 = 6$, so $P_c \approx 6/(4*11) = 0.14$. If only those that were not on failed soil are considered, $N_4 = 3$ and $N_5 = 4$, so $P_c \approx 4/(4*7) = 0.14$, the same as before.

What if we assume that HAZUS's complete damage state is broader than the ATC-13 major plus destroyed damage states (ATC-13 damage states 6 and 7) and includes those in the heavy damage state (ATC-13 damage state 5)? Then, using Figure 7-13a, $P_c = 4/(4*9) = 0.11$; using both Figure 7-13a and Figure 7-13b, $P_c = 6/(4*17) = 0.088$. Not shown in either figure is that Harris and Egan (1992) estimated that three buildings on firm-soil profiles experienced ATC-13 damage state 5, which would lead to $P_c = 6/(4*20) = 0.075$.

So depending on how one equates the ATC-13 and HAZUS damage states, P_c for corner buildings might be anywhere from 0.075 to 0.14. Both in order to acknowledge this uncertainty and to avoid the appearance of unjustified accuracy, let us take $P_c = 0.1$.

None of the buildings in the Harris and Egan (1992) dataset is known to have been seismically retrofitted, and it seems unlikely that any had been. No other data appear to be readily available to inform P_c for retrofits 1 through 3. Let us assume, therefore, that seismic retrofit 1 would reduce P_c by perhaps one-third to one-half, say to 0.06 (double the value assumed in HAZUS®-MH for W1 and W2), and that retrofits 2 and 3 would virtually eliminate ground-story collapse, possibly shifting any collapse to the second floor. For retrofits 2 and 3, P_c will be taken as 0.015, half the value for W1 or W2.

Fragility approach to collapse. A fragility approach was recommended by the CAPSS Project Engineering Panel in a January 2009 meeting. Recall that the data in Harris and Egan (1992) seem to suggest three collapses out of seven buildings at 12 inch spectral displacement, one collapse out of eleven buildings at 9 inches, and none with $4 \leq S_d < 8$ inches collapsed. Fitting a curve to these points suggests a median collapse capacity of approximately 13 inches, and a logarithmic standard deviation of 0.2.

This uncertainty value includes uncertainty associated with structural response given ground motion (since the models were simplistic), and collapse given structural response (since it seems likely that there would be variability in collapse between real buildings known to have experienced the same level of structural response). It largely excludes variability in ground motion given magnitude and distance, since the buildings are relatively close together (little intra-event variability), and the data are drawn from a single earthquake (no inter-event variability). For future earthquakes, one can consider an additional contribution of perhaps 0.6 (the value of $\sigma_{\ln Y}$ for T = 1 sec in Boore et al. 1997), which is SRSS'd with the value of 0.2 (SRSS: square root of the sum of the squares) to produce a total logarithmic standard deviation of 0.63.

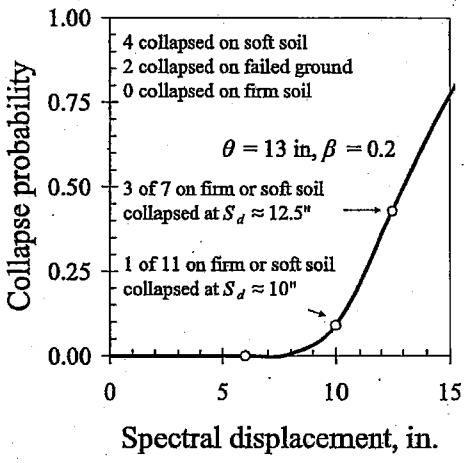


Figure 7-16 Collapse fragility function inferred from the Harris and Egan (1992) data.

7.10 Summary

To review: in laboratory tests of wood lath and plaster walls by Trayer (1956) and Schmid (1984), at $S_d \approx 0.06$ inch, small cracks appeared near corners of openings in lath and plaster walls. At $S_d \approx 0.4$ inch, small cracks appeared throughout the ground-floor lath and plaster walls, calling for more significant patching and repainting. A study by Jalil et al. (1992) suggests that at about the same level of drift, the brick veneer begins to fall off. Earlier fragility analysis of stucco finish in Porter et al. (2002) suggests that at $S_d \approx 1.5$ inches, ground-floor stucco delaminates from the wood lath and requires demolition and replacement. At about the same level of drift, from Trayer's (1956) and Schmid's (1984) test results, the ground-floor lath and plaster walls exhibit large cracks.

From tests by Trayer (1956) and Elkhoraibi and Mosalam (2007a,b), one can estimate that at $S_d \approx 3.0$ inches, nails in straight sheathing have become so heavily deformed in exterior straight sheathing that the finish requires demolition and replacement, though the building might not represent an immediate collapse hazard.

At $S_d \approx 5$ inches, Deirelein's (2007) analysis suggests that a reasonable estimate of residual drift in the ground floor is 2 inches, which would trigger a red tag. This figure tends to be supported by the fact that Harris and Egan (1992) suggest that in the San Francisco Marina District during the 1989 Loma Prieta earthquake, 35 to 45 corner apartment buildings experienced 5 inches of drift or more, and according to Seekins et al. (1990), approximately 33 corner buildings were red-tagged or collapsed.

At $S_d \approx 13$ inches, collapse occurs, as shown by an examination of Harris and Egan's (1992) estimates of spectral displacement and damage to corner apartment buildings in the Marina District in 1989. (The assumption is that other large soft-story wood-frame buildings in San Francisco will behave like those in the Marina District in 1989.) Using the HAZUS®-MH approach to collapse, the evidence from Harris and Egan's (1992) damage-state estimates of the same buildings suggests that P_c, the fraction of building area in the complete damage state that has collapsed, was approximately 0.1.

The damage-state descriptions just summarized can be compared with those of the HAZUS®-MH damage states for W1, whose relevant portions are quoted in Table 7-6. The table shows a range of S_d values at which these damage states seem to occur, with the lower figure reflecting as-is conditions, and the upper figure for

Table 7-6 Relationship Between Experimental Observations and Damage States

Tag	Experimental Observations	S_d, in.[a]	HAZUS Structural Damage
Green	Small cracks appear near corners of openings in lath and plaster walls	0.06 - 0.07	*Slight:* Small plaster or gypsum-board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry veneer.
	Small cracks appear throughout the ground-floor lath and plaster walls; brick veneer begins to fall off	0.4 - 0.5	*Moderate:* Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels
	Ground-floor stucco delaminates from wood lath; ground-floor lath and plaster walls exhibit large cracks	1.5 - 1.9	
Yellow	Nails heavily deformed in exterior straight sheathing	2.9 - 3.6	*Extensive:* Permanent lateral movement of floors and roof... partial collapse of "room-over-garage" or other "soft-story" configuration
	Residual drift in the ground floor ≥ 2 inches; no collapse	5 - 8	*Complete*: Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse. Approximately 3% of the total area of W1 buildings with Complete damage is expected to be collapsed.
	Collapse occurs P_c = 0.1 (as-is) to 0.015 (retrofit 3)[b]	13-?	

Notes:
a. Lower value in range refers to as-is conditions, upper to retrofitted conditions.
b. P_c is used for the conventional HAZUS®-MH approach, and drift for use with fragility.

retrofit. The table also shows the approximate ATC-20 safety inspection result. There is an imperfect match between the experimental observations and HAZUS®-MH structural damage state description, especially for HAZUS' slight and moderate damage states.

A preliminary equivalence was made in consultation with structural engineering members of the CAPSS project Advisory Committee in October 2008, and revised in consultation with members of the CAPSS Project Engineering Panel and other members of the CAPSS project team in January 2009. The former assignments were more conservative than the latter. That is, in the January 2009 consultation, HAZUS damage states were associated with higher values of spectral displacement.

7.11 Conclusions

Experimental and earthquake evidence is sufficient to create new fragility functions for common building components of large residential San Francisco wood-frame buildings. Table 7-7 shows the final relationships between SPUR performance level, ATC-20 tag color, HAZUS®-MH structural damage state, and several values of median spectral displacement: those derived from the experiments discussed above (labeled "CAPSS"); the judgment of the January 22, 2009 meeting of the Project Engineering Panel, and the HAZUS®-MH capacities for the structural component of W1 and W2 pre-code structure types. The column labeled β refers to the logarithmic standard deviation of capacity proposed for use here. HAZUS®-MH offers β values for W1 and W2 pre-code that are all approximately 1.0, which are used here, except for collapse, where a value of 0.6 is used, as discussed above. The table shows two ranges for CAPSS fragility parameters, reflecting the ambiguity in mapping from experimental damage states to HAZUS and SPUR damage states. In each case, a range "X-Y" means that X would be the median for as-is conditions, Y for retrofitted conditions. "Lower" refers to the lesser of the two ranges—note that using lower values tends to result in higher damage estimates—while "upper" is the larger of the two, producing lower damage at a given value of shaking intensity.

Table 7-7 Damage State Characterizations and Proposed Fragility Parameters

Damage State			Median Spectral Displacement, Inches					β
SPUR	ATC-20 Tag	HAZUS	PEP[c] Judgment	W1 Precode	W2 Precode	CAPSS[a]		
						Lower	Upper	
A	Green	Slight	0.5	0.4	0.69	0.06 - 0.07	0.4 - 0.5	1.0
B	Green	Moderate	1.5	1.0	1.71	0.4 - 0.5	1.5 - 1.9	1.0
C	Yellow	Extensive	3	3.09	5.29	1.5 - 1.9	2.9 - 3.6	1.0
D	Red	Complete	6 – 8	7.56	12.96	2.9 - 3.6	5 - 8	1.0
E	Collapse	Collapse	12	N/A	N/A	b	13 - ?	0.6

Notes:

a: where a range "X-Y" is given, X refers to as-is conditions, Y to retrofitted. "Lower" refers to the lesser of the two ranges—note that using lower values tends to result in higher damage estimates—while "upper" is the larger of the two, producing lower damage at a given value of shaking intensity.

b: use HAZUS®-MH approach to estimate area collapsed, as fraction of area in "complete" damage.

c: Decisions made during CAPSS Project Engineering Panel (January 22, 2009 meeting)

APPENDIX 8: SEISMIC VULNERABILITY OF FOUR SOFT-STORY WOOD-FRAME INDEX BUILDINGS AND THEIR RETROFITS

8.1 Executive Summary

Described in this appendix is the derivation of motion-damage relationships (vulnerability functions) for the four Index Buildings described in Appendix 4, considering both as-is and retrofitted configurations. The derived relationships are based on several related City of San Francisco Community Action Plan for Seismic Safety (CAPSS) project efforts, including (1) the development of fragility functions for major components common to multi-family, soft-story, wood-frame dwellings (see Appendix 7); (2) the development of capacity curves for the as-is and retrofitted configurations of the four multi-family, soft-story, wood-frame Index Buildings (see Appendix 4); and (3) a non-iterative approach to the capacity spectrum method of structural analysis (described herein) to create seismic vulnerability functions (relationships) that provide damage and loss estimates as a function of 5%-damped spectral acceleration response at 0.3 sec and 1.0 sec periods. The relationships derived herein provide the mean damage factor (repair cost as a fraction of replacement cost) and damage-state probabilities for each as-is and retrofitted configuration of the four Index Buildings as functions of spectral acceleration response, earthquake magnitude, distance to fault rupture, and National Earthquake Hazard Mitigation Program (NEHRP) site soil class. The results, illustrated in Figures 8-1 through 8-3, were developed to study seismic risk mitigation options for the City of San Francisco. They may be useful for other purposes as well.

8.2 Objectives and Scope of Work

The CAPSS project sought, among other things, to assess the impacts of various realistic earthquake scenarios on the City's housing stock, with emphasis on one of its more widespread and vulnerable classes of housing: older, wood-frame, multi-family dwellings (with five or more housing units) with soft-story conditions. The relevant housing stock was idealized via four "Index Buildings" shown in Figure 8-4: (1) a 3,600-sq. ft., three-story pre-World War II (WWII), wood frame with garage door openings along one entire side of the building, with few transverse walls at ground level; (2) a 5,800-sq. ft., four-story pre-WWII, wood-frame corner building with garage door openings along two sides of the building and internal walls at ground level between several parking spaces; (3) a 2,300-sq. ft., midblock, pre-WWII, four-story building with a neighbor on both sides; and (4) a 1,800-sq. ft., midblock, three-story 1950s building, > 80% open on ground-floor façade, with neighbors on both sides.

This study focused on the development of seismic vulnerability functions for the four Index Buildings.

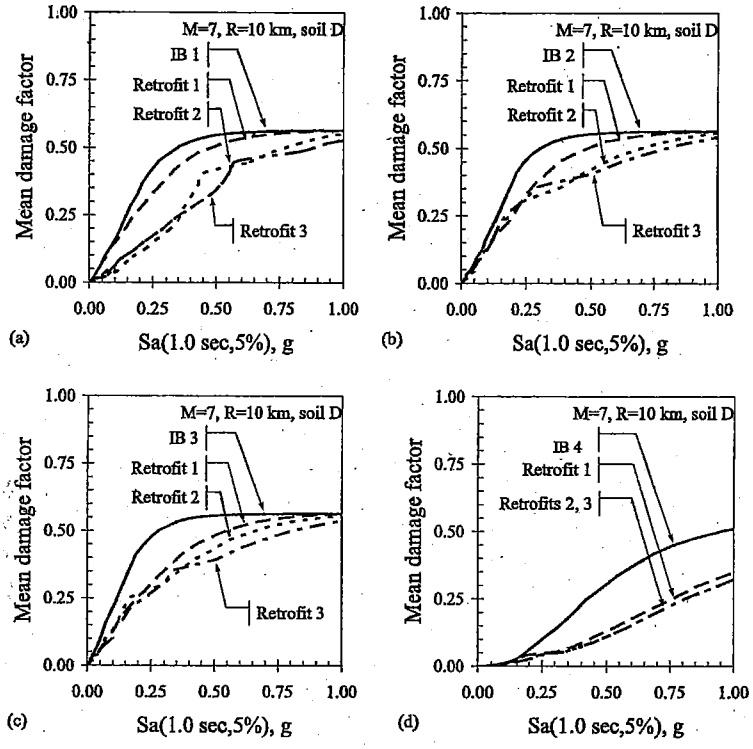


Figure 8-1 Vulnerability functions for the four Index Buildings (IB) as a function of spectral acceleration, Sa(1.0 sec, 5% damped).

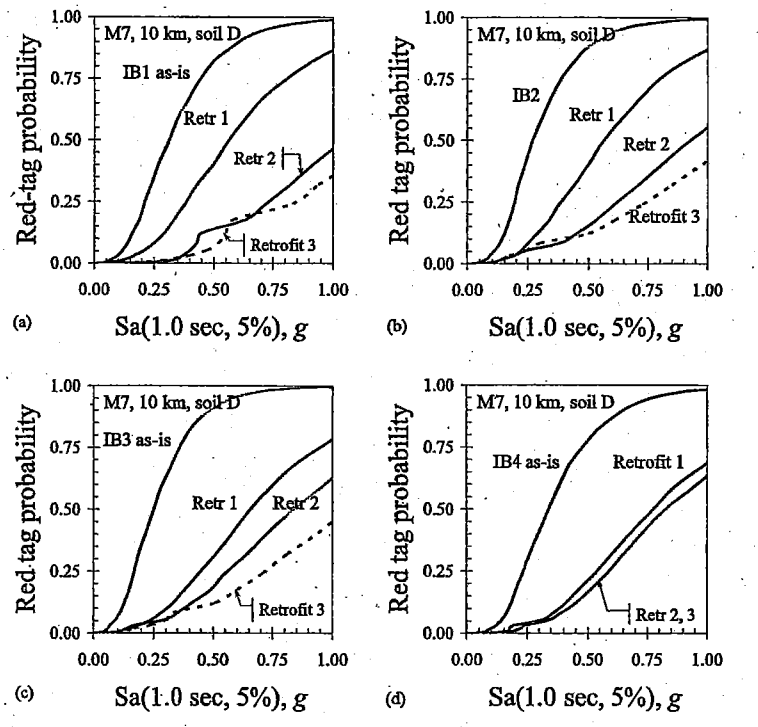


Figure 8-2 Red-tag probability as a function of spectral acceleration, Sa(1.0 sec, 5% damped), for the four Index Buildings (IB).

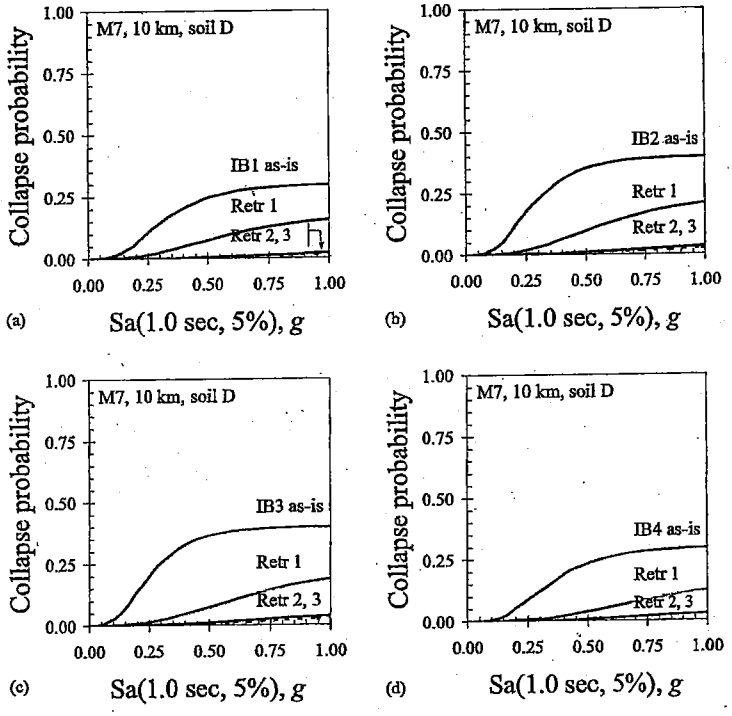


Figure 8-3 Collapse probability as a function of spectral acceleration, Sa(1.0 sec, 5% damped), for the four Index Buildings (IB).

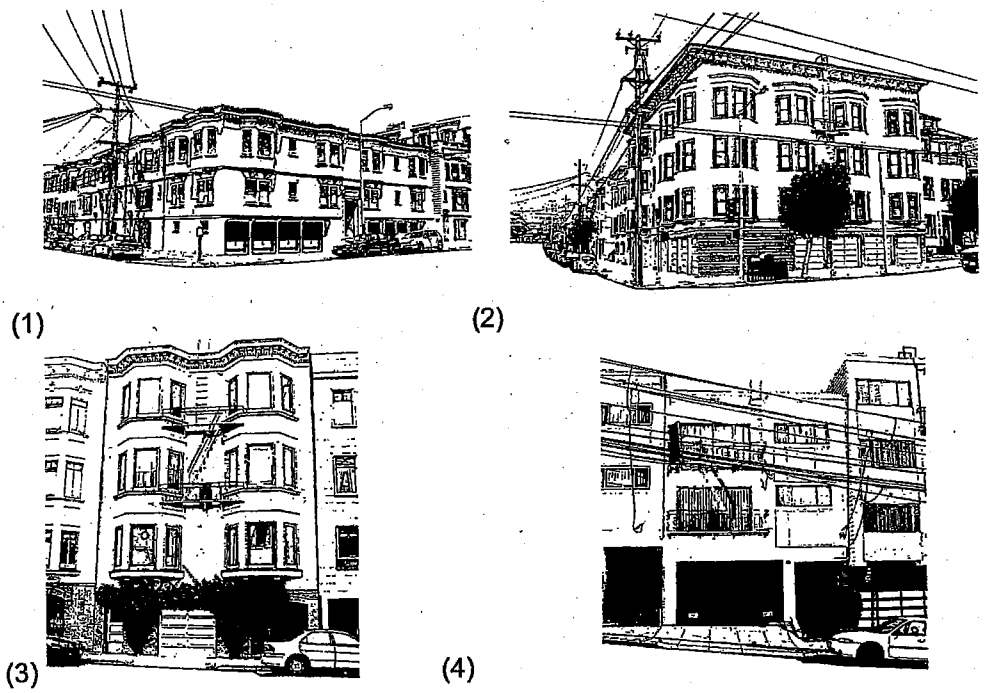


Figure 8-4 Index Buildings: four older, soft-story, wood-frame, multi-family dwellings representing a realistic range of performance of buildings of this class in San Francisco: (1) corner, 3 story, no interior walls at garage level, one street facade ≥ 80% open at ground floor; (2) corner, 4 story, both street facades ≥ 50% open at ground floor; (3) mid-block, 4 story, pre-WWII, neighbors on both sides; (4) mid-block, 3 story, post-1950, neighbors on both sides. Square footage is 3,600, 5,800, 2,300, and 1,800 sq. ft., respectively.

8.3 Available Vulnerability Methodologies

The Pacific Earthquake Engineering Research (PEER) Center methodology (e.g., Porter et al., 2002) and HAZUS®-MH methodology (FEMA, 2003a) both offer the means to relate probabilistic damage, economic, or life-safety losses to ground motion measures, such as 5%-damped elastic spectral acceleration response. The PEER approach models a building at the level of detail of structural design, uses multiple 2-dimensional (2-D) or 3-D nonlinear dynamic structural analyses, and applies fragility functions at the level of individual wall segments.

The HAZUS®-MH approach, by contrast, idealizes a building as a single-degree-of-freedom (SDOF) nonlinear oscillator and employs the capacity spectrum method of structural analysis. It simplifies a building as comprising only three aggregate components: structural, nonstructural drift-sensitive, and nonstructural acceleration sensitive, each with five or six somewhat qualitative damage states. When both approaches are applied carefully, the PEER approach offers far greater resolution, but it is far more labor intensive, largely because of the effort involved in creating a probabilistic structural model, and it can be computationally expensive for large buildings modeled in three dimensions. The HAZUS®-MH approach offers less fidelity to the behavior of real buildings but has been used to hindcast societal losses with ± 50% accuracy in the 1989 Loma Prieta and 1994 Northridge earthquakes (FEMA, 2001). The HAZUS®-MH approach has produced what are deemed to be realistic estimates of losses in a future repeat of the 1906 San Francisco earthquake (Kircher *et al.* 2006) and in a possible future magnitude 7.8, 300-km-long rupture of the southern San Andreas fault (Jones et al. 2008). For purposes of the CAPSS study, the HAZUS®-MH approach is practical, and the PEER approach is not. Furthermore, since CAPSS aims at societal-level risk assessment, the fidelity offered by a HAZUS®-MH approach is deemed adequate.

HAZUS®-MH reflects old, large wood-frame buildings with the seismic vulnerability model W2 pre-code. HAZUS®-MH also contains another building type for wood-frame construction (W1), but this type is generally smaller than the Index Buildings, both in terms of height (W1 is idealized with a one-story building) and area (W1 has an area of less than 5,000 sq. ft.). The HAZUS®-MH W2 type alone cannot distinguish the effects of building configuration or details such as soft-story and the detailed seismic retrofits examined here. The HAZUS®-MH Advanced Engineering Building Module (AEBM; FEMA, 2003b) provides the means to calculate the seismic performance of particular buildings. However, the AEBM was found to have a programming flaw in calculating the performance point, when it lies on the constant-velocity portion of the idealized response spectrum with effective damping greater than 5%. It is unclear how frequently and severely the flaw impacts results. A patch was not available at the time of this work.

Because of these challenges to using HAZUS®-MH and the AEBM, an alternative approach developed by Porter (2009b) was used here. The alternative honors all HAZUS®-MH modeling assumptions, while avoiding the use of AEBM and the requirement for iterative calculation of the performance point. It has been peer reviewed and its results, independently duplicated by several researchers.

8.4 Selected Methodology

This CAPSS effort concerns the effort of relating 5%-damped spectral acceleration response at 0.3 sec or 1.0-sec periods to damage and loss, not the calculation of loss

given some scenario shaking. The interested reader is referred to Porter (2009b,c) for details on the methodology. In brief, one must create a pushover curve, referred to as a capacity curve in the HAZUS®-MH methodology, which relates the peak acceleration of the equivalent SDOF nonlinear oscillator to its displacement, i.e., in the space of spectral displacement (S_d) and spectral acceleration (S_a) response. As shown in Figure 8-5, the capacity curve has a linear portion between the origin and a yield point denoted by (D_y, A_y), a perfectly plastic portion when displacement exceeds an ultimate point denoted by (D_u, A_u), and a portion of an ellipse connecting the two segments. It is discretized into a number of points; Porter (2009b) uses 51 equally logarithmically spaced values of S_d between 0.01 inch and 1000 inches, though for low- and mid-rise wood-frame buildings, a useful upper limit is more like 10 inches to perhaps 100 inches. At each S_d value, one calculates the corresponding S_a value and the effective damping ratio, denoted by B_{eff} and calculated as

$$B_{eff} = B_E + \kappa\left(\frac{Area}{2\pi S_d S_a}\right) \tag{1}$$

where B_E is the elastic damping of the model building type, κ is a degradation factor, and *Area* is the area enclosed by the hysteresis loop, as in Figure 8-5. Ignoring the rounded corners,

$$Area \approx 4S_a\left(S_d - \frac{S_a}{A_y/D_y}\right) \tag{2}$$

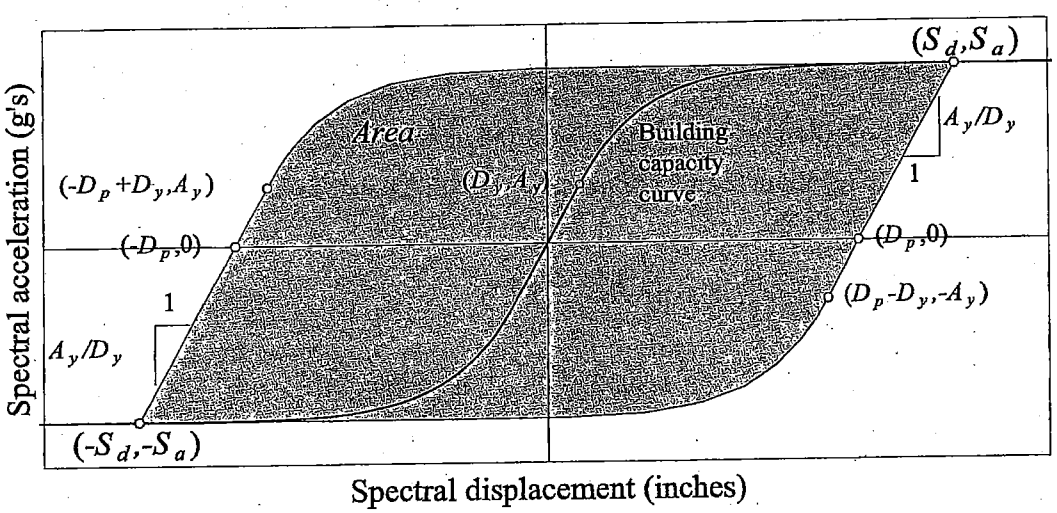


Figure 8-5 Establishing effective damping ratio at HAZUS®-MH performance point (Porter, 2009b).

Omitting details, the performance point (S_d, S_a, B_{eff}) lies on an idealized, site-soil-adjusted response spectrum with the same effective damping ratio and called the *demand spectrum*. Considering the effect of damping and site soil amplification, the demand spectrum is then related to a 5%-damped site-soil-adjusted response spectrum referred to as the *index spectrum*. The index spectrum has a constant-acceleration portion parameterized via its 5%-damped spectral acceleration response at 0.3 sec period denoted by S_a(0.3 sec, 5%), and a constant-velocity portion

parameterized via S_a(1.0 sec, 5%). The relationships between the spectral acceleration response at 0.3 and 1.0 sec on both demand and index spectra, and whether the performance point lies on the constant-acceleration, or constant-velocity portions of the demand spectrum, depend on several parameters: the earthquake magnitude, M; fault distance, R; mean shearwave velocity in the top 30m of soil, Vs30; and whether the site is near a plate boundary or in a continental interior.

Probabilistic structural damage at the performance point is then calculated using fragility functions of the form:

$$
\begin{aligned}
P\left[D=d\middle|S_d=x\right] &= 1-\Phi\left(\frac{\ln[x/\theta_1]}{\beta_1}\right) && d=0 \\
&= \Phi\left(\frac{\ln[x/\theta_d]}{\beta_d}\right)-\Phi\left(\frac{\ln[x/\theta_{d+1}]}{\beta_{d+1}}\right) && 1\le d\le 3 \\
&= (1-P_c)\Phi\left(\frac{\ln[x/\theta_4]}{\beta_4}\right) && d=4 \\
&= P_c\Phi\left(\frac{\ln[x/\theta_4]}{\beta_4}\right) && d=5
\end{aligned}
\qquad (3)
$$

where $P[D=d|S_d=x]$ denotes the probability of structural damage state, d, given that S_d takes on some particular value, x, and Φ denotes the cumulative standard normal distribution. The parameters θ_i, β_i, and P_c denote, respectively, the median and logarithmic standard deviation values of the component capacity to resist damage state, i, and the fraction of buildings in the complete damage state that are expected to be collapsed. Damage to the nonstructural drift-sensitive component is similar, except that only four damage states are considered. Damage to the nonstructural acceleration-sensitive component is also similar, again with only four damage states and instead of conditioning on S_d, it uses S_a as the input to the fragility functions.

An alternative to Equation 3 can be formulated, wherein collapse fragility is explicitly modeled, as in

$$
\begin{aligned}
P\left[D=d\middle|S_d=x\right] &= 1-\Phi\left(\frac{\ln[x/\theta_1]}{\beta_1}\right) && d=0 \\
&= \Phi\left(\frac{\ln[x/\theta_d]}{\beta_d}\right)-\Phi\left(\frac{\ln[x/\theta_{d+1}]}{\beta_{d+1}}\right) && 1\le d\le 4 \\
&= \Phi\left(\frac{\ln[x/\theta_5]}{\beta_5}\right) && d=5
\end{aligned}
\qquad (4)
$$

where θ_5 and β_5 represent median and logarithmic standard deviation of spectral displacement associated with collapse (a damage state that applies only to the structural component). In either case, given structural response S_d and S_a, Equations 3 and 4 each produce a probability mass function for the damage state of the structural, nonstructural drift-sensitive, and nonstructural acceleration-sensitive building components. These uncertain damage states are denoted here by D_1, D_2, and D_3, respectively. With these probability mass functions available, the expected value of repair cost is calculated as

$$E[L] = \sum_{d=1}^{5} P[D_1 = d | S_d = x] L_{1d} + \sum_{d=1}^{4} P[D_2 = d | S_d = x] L_{2d} + \sum_{d=1}^{4} P[D_3 = d | S_a = x] L_{3d} \quad (5)$$

where L_{1d}, L_{2d}, and L_{3d} represent the repair cost to the same three components, given that the component is in damage state, d.

8.5 Parameter Values for CAPSS Index Buildings

Pushover curve parameters D_y, A_y, D_u, and A_u are taken from analysis by Cobeen (summarized in Appendix 4), and are recapped in Table 8-1, along with calculated elastic period, T_E, and ductility capacity, μ ($=D_u/D_y$). Units of D, A, T_E, and μ are inches, fraction of gravity, seconds, and unitless, respectively. Several checks

Table 8-1 Capacity Curve Parameters for Four Index Buildings

Index Building	D_y	A_y	D_u	A_u	T_E	μ
Building 1. 3-story corner building one side > 80% open no walls between garages	0.57	0.06	0.76	0.08	1.00	1.32
Index Building 1 Retrofit 1. New wood shearwalls at garage end walls, steel frames at garage doors	0.70	0.08	1.41	0.13	0.92	2.02
Index Building 1 Retrofit 2. Ditto but new wood shearwalls at all ground-floor walls	0.34	0.23	0.95	0.37	0.39	2.79
Index Building 1 Retrofit 3. Ditto but cantilever columns at garage openings instead of moment frames	0.55	0.28	1.08	0.38	0.45	1.96
Building 2. 4-story corner building both sides > 50% open, walls between garages	0.51	0.05	0.71	0.06	1.00	1.38
Index Building 2 Retrofit 1. Ditto with new steel frames both facades	0.68	0.11	1.03	0.13	0.80	1.51
Index Building 2 Retrofit 2. Ditto but wood shearwalls all interior garage walls	0.84	0.20	2.09	0.31	0.65	2.49
2r3. Ditto but cantilever columns at garage openings instead of moment frames	0.99	0.23	2.62	0.37	0.67	2.64
Building 3. 4-story midblock building pre-WWII, front façade > 80% open	0.65	0.04	1.42	0.05	1.31	2.18
Index Building 3 Retrofit 1. Ditto, plus transverse wood-frame shearwalls	0.81	0.13	1.57	0.18	0.81	1.93
Index Building 3 Retrofit 2. Ditto, transverse steel frames and longitudinal shearwalls	0.84	0.19	1.60	0.25	0.68	1.90
Index Building 3 Retrofit 3. Ditto, cantilever columns not steel frames, more longitudinal shearwalls	0.84	0.23	1.69	0.30	0.61	2.01
Building 4. 3-story midblock 1950s building front façade > 80% open	0.11	0.02	0.84	0.06	0.75	7.75
Index Building 4 Retrofit 1. Ditto, plus wood-frame shearwalls on longitudinal end walls and back wall	0.29	0.11	0.76	0.17	0.53	2.65
Index Building 4 Retrofit 2. Ditto, plus steel moment frame at front	0.23	0.11	0.65	0.17	0.47	2.83
Index Building 4 Retrofit 3. Ditto, but cantilever columns inboard instead of steel moment frame at front	0.23	0.11	0.65	0.17	0.47	2.83

imply internal consistency and reasonable comparison with HAZUS®-MH, as follows:

1. Ultimate strengths (A_u) increase with retrofit level;
2. Periods generally decrease with retrofit, though Index Building 1 Retrofit 3 has slightly longer period than Index Building 1 Retrofit 2, as does Index Building 2 Retrofit 3 versus Index Building 2 Retrofit 2, which at first glance appears questionable, given the greater number of columns with roughly same member size (W10x45) as columns in the bents (W10x45 and W12x45 in Building 1 Retrofit 3 and Building 2 Retrofit 3, respectively), and the presumably nearly fixed base of the W10 cantilever columns.
3. Ductility capacity D_u/D_y generally increases, from 1.3 to 2.8, though D_u/D_y drops from Index Building 1 Retrofit 2 to Index Building 1 Retrofit 3.
4. Ultimate strengths for as-is Building Index1 and as-is Building Index 2 are 25-33% that of HAZUS®-MH values for W2 pre-code ($A_u = 0.25$g), which seems reasonable.
5. Ultimate strengths for Index Building 1 Retrofit 3 and Index Building 2 Retrofit 3 are between W2 low-code and moderate-code ($A_u = 0.25$g and 0.5g, respectively), which seems reasonable.
6. Periods for as-is Building Index 1, Index Building 1 Retrofit 1, and all variants of as-is Building Index 2 are longer than HAZUS®-MH W2, which has $T_E = 0.4$, despite comparable height. However, HAZUS®-MH W2 assumes two 12-foot stories, so perhaps half the mass per square foot above first story, ~1-2x stiffness per square foot at first story, and no soft-story, so one would expect periods of 1.4 to 2.8 times longer than HAZUS®-MH W2 for the as-is buildings, which is what is observed.
7. Ductility capacities are small compared with all HAZUS W2 even pre-code, which has $D_u/D_y = 15$. However the HAZUS®-MH figure seems unrealistic.

Median capacities for the drift-sensitive components are taken from Porter (2009b, see Appendix 7) and are recapped in Table 8-2. Since the mapping from observable damage states to HAZUS®-MH damage states was shown to be uncertain, a second alternative for median capacities is shown in Table 8-3. Other values are taken as the HAZUS®-MH defaults, as recapped in Table 8-2.

8.6 Results

The methodology presented in Porter (2009b,c) and summarized above was employed to develop a vulnerability function for each of the Index Buildings listed in Table 8-1. The calculations were performed for every combination of 16 variants of the Index Buildings, one occupancy type (multi-family residential, denoted by RES3 in HAZUS®-MH), 5 NEHRP site soil classes (A, B, C, D, and E), four earthquake magnitudes (5, 6, 7, and 8), four site distances (10, 20, 40, and 80 km), and one seismic region: western United States. The mean damage factor results are compiled in a database table laid out as shown in Table 8-4. The fragility results are compiled in a database table laid out as shown in Table 8-5.

Table 8-2 Parameters Employed in Study, Alternative 1

Parameter		Source
K_S	Degradation factor short-duration event (M ≤ 5.5)	IB1-3 as-is: 0.40 = HAZUS®-MH wood frame > 5000 sq. ft. pre-code Retrofits 1-3: 0.60, 0.80, 0.90 resp. = low-, mod-, high-code IB4 as is: 0.80 = HAZUS®-MH wood frame > 5000 sq. ft.mod code IB4 retrofit 1: 0.85, retrofits 2-3: 0.90 = ditto, high code
K_M	Ditto, medium duration (5.5 < M < 7.5)	IB1-3 as-is: 0.2, retrofit 1: 0.3, retrofit 2: 0.4, retrofit 3: 0.6 IB4 as-is: 0.4, retrofits 1: 0.5, retrofits 2-3: 0.6
K_L	Ditto, long duration (M ≥ 7.5)	IB1-3 as-is: 0.0, retrofit 1: 0.1, retrofit 2: 0.2, retrofit 3: 0.4 IB4 as-is: 0.2, retrofits 1: 0.3, retrofits 2-3: 0.4
B_E	Elastic damping ratio	Porter *et al.* (2002): 10%, from system identification of strong-motion records from several California wood-frame buildings
θ_{11}	Median S_d where structural component reaches or exceeds "slight" damage	IB1-3: Porter (2009a): 0.06 in; from lab tests of older materials IB4: 0.86 in. = HAZUS®-MH for mod-code wood frame > 5000 sq. ft.
θ_{12}	Ditto, moderate	IB1-3: Ditto, 0.4 in. for buildings with brick veneer, else 1.2 in. IB4: 2.14 in. = HAZUS®-MH for mod-code wood frame > 5000 sq. ft.
θ_{13}	Ditto, extensive	IB1-3: Ditto, 1.2 in. IB4: 6.62 in. = HAZUS®-MH for mod-code wood frame > 5000 sq. ft.
θ_{14}	Ditto, complete	IB1-3: Ditto, 2.5 in. IB4: 16.2 in. = HAZUS®-MH for mod-code wood frame > 5000 sq. ft.
P_c	Fraction of building area collapsed, given complete damage	IB1-2 as-is: 14%, from San FranciscoMarina District 1989 IB1-2 retrofits 1-3: 6%, 1.5%, 1.5%, respectively IB3-4 as-is: 3%, retrofits 1-3: 2%, 1.5%, 1% respectively
θ_{21}	Median S_d for slight nonstructural drift-sensitive damage	Taken same as θ_{11}
θ_{22}	Ditto, moderate	Taken same as θ_{12}
θ_{23}	Ditto, extensive	Taken same as θ_{13}
θ_{24}	Ditto, complete	Taken same as θ_{14}

Note: IB = Index Building

Table 8-2 Parameters Employed in Study, Alternative 1 (continued)

	Parameter	Source
θ_{31}	Ditto, S_a, nonstructural acceleration-sensitive, slight	HAZUS®-MH default for wood frame > 5000 sq. ft.: 0.2g
θ_{31}	Ditto, S_a, nonstructural acceleration-sensitive, slight	HAZUS®-MH default for wood frame > 5000 sq. ft.: 0.2g
θ_{32}	Ditto, moderate	Ditto: 0.4g
θ_{33}	Ditto, extensive	Ditto: 0.8g
θ_{34}	Ditto, complete	Ditto: 1.6g
β_{11}	Log standard deviation of S_d where structural component reaches or exceeds "slight" damage	Ditto: 1.0
β_{12}	Ditto, moderate	Ditto: 1.0
β_{13}	Ditto, extensive	Ditto: 1.0
β_{14}	Ditto, complete	Ditto: 1.0
β_{21}	Ditto, nonstructural drift-sensitive, slight	Ditto: 1.0
β_{22}	Ditto, moderate	Ditto: 1.0
β_{23}	Ditto, extensive	Ditto: 1.0
β_{24}	Ditto, complete	Ditto: 1.0
β_{31}	Ditto, S_a, nonstructural acceleration-sensitive, slight	Ditto: 0.7
β_{32}	Ditto, moderate	Ditto: 0.7
β_{33}	Ditto, extensive	Ditto: 0.7
β_{34}	Ditto, complete	Ditto: 0.7
L_{11}	Repair cost, structural, slight, fraction of replacement cost	HAZUS®MH default for multi-family dwelling: 0.003
L_{12}	Ditto, moderate	Ditto: 0.014
L_{13}	Ditto, extensive	Ditto: 0.069
L_{14}	Ditto, complete	Ditto: 0.138
L_{15}	Ditto, collapse	Ditto: 0.138
L_{21}	Ditto, nonstructural drift-sensitive, slight	Ditto: 0.009
L_{22}	Ditto, moderate	Ditto: 0.043
L_{23}	Ditto, extensive	Ditto: 0.213
L_{24}	Ditto, complete	Ditto: 0.425
L_{31}	Ditto, nonstructural acceleration-sensitive, slight	Ditto: 0.008
L_{32}	Ditto, moderate	Ditto: 0.043
L_{33}	Ditto, extensive	Ditto: 0.131
L_{34}	Ditto, complete	Ditto: 0.437

In Table 8-4, the record is interpreted this way: if a CAPSS Index Building 1 were standing on site class E in the western United States, and it were shaken at intensity S_a(1.0 sec, 5%) = 0.16g, then on average, the repairs would cost 28% of the replacement cost of the building. "M" (magnitude) and "R" (distance) are used only

Table 8-3 Fragility Parameters Employed in Study, Alternative 2

Parameter		Source
θ11	Median S_d where structural component reaches or exceeds "slight" damage	IB1-3: Porter (2009a): 0.4 in; from lab tests of older materials IB4: 0.86 in. = HAZUS®-MH for mod-code wood frame > 5000 sq. ft.
θ12	Ditto, moderate	IB1-3: Ditto, 1.5 in. for buildings with brick veneer, else 1.2 in. IB4: 2.14 in. = HAZUS®-MH for mod-code wood frame > 5000 sq. ft.
θ13	Ditto, extensive	IB1-3: Ditto, 3.0 in. IB4: 6.62 in. = HAZUS®-MH for mod-code wood frame > 5000 sq. ft.
θ14	Ditto, complete	IB1-3: Ditto, 5.0 in. as-is, 8 in retrofit IB4: 16.2 in. = HAZUS®-MH for mod-code wood frame > 5000 sq. ft.
θ15	Ditto, collapse	IB1-3: 13 in. IB4: 24 in. = 1.5 x θ14
θ21	Median S_d for slight nonstructural drift-sensitive damage	Taken same as θ11
θ22	Ditto, moderate	Taken same as θ12
θ23	Ditto, extensive	Taken same as θ13
θ24	Ditto, complete	Taken same as θ14
θ31	Ditto, S_a, nonstructural acceleration-sensitive, slight	HAZUS®-MH default for wood frame > 5000 sq. ft.: 0.2g
θ32	Ditto, moderate	Ditto: 0.4g
θ33	Ditto, extensive	Ditto: 0.8g
θ34	Ditto, complete	Ditto: 1.6g

Note: IB = Index Building

Table 8-4 Sample Layout of Vulnerability-Function

IB	Occ	Domain	M	R	Siteclass	IM	S_SF_a	S_1F_v	L
CAPSS1	RES3	WUS	7	80	E	Sa10	0.25	0.16	0.28
CAPSS1	RES3	WUS	7	80	E	Sa10	0.28	0.19	0.33

Notes:

IB:	Index Building (e.g., CAPSS1r1 = CAPSS Index Building 1, retrofit 1).
Occ:	HAZUS occupancy class (e.g., RES3 = multi-family dwelling).
Domain:	whether the function is appropriate for western United States ("WUS") or central and eastern US ("CEUS")—only WUS is used here.
M:	approximate magnitude.
R:	approximate distance to the earthquake source zone.
Siteclass:	NEHRP site soil classification (A, B, C, D, or E).
IM	Performance point indicator.
S_SF_a:	5%-damped, site-soil-adjusted spectral accel. response at 0.3 sec period.
S_1F_v:	5%-damped, site-soil-adjusted spectral accel. response at 1.0 sec period.
L:	mean damage factor, which here gives the expected value of repair cost as a fraction of replacement cost new.

Table 8-5 Sample Layout of Fragility-Function[a]

IB	Occ	Domain	M	R	Siteclass	IM	$S_S F_a$	$S_1 F_v$	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}
CAPSS1	RES3	WUS	7	80	E	Sa10	0.25	0.16	1.00	0.92	0.61	0.32	0.03
CAPSS1	RES3	WUS	7	80	E	Sa10	0.28	0.19	1.00	0.95	0.69	0.41	0.04

[a] Note: See Table 8-4 for definitions of parameter in columns 1 through 10 (from left); P11 through P15 refer to the probability that the structural component reaches or exceeds damage states 1 through 5: slight, moderate, extensive, complete, and collapse, respectively.

for spectral shape and duration effects, and "IM" indicates whether the performance point corresponds to a point on the constant-acceleration portion of the index spectrum ("Sa03") or on the constant-velocity portion of the index spectrum ("Sa10") and therefore, which of the two subsequent intensity measures is probably more appropriate to use to estimate loss:. Each record in Table 8-4 is only valid for an earthquake of magnitude between 6.5 and 7.5, at a distance of roughly 80 km. The record also says that the same loss could be expected for S_a(0.3 sec, 5%) = 0.25g, but that one should probably use S_a(1.0 sec, 5%) as the intensity measure instead.

In Table 8-5, P11 through P15 refer to the probability that the structural component reaches or exceeds damage states 1 through 5: slight, moderate, extensive, complete, and collapse, respectively. The first record means that the building is almost certainly damaged at least slightly when shaken at S_a(1.0 sec, 5%) = 0.16g, that there is 92% probability of at least moderate damage, 61% probability of extensive damage, 32% probability of complete damage, and that 3% of building area at this level of shaking would be collapsed.

The resulting data tables are too voluminous to present here, but some sample, summary charts are provided in Figure 8-6. The vulnerability functions show mean damage factor on the y-axis as a function of 1.0-sec, 5%-damped spectral acceleration response on the x-axis. "Mean damage factor" refers to the average repair cost as a fraction of the replacement cost (new, not depreciated) of the building. The x-axis is limited to 1.0g (roughly six times the shaking in the Marina District in the 1989 Loma Prieta earthquake) because this is the largest shaking estimated by the CAPSS hazard modeler Treadwell and Rollo (authors of Appendix 6) anywhere in San Francisco, in the earthquake scenarios that they examined. The vulnerability functions show that the retrofits generally reduce damage by up to 30-70% depending on shaking intensity, but that the benefit is limited when S_a(1.0 sec, 5%) exceeds about 0.5g (roughly three times the shaking experienced in the Marina District in the 1989 Loma Prieta earthquake).

The vulnerability functions shown here are labeled M = 7, R = 10 km, soil = D, because the HAZUS®-MH methodology holds that these parameters affect the shape of the response spectrum and effective damping and thus, they affect structural response, damage, and loss. The vulnerability functions shown in Figure 8-6 are limited to $5.5 < M < 7.5$, $R \leq 15$ km, and the average shearwave velocity in the top 30 m of soil is limited to the range $600 \leq Vs30 \leq 1200$ ft/sec.
The vulnerability functions asymptote to a mean damage factor near 0.6. The reason stems from the fact that the Index Buildings have low values for A_u, as low as 0.05g for one Index Building and in no case higher than 0.4g. Under the capacity spectrum method of structural analysis, the building cannot experience acceleration greater

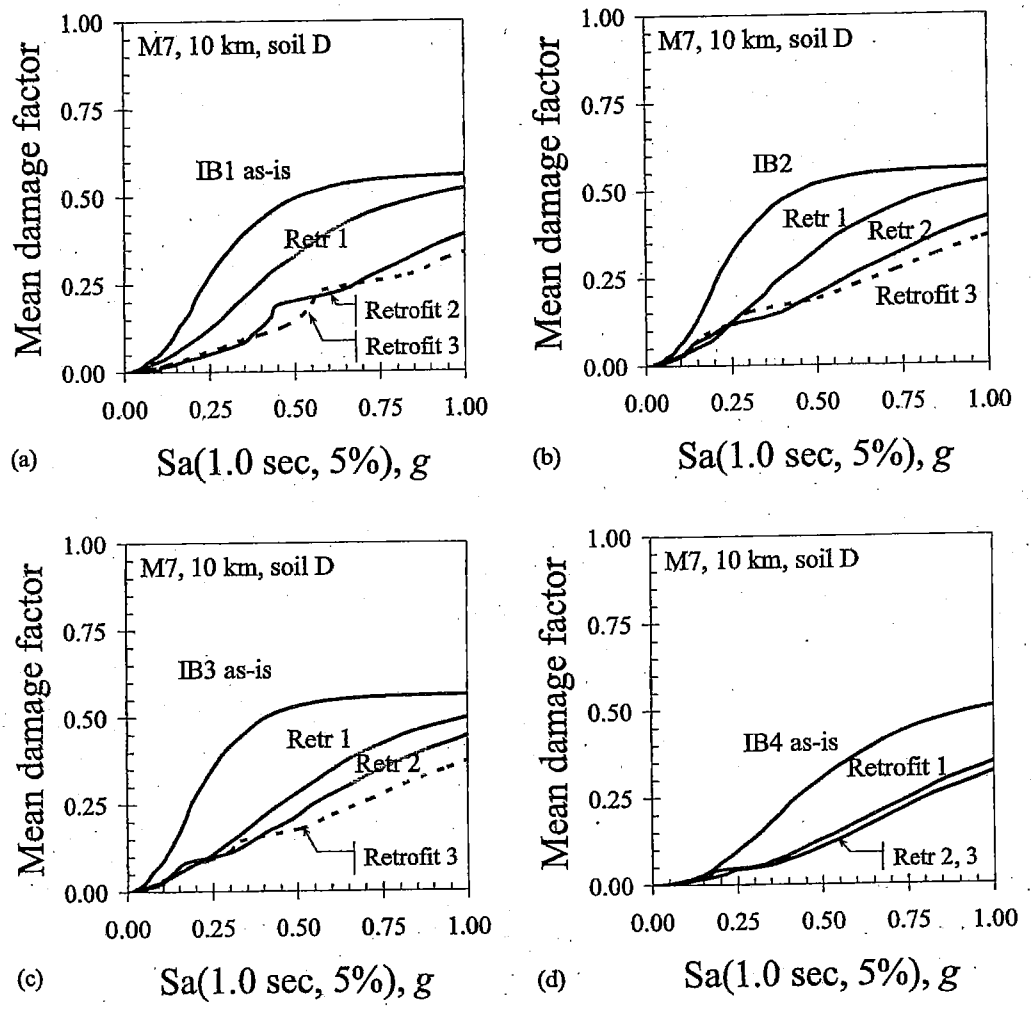


Figure 8-6 *Vulnerability functions for Index Buildings 1-4 under the more conservative (lower-loss) fragility alternatives: (a) Index Building 1 (IB1), (b) Index Building 2 (IB2), (c) Index Building 3 (IB3), and (d) Index Building 4 (IB4). The x-axis shows 1-sec, 5% damped spectral acceleration response on NEHRP site class D. The y-axis shows damage factor, which is the average repair cost as a fraction of the replacement cost of the building.*

than A_u. The building's acceleration-sensitive nonstructural components, which represent 44% of building value, cannot experience acceleration greater than A_u. The HAZUS®-MH default fragility functions for these components have median capacities of 0.2g for slight damage, 0.4g for moderate damage, and 0.8 and 1.6g for extensive and complete damage. Consequently, there is a low probability that this 44% of building value ever experiences greater than slight or moderate damage, associated with loss of 0.8% and 4.3% of building value, respectively. As a result, there is a low probability that the total repair cost ever exceeds 60% of building replacement cost. Presumably the acceleration-sensitive building components in the ground story are destroyed if the ground story collapses, but this fact is not addressed in FEMA (2003a).

Another notable feature of the vulnerability functions is that they are sometimes not smooth. The wiggles in these curves are artifacts of the fact that the estimated loss is actually a function of two measures of ground motion: S_a(0.3 sec, 5%) and S_a(1.0 sec, 5%). At low levels of ground motion, S_a(0.3) controls the structural response and is used as the intensity measure for purposes of calculating damage and loss; at higher levels, S_a(1.0) controls and is used. The wiggles in the plots of loss versus S_a(1.0) occur at the transition between the two domains. In practice, and as applied here, the proper intensity measure is used.

Not shown in the sample vulnerability functions but apparent in the tables, is that magnitude has a significant impact on loss given S_a, largely because of its modeled impact on effective damping. Distance and site soil class make little difference given M and S_a, largely because at fixed values of M and S_a, distance and site class primarily affect the period at the intersection between the constant-acceleration and constant-velocity portions of the response spectra, which rarely matters. S_a(1.0 sec, 5%) is usually the preferred intensity measure, i.e., the performance point is usually on the constant-velocity portion of the demand spectrum.

Figure 8-7 shows the red-tag fragility functions for these sixteen variants of the four Index Buildings. It suggests, for instance, that when Index Buildings 1 or 2 are subjected to S_a(1.0) ≈ 0.17g, as estimated from the USGS *ShakeMap* of the Marina

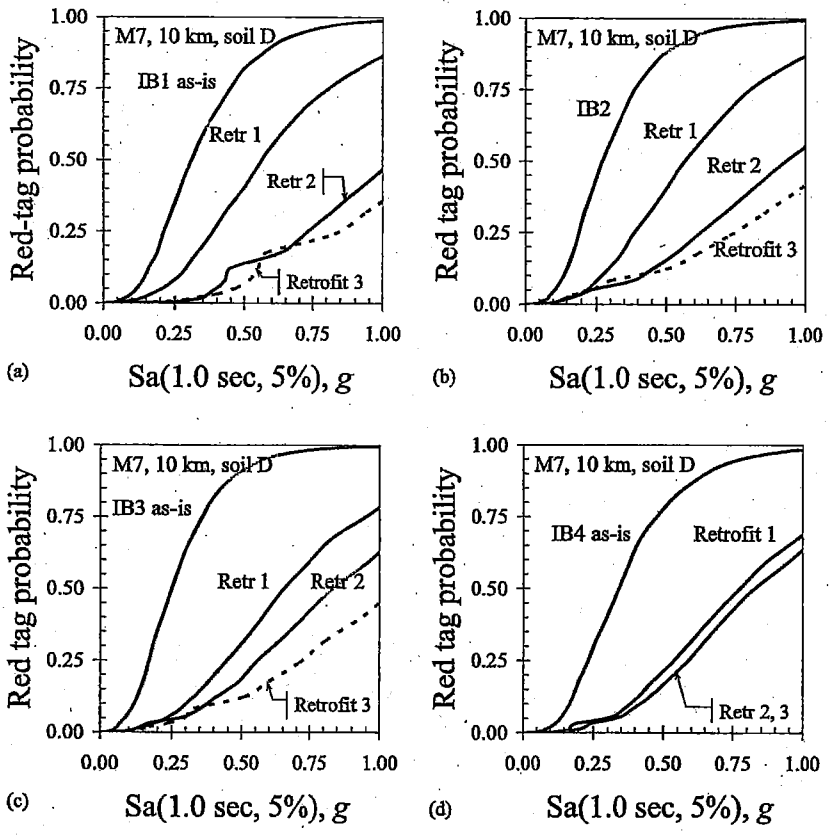


Figure 8-7 Post-earthquake red-tag probability as a function of spectral acceleration, Sa(1.0 sec, 5% damped), for (a) Index Building 1 (IB1), (b) Index Building 2 (IB2), (c) Index Building 3 (IB3), and (d) Index Building 4 (IB4).

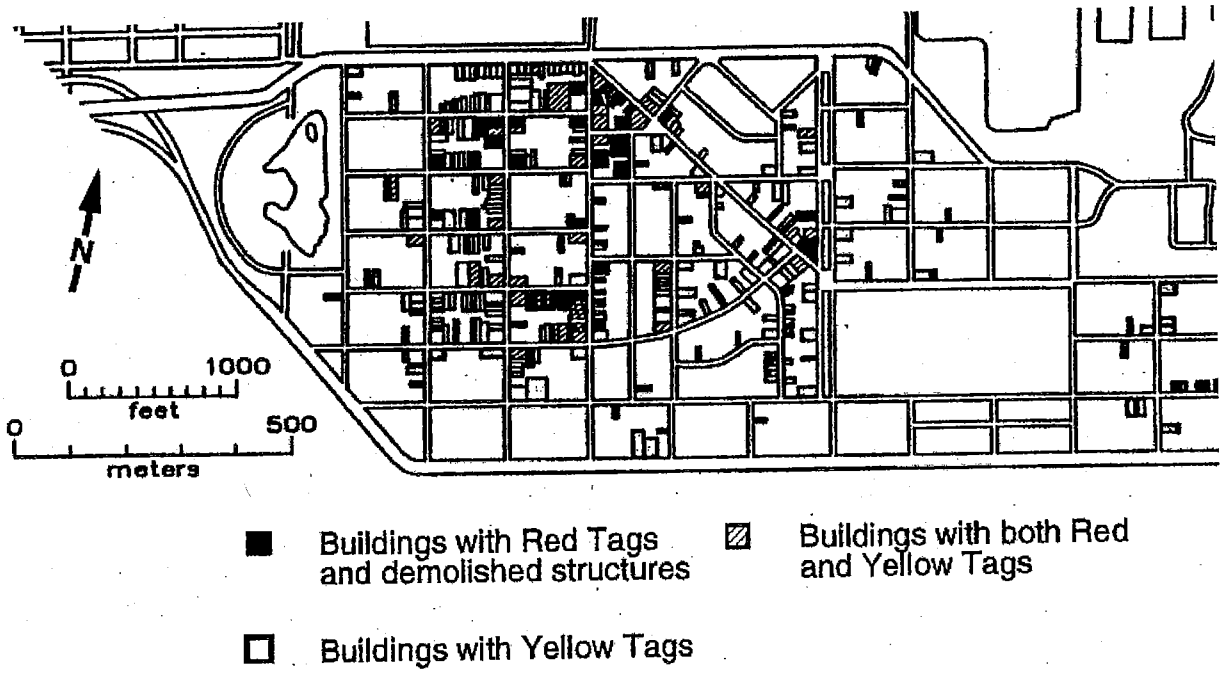


Figure 8-8 Post-earthquake safety tags in the San Francisco Marina District after the 1989 Loma Prieta earthquake (Seekins et al., 1990 via Scawthorn et al., 1992).

District in the 1989 Loma Prieta earthquake, then approximately 20% to 25% would be red-tagged. A San Francisco Department of Building Inspection (DBI) database lists 111 soft-story corner buildings in the Marina District. One would therefore estimate approximately 22 to 28 red tags in corner soft-story buildings in the Marina in 1989. There appear to have been about 33, as shown in Figure 8-8, suggesting an underestimate but perhaps reasonable agreement. Figure 8-9 shows collapse probability for the Index Buildings. At $S_a(1.0) \approx 0.17$g, one would expect a 5 to 10% collapse rate among the approximately 111 corner soft-story buildings in the Marina. There were six, again suggesting reasonable agreement.

8.7 Conclusions

A set of relationships between shaking intensity, damage, and loss was created for four buildings that are characteristic of soft-story multi-family wood-frame dwellings in San Francisco. Vulnerability and fragility functions were also created for three retrofits of each building, for a total of sixteen variants of the four Index Buildings described in Appendix 4. The relationships were calculated using the HAZUS®-MH framework (FEMA, 2003a). While simpler and offering less fidelity than a second-generation performance-based earthquake engineering model, the HAZUS®-MH methodology has been shown in several instances to produce realistic aggregate results. (A second-generation performance-based earthquake engineering approach would employ a multi-degree-of-freedom structural model examined using nonlinear dynamic structural analysis, along with disaggregated fragility functions, damage, and loss estimates, but would have exceeded the available resources for this project.)

A vulnerability-calculation procedure was applied that honors all HAZUS®-MH methodologies, while avoiding the iteration of the capacity spectrum method and a programming error recently discovered in the HAZUS®-MH Advanced Engineering

Building Module. The results appear to hindcast reasonably the experience of corner soft-story apartment buildings in the Marina District in the 1989 Loma Prieta earthquake.

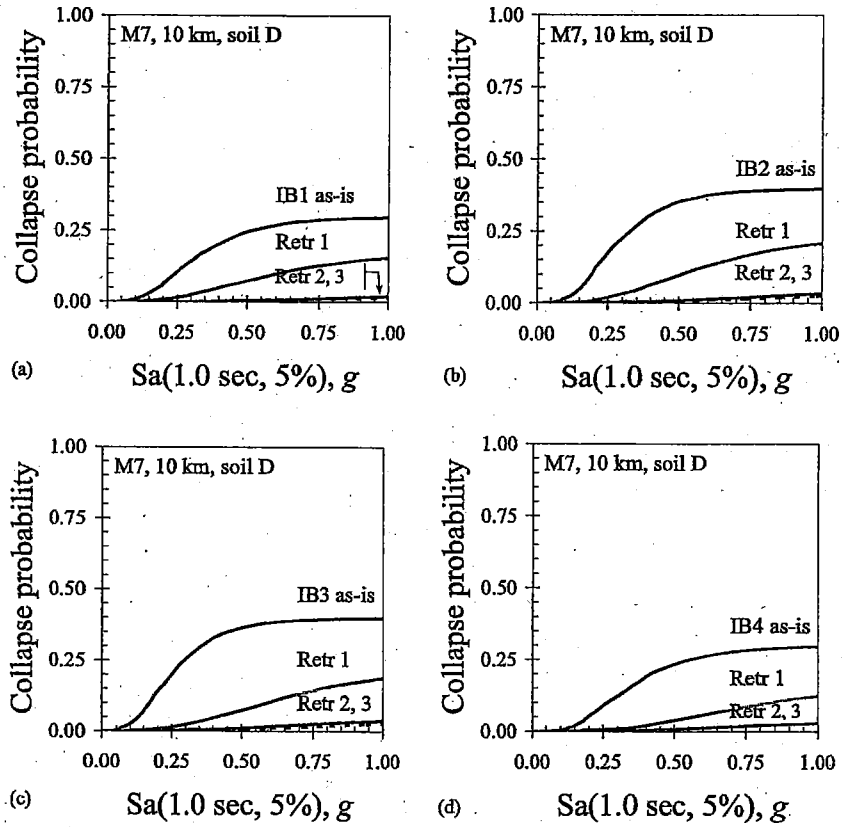


Figure 8-9 *Collapse probability as a function of spectral acceleration, Sa(1.0 sec, 5% damped) for (a) Index Building 1 (IB1), (b) Index Building 2 (IB2), (c) Index Building 3 (IB3), and (d) Index Building 4 (IB4).*

APPENDIX 9: ESTIMATES OF EARTHQUAKE SCENARIO LOSSES TO LARGE SOFT-STORY WOOD-FRAME BUILDINGS IN SAN FRANCISCO

9.1 Executive Summary

San Francisco has 2,800 wood-frame, soft-story buildings with at least three stories and five dwellings each. "Soft-story" means that the lowest story is much weaker or more flexible than those above it. Here, that means that one ground-story façade is at least 80% open (i.e., the wall has window and door openings covering at least 80% of the gross area of the ground-story façade), or that two are at least 50% open. These buildings, which perform poorly in earthquakes, house 58,000 people—8% of the population—in 29,000 dwelling units. To inform public policy, a study for San Francisco's Community Action Plan for Seismic Safety (CAPSS) quantified the risk. The impacts on these buildings were estimated for four large, hypothetical, realistic earthquakes.

In one scenario (a magnitude 7.2 earthquake on the San Andreas fault), 80% of these buildings are expected to be posted unsafe to occupy, and 30% are expected to collapse—that is, in just this one class, over 2,000 buildings are expected to be posted unsafe (rendering 46,000 persons homeless) and over 800 buildings (housing 17,000 persons) are expected to collapse. These results seem realistic: average shaking Citywide in this scenario is expected to be four times stronger than in the Marina District in the 1989 Loma Prieta earthquake, where approximately one in four corner soft-story apartment buildings were posted as unsafe to enter or occupy (red-tagged) or collapsed.

Retrofitting ground stories with cantilever steel columns and wood sheathing reduces red tags to fewer than 10%. It reduces collapses to fewer than one in one hundred. Retrofitting of these buildings would cost $260 million, equivalent to $10,000 to $20,000 per dwelling unit, depending on building details. The methodology is validated by comparison to actual experience in the 1989 Loma Prieta earthquake.

9.2 Objectives and Scope of Work

Soft-story conditions make wood-frame buildings significantly more vulnerable. Buildings like these collapse at lower excitation than do other wood-frame buildings of comparable size. To quantify the number of such buildings in San Francisco, volunteer structural engineers working under the direction of the San Francisco Department of Building Inspection (DBI) performed a sidewalk survey of at least 4,400 residential wood-frame buildings in the city, in order to ascertain a number of potentially seismically important parameters: height, number of housing units, evidence of retrofit, corner versus mid-block location, sloped versus level site, first story use, and openness of each ground-level façade. To this database was added

information from the county tax assessor and from a Dun & Bradstreet database: square footage, year built, number of businesses, and number of employees.

The efforts (described in this appendix) to quantify the risk that these buildings pose in large San Francisco earthquakes were undertaken at the direction of Mayor Gavin Newsom. The study objective was to estimate the damage and potential repair costs in each of several scenario earthquakes and to quantify costs and benefits that might result from practical seismic rehabilitation to these buildings.

The work considered only those buildings that have three or more stories, five or more housing units, and soft-story conditions meeting either of two criteria: at least 80% open on one street-level façade or at least 50% open on two. This subset of buildings contains 29,000 housing units (7% of the total in San Francisco) and is home to 58,000 residents—8% of the city's population—along with 2,100 businesses and 6,900 employees.

9.3 Available Methodologies

Several methodologies exist to estimate earthquake risk. Commercial loss-estimation firms such as RMS, EQECAT, and AIR offer proprietary loss-estimation models, based in part on empirical seismic vulnerability functions developed from earthquake experience of various insurance companies. In general, however, these seismic vulnerability functions lack resolution of various categories of soft-story wood-frame construction with or without various seismic retrofit options, and they are generally unavailable for open review.

Early among open models (i.e., models whose derivation and parameter values are available for review), the ATC-13 effort led by the Applied Technology Council (ATC, 1985) developed probabilistic relationships between shaking intensity, measured in terms of Modified Mercalli Intensity (MMI), and the probability of each of 38 general building classes entering each of 7 discrete damage states (defined in terms of damage factor, meaning the repair cost as a fraction of replacement cost). The ATC-13 damage-probability matrices (DPMs) were derived from a modified Delphi process, in which multiple experts rendered initial judgments about seismic vulnerability, self-judged their level of expertise, and revised the initial estimates based on a review of estimates by others, to provide a basis for reconciling significant differences among experts. Their judgments were combined to create weighted average DPMs and relationships between MMI and the conditional probability distribution of damage factor. The ATC-13 methodology does not distinguish between varieties of wood-frame buildings, however, and cannot resolve the effects of soft-story construction or seismic retrofit.

The HAZUS®-MH methodology (FEMA, 2003a) was developed during the 1990s with the support of the Federal Emergency Management Agency (FEMA), and it reflects performance-based earthquake engineering principles. Instead of relying on expert opinion to relate shaking intensity directly to damage and loss, the HAZUS®-MH methodology applies engineering principles: it idealizes a building as a single-degree-of-freedom nonlinear damped harmonic oscillator, and applies the capacity spectrum method (CSM) of structural analysis to estimate the building's structural response in a particular earthquake. It applies relationships between structural response and damage developed from laboratory tests and earthquake experience, in order to estimate the probabilistic damage state of the building's various components, and it applies estimates of repair cost given each level of damage. HAZUS®-MH

differentiates among eight classes of wood-frame construction based on size (two categories) and code era (four categories). It does not address soft-story construction or the benefits to be derived from various seismic retrofit options.

The HAZUS®-MH Advanced Engineering Building Module (AEBM; FEMA, 2003b) is software developed to model the seismic performance of individual buildings, by allowing the user to input the values of the various parameters of structural performance, damage, and loss. These are the same parameters as are used in the main HAZUS®-MH methodology (FEMA, 2003b), which provides some guidance on how to develop these parameters. The AEBM software has been found to have a programming flaw that causes it not to follow the HAZUS®-MH methodology accurately. As of this study, the frequency with which the flaw occurs has not been definitively established, nor had the severity of the error, when it does.

For this study, an adaptation of the HAZUS®-MH methodology was developed that honors all HAZUS®-MH principles but avoids the iteration sometimes required in the CSM, and that performs the calculations outside of HAZUS®-MH or the AEBM, thus avoiding the programming flaw. The methodology, detailed in Porter (2009c, d) and summarized in Appendix 8 of this volume, can be performed in a spreadsheet, database, or other programming environment. The methodology has been peer reviewed by six engineers and independently validated by three people. It produces tables relating probabilistic damage state and mean damage factor to shaking intensity in terms of $S_a(0.3, 5\%)$ and $S_a(1.0, 5\%)$, conditioned on magnitude, distance range, site soil classification, occupancy category, and seismic domain (plate boundary or continental interior). Mean damage factor is defined as the expected (average) repair cost as a fraction of replacement cost new. The adaptation of the HAZUS®-MH methodology developed for this study does not have the limitations of the foregoing models; rather, it has the capability to produce transparent and validated results.

9.4 Details of the Selected Methodology

Damage is estimated using Equation 9-1 and economic loss, according to Equation 9-2.

$$E[N_d] = \sum_{i=1}^{n} p_i \left[D = d \middle| S = s \right] \tag{9-1}$$

$$E[L] = \sum_{i=1}^{n} R \cdot A_i \cdot y_i(s_i) \tag{9-2}$$

In Equation 9-1, $E[N_d]$ refers to the expected value of the number of subject buildings in the study area that would be in damage state, d, after a given earthquake scenario. The damage states are red-tagging (e.g., posting a damaged building with a red UNSAFE ATC-20 placard), collapse, and the structural and nonstructural drift-sensitive damage states of HAZUS®-MH. See FEMA (2003a) or Kircher et al. (1997) for detail on the latter damage states. In the equation, n is the number of buildings under consideration, and $p_i[D = d|S = s]$ refers to the probability that the ith building is in damage state d, given that it is subjected to shaking intensity s. In Equation 9-2, $E[L]$ refers to the expected value of repair cost L in a given earthquake scenario, R is the estimated replacement cost per square foot, A_i is the square footage of the ith building, and $y_i(s_i)$ is the mean damage factor to the ith building (damage factor means repair cost as a fraction of building replacement cost new), given that it is subjected to shaking of intensity s_i. Shaking intensity is measured either in terms of

S_a(0.3 sec, 5%) or S_a(1.0 sec, 5%), depending on whether a capacity-spectrum-method analysis indicates the performance point lies on the constant-acceleration or constant-velocity portion of an idealized acceleration response spectrum. See Porter (2009c) for more detail on that issue. In most cases relevant here, the performance point lies on the constant-velocity portion of the response spectrum.

9.5 Methodology Application to San Francisco Soft-Story Dwellings

Characteristics and Distribution of Index Buildings. The locations and square footage of each subject building were taken from the DBI database described in Appendix 1. Analysis of the San Francisco Department of Building Inspection database indicated that there are an estimated 29,000 housing units in 2,800 large wood-frame buildings with soft-story conditions. "Large" here means three or more stories and five or more housing units, and "soft-story" means that the building meets either or both of two criteria: one ground-story façade is at least 80% open, or two are each at least 50% open. They house approximately 58,000 people, representing 8% of the population and 7% of its stock of housing units.

Cobeen (see Appendix 4) designed four prototypical Index Buildings to represent the range of housing addressed here (Figure 9-1). The designs and three retrofits each were selected in consultation with DBI and consulting structural engineers. Each building in the exposed building stock was associated with the damageability information described in Appendix 7, as follows.

- Index Building 1 (IB1): This is a three-plus story corner building with garage openings on one side of the building only. Therefore, corner wood-frame buildings in the DBI database were associated with IB1 when they met the CAPSS "Significant Ground Floor Openings" criterion 1 (80% or more open on any one side), but did not meet criterion 2 (50% or more open on any two sides).
- Index Building 2 (IB2): This is a three-plus story corner building with ground-story openings for garages on two sides of the building. Corner wood-frame buildings in the DBI database were associated with IB2 when they met criterion 2 (at least 50% open on any two sides).
- Index Building 3 (IB3) is a mid-block structure built before 1950, which most likely has straight sheathing on the exterior wall and wood lath and plaster interior wall finish. Accordingly, mid-block soft-story buildings with three-plus stories and five-plus housing units, built before 1950 were associated with IB3.
- Index Building 4 (IB4) is a mid-block post-1950 building. The most important feature of IB4 is plywood sheathing on exterior walls and gypsum-board interior wall finish. IB4 is therefore likely to be stiffer, stronger, and more damage resistant than IB3. Therefore, mid-block soft-story buildings with three-plus stories and five-plus housing units built after 1950 were associated with IB4.

By associating buildings in the DBI database with Index Buildings 1 through 4 on this basis, it was found that the total building area is fairly evenly distributed among the four Index Buildings: 19% are Index Building 1, 25% are Index Building 2, 35% are Index Building 3, and 21% are Index Building 4. Most of the area is built at a location whose NEHRP site soil classification is D. The distribution of Index

Buildings and site conditions by type replacement cost, percent of dwelling units, percent of area and value are summarized in Table 9-1.

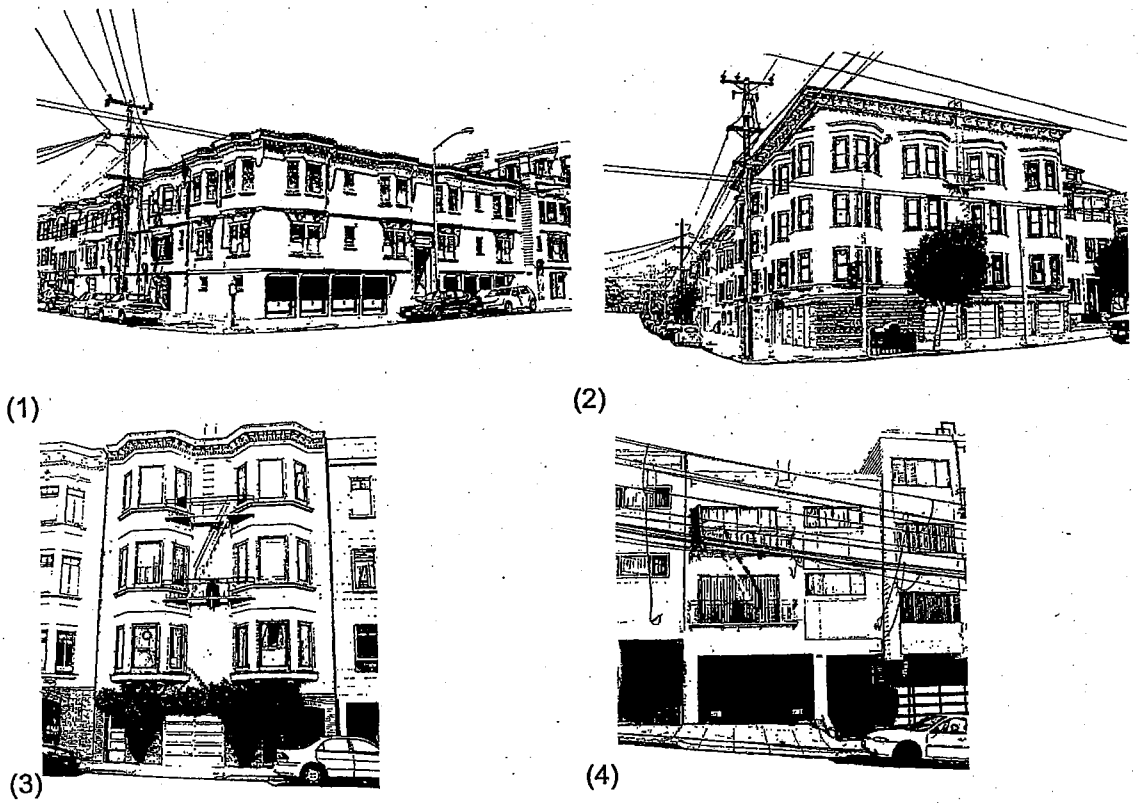


Figure 9-1 *CAPSS Index Buildings. Four older, soft-story, wood-frame, multi-family dwellings representing a realistic range of performance of buildings of this class in San Francisco: (1) corner, 3 story, no interior walls at garage level, one street facade ≥ 80% open at ground floor; (2) corner, 4 story, both street facades ≥ 50% open at ground floor; (3) mid-block, 4 story, pre-WWII, neighbors on both sides; (4) mid-block, 3 story, post-1950, neighbors on both sides. Square footage is 3,600, 5,800, 2,300, and 1,800 sq. ft., respectively.*

Table 9-1 Area and Replacement Cost by Index Building and Site Class

Index Building (IB) / Site Class	Replacement Cost, $Billions	Percent of Units	Percent of Area and Value
IB1	$2.8	20%	19%
IB2	$3.5	26%	25%
IB3	$4.9	33%	35%
IB4	$3.0	21%	21%
Site class B	$1.6	10%	10%
Site class C	$1.2	8%	8%
Site class D	$10.5	73%	74%
Site class E	$1.1	8%	8%

Building adjacency. Several questions relating to building adjacency were considered: Do mid-block buildings, with buildings on either side to support them, actually collapse in earthquakes? Can they be modeled as Cobeen (Appendix 4) has done in the CAPSS study, as if they were freestanding, i.e., ignoring pounding? The issue of adjacency is important because this type of building appears to have collapsed in the 1906 San Francisco earthquake, based on the high number of mid-block wood-frame building collapses that appear in photographs of documents that archive the event: for example, Gilbert et al. (1907), Pierce et al. (1906), Klett and Lundgren (2006), and Tobriner (2006). Examples of such photographs are provided in Figure 9-2. However, it is unclear from most of the available photos how close the collapsed mid-block buildings were to their neighbors. The DBI database has no field for adjacency: the field surveyors did not record gap widths.

Based on the limited 1989 earthquake data available from the Marina District, where only one of the seven collapsed buildings was mid-block, it seems that mid-block soft-story buildings are less likely to collapse than are corner soft-story buildings, all else being equal. Ultimately a very simple approach was used here to deal with pounding and adjacency. The structural models described in Appendix 4 do not treat pounding or adjacency, and the loss model makes mid-block buildings less likely to collapse than corner buildings and at least as likely as the average pre-code one- or two-story wood-frame building. It does so by setting the vulnerability term, P_c (fraction of area collapsed in buildings with complete structural damage), for as-is Index Buildings 3 and 4 to the HAZUS®-MH default value of 3%, in contrast to the 10% figure used for corner buildings (see Appendix 7).

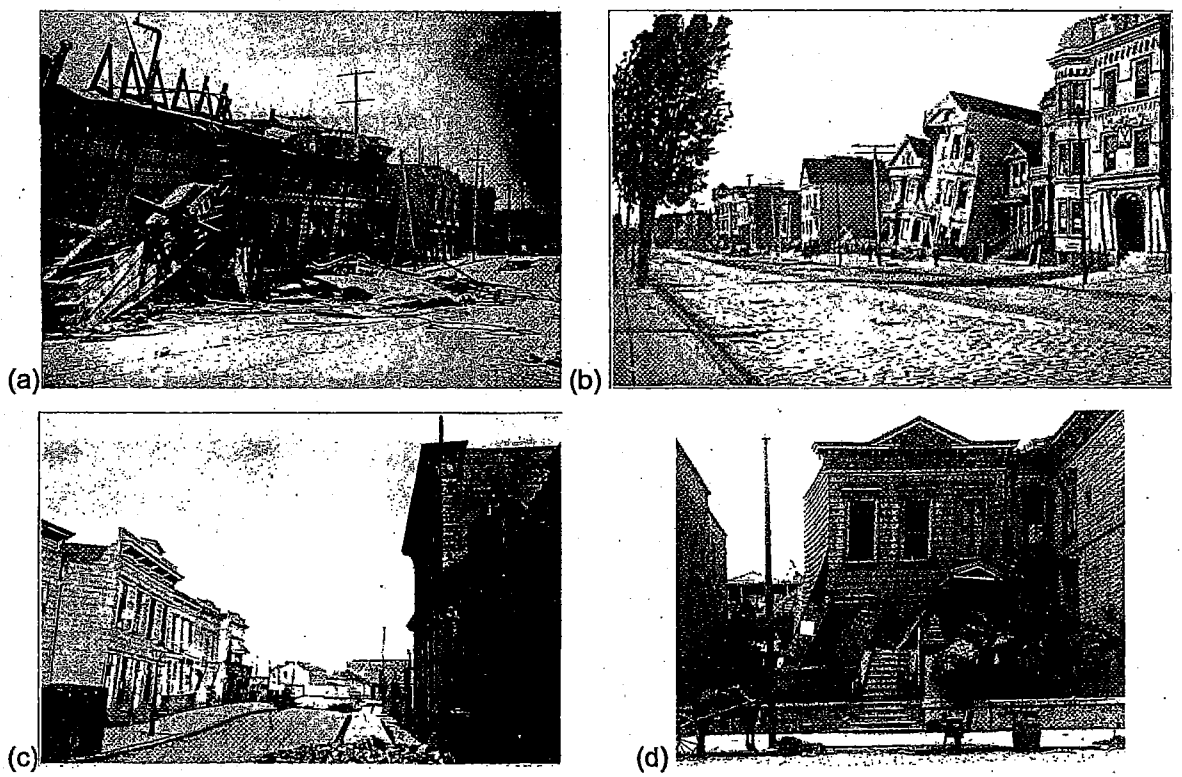


Figure 9-2 Collapses of large mid-block wood-frame building in the 1906 San Francisco earthquake: (a) Valencia St. Hotel (Pierce et al., 1906), (b) Howard St (Gilbert et al., 1907), (c) Dore St. between Bryant and Brannan (Gilbert et al., 1907), (d) unknown location, where collapse is associated with "cripple-wall and shear failure" (Tobriner, 2006).

Seismic Retrofits. As described in Appendix 4, three seismic retrofits were designed for each Index Building. The retrofits were designed to meet various performance objectives defined in SPUR (2008). Retrofit 1 is intended to meet SPUR performance category D, safe but not repairable, meaning that "Buildings may experience extensive structural damage and may be on the verge of collapse. They ... are expected to receive a red tag (UNSAFE placard) after the expected earthquake." The "expected" earthquake is one that produces shaking with 10% exceedance probability in 50 years, and is approximated here by a magnitude 7.2 earthquake on the Peninsula segment of the San Andreas fault. Retrofit 1 generally comprises the addition of a steel frame at openings and some wood sheathing at existing walls. Retrofit 2 is intended to make the building meet SPUR performance category C, safe and usable after repair, meaning that the building "may experience significant structural damage that will require repairs prior to resuming unrestricted occupancy and therefore is expected to receive a yellow tag (RESTRICTED USE placard) after the expected earthquake." Retrofit 2 generally comprises the steel frame and more structural sheathing. Retrofit 3 is intended to make the building approximately satisfy SPUR performance category B, safe and occupiable during repair, meaning that "Buildings will experience damage and disruption to their utility services, but no significant damage to the structural system. They may be occupied without restriction and are expected to receive a green tag (INSPECTED placard) after the expected earthquake."

Detailed cost estimates (Appendix 5) of the retrofit designs (Appendix 4) indicate that the seismic retrofits would cost between $50,000 and $130,000 per building, as summarized in Table 9-2, or $6,000 to $30,000 per housing unit (apartment or condominium) per Table 9-3. The costs account for local construction costs, permit fees, removal and replacement of finishes and other materials at the ground floor during construction, and other contingencies. The costs do not include engineering design fees or business relocation or interruption expenses, and are appropriate for San Francisco construction in 2008. The detailed cost estimates of Appendix 5 are summarized in Table 9-2. It is noteworthy that retrofit 3, intended for better performance than retrofit 2, generally costs less. The total cost to retrofit all such buildings in the City is roughly $200 to 300 million, as shown in Table 9-4.

The Index Buildings have on average somewhat fewer dwellings per building than the average real building stock, and there are other differences between the Index Buildings and real building stock, so the real cost of retrofit per dwelling unit might differ somewhat from these figures, but a figure of $10,000 to $20,000 per dwelling unit agrees with the experience of several engineers consulted for this project.

Table 9-2 Summary of Retrofits Costs per Building

Retrofit	SPUR (2008) Performance Objective	Cost Per Building, $000			
		IB1	IB2	IB3	IB4
1. Steel frames, shearwalls	D, safe not repairable	$79	$71	$59	$49
2. Same, more shearwalls	C, safe, usable after repair	120	130	110	59
3. Cantilever columns + shearwalls	C or B, safe and usable during repair	110	110	96	58

Table 9-3 Retrofits Cost per Housing Unit (Using Number of Units per Index Building)

Retrofit	SPUR (2008) Performance Objective	Cost Per Unit, $000			
		IB1	IB2	IB3	IB4
1. Steel frames, shearwalls	D, safe but not repairable	$20	$6	$10	$12
2. Same, more shearwalls	C, safe and usable after repair	30	11	18	15
3. Cantilever columns + shearwalls	C or B, safe and usable during repair	28	9	16	15

Table 9-4 Total Estimated Retrofits Cost for All 2,800 Buildings

Retrofit	SPUR (2008) Performance Objective	Total Retrofit Cost, $ Million
1. Steel frames, shearwalls	D, safe but not repairable	$180
2. Same, more shearwalls	C, safe and usable after repair	$300
3. Cantilever columns + shearwalls	C or B, safe and usable during repair	$260

Shaking Intensity. During an earlier stage of the CAPSS project, Treadwell and Rollo estimated the shaking intensities across San Francisco for each of four scenario earthquakes: a magnitude 7.9 earthquake on the San Andreas fault, representing a repeat of the 1906 earthquake; a magnitude 7.2 event rupturing the Peninsula segment of the San Andreas fault; a magnitude 6.5 event on a smaller portion of the San Andreas fault, and a magnitude 6.9 event on the Hayward fault (see Appendix 6). The study predated the Next Generation Attenuation (NGA) relationships; see Power et al. (2008) for an overview of NGA. The authors used then-current leading attenuation relationships, an equally weighted average of the Abrahamson and Silva (1997), Campbell (1997), and Sadigh et al. (1997) relationships. They accounted for site soil amplification, using the median relationship for rock to reflect NEHRP site class B, the median relationship for soil to reflect site class D, and the average of the two to reflect site class C. The equally weighted average of the three relationships' median spectral acceleration response on rock, and the 1997 NEHRP amplification factors for site class E, were used to estimate shaking on site class E. The resulting maps of shaking intensity in terms of peak ground acceleration are shown in Figure 9-3. Maps measuring shaking in terms of 5%-damped, 0.3-sec and 1.0-sec spectral acceleration response were also generated, but are not shown here.

Treadwell and Rollo's estimates suggest average shaking on the order of S_a(1.0 sec, 5%) = 0.30g in the magnitude 6.9 Hayward fault event, 0.35g in the magnitude 6.5 San Andreas fault event, 0.50g in the magnitude 7.2 San Andreas fault event, and 0.67g in the magnitude 7.9 San Andreas fault event. "Average shaking" here means an equally weighted average of the S_a(1.0 sec, 5%) values estimated at the sites of each of the 2,800 large, soft-story wood-frame buildings considered in this study. For reference, the USGS ShakeMap for the 1989 Loma Prieta earthquake estimates that sites in the San Francisco Marina District on soft soil (NEHRP categories D or E) experienced roughly S_a(1.0 sec, 5%) = 0.17g, i.e., one-fourth to one-half the average citywide shaking of any of these four scenario events.

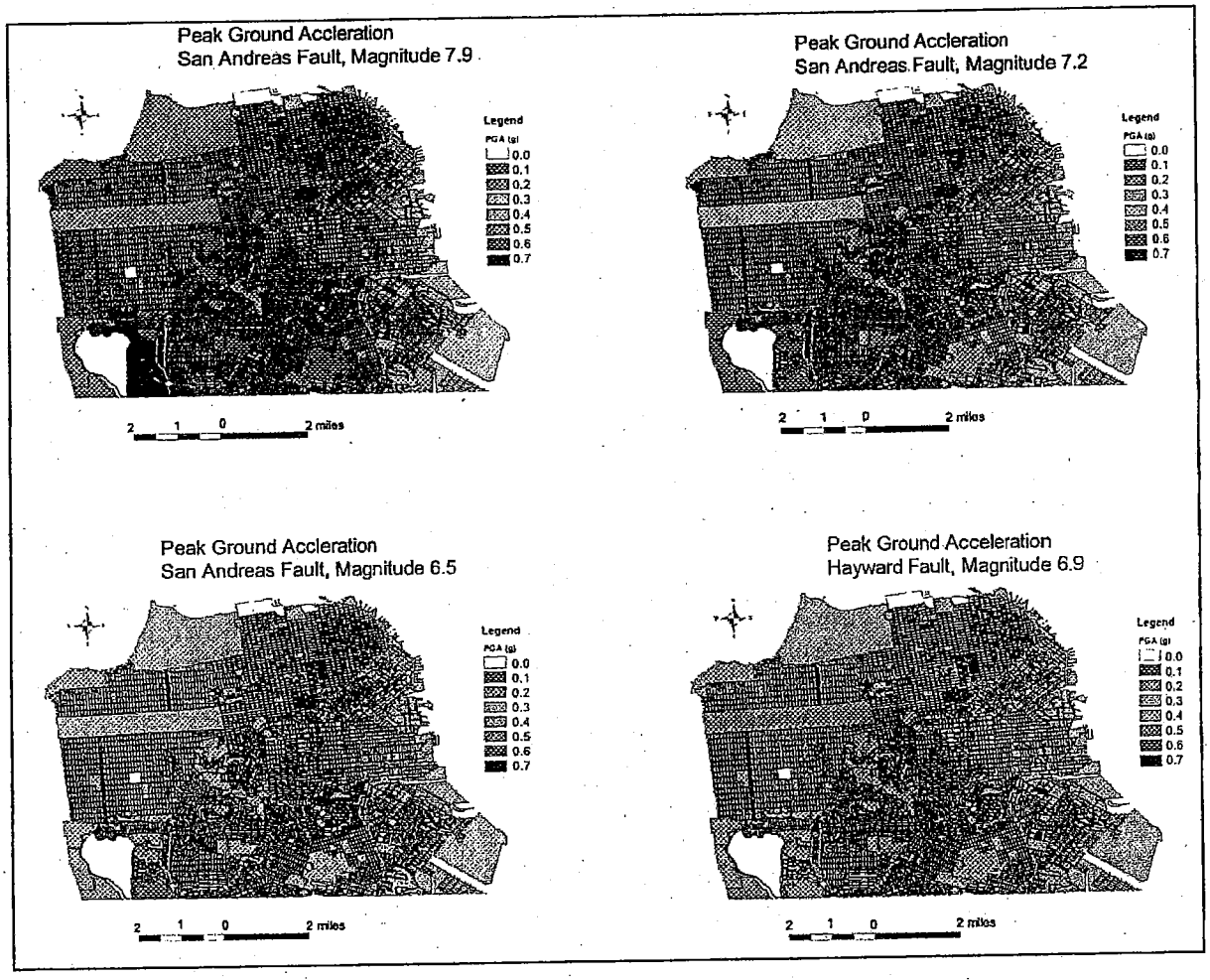


Figure 9-3 *Shaking intensity in four scenario earthquakes. Source: internal ATC report prepared by Golesorkhi and Gouchon submitted to DBI in 2003 as one of the initial CAPSS project deliverables.*

For reference, of the 111 corner, soft-story wood-frame buildings of three or more stories and five or more dwelling units in the Marina District that are shown in the DBI database, approximately 33 were red-tagged after the 1989 Loma Prieta earthquake (i.e., 30%), including 6 collapses (5%), per the map prepared by Seekins, Lew, and Kornfield (1990). Harris and Egan (1992) studied 74 soft-story apartment buildings in the Marina District and report that 11 of the 74 (15%) experienced major damage or collapsed. Here, major damage refers to ATC-13 (1985) damage state 6, equivalent to the HAZUS®-MH (FEMA, 2003a) complete damage state[1]. Collapse here means that at least the first story gravity system failed to the point that the second floor dropped to the ground, touching the first floor. Thus, the CAPSS scenarios produce shaking that is 2-to-4 times the 1989 shaking in the Marina District, which caused 30% of corner buildings to be red-tagged, 5% of them to

[1] This equivalence is only approximate, since ATC-13 damage states deal with the damage to the building as a whole, whereas in HAZUS®-MH one assigns a damage state to each of three general components separately.

collapse, and 15% to suffer total economic loss (repairs costing ≥ 60% of replacement cost).

Replacement Cost. Five local specialists were asked to give their estimates of the per-square-foot cost to build new multi-family wood-frame apartment buildings, with either garage or commercial space at the ground floor, in San Francisco in 2008. These specialists included a local architect, who had recently constructed this type of building; an employee of a local development company that had recently constructed this type of building; a local insurance agent; an insurance analyst, who worked with software that calculates building replacement costs, and; a risk modeling company that provided services to the insurance industry. These estimates ranged from $190 per square foot to $350 per square foot. The two lowest values came from insurance-company models that one specialist acknowledged were likely to be lower than actual building costs. The two highest estimates, both $350 per square foot, stated that this was a minimum cost and that actual construction costs could be higher. Estimates from local professionals working in San Francisco might reasonably be considered more credible than estimates generated from computer models; therefore, the two estimates from computer models were discarded. The average value of the remaining three estimates, $330 per square foot, was used was to estimate post-earthquake rebuilding and repair costs (calculated as a percentage of rebuilding costs). This value does not take into account that construction costs may be higher than normal after an earthquake, due to labor and materials shortages and other phenomena often collectively referred to as "demand surge."

At $330 per square foot replacement cost, these soft-story buildings have a total value of $8.1 billion. Residential content value is commonly estimated by insurers to represent roughly 40% of total replacement cost, so the total replacement cost of these multi-family dwellings is estimated to be approximately $14 billion.

Seismic Vulnerability Functions. Seismic vulnerability functions, $y(s)$, and fragility functions $p[D=d|S=s]$ were developed for each of the four Index Buildings for as-is and each of three retrofitted conditions (see Appendix 8). In general, the retrofits reduce damage by up to half, though at high levels of shaking, the benefit of retrofit is reduced. Note that the HAZUS®-MH methodology does not estimate the number of buildings in the collapsed damage state but rather, estimates the fraction of total square footage that is collapsed. In the case of soft-story wood-frame buildings, this would generally be the bottom floor; therefore, one can estimate the total square footage of subject buildings in which at least part of the building is collapsed by multiplying the fraction collapsed by the average number of stories, which here is roughly four.

The HAZUS®-MH structural damage states and SPUR performance levels can be approximately equated with safety tag (placard) colors as defined in ATC-20 (Applied Technology Council, 1989, 1995, 1999). ATC-20 is the *de facto* international standard for rapid and detailed post-earthquake safety evaluation of buildings. In this study, the HAZUS®-MH complete structural damage state and SPUR performance level D are equated with a red tag in ATC-20, indicating unsafe to enter or occupy. HAZUS®-MH's extensive structural damage and SPUR performance level C are equated with a yellow tag, indicating that restricted use is allowed. Lower HAZUS®-MH structural damage states and SPUR performance levels A and B are equated with green (INSPECTED) tag.

9.6 Results

Equations 9-1 and 9-2 were evaluated for each of four earthquake scenarios and four sets of retrofit conditions: all buildings as-is, and all buildings with retrofit 1, 2, and 3, respectively. Estimated losses are as follows. Under as-is conditions, the scenario earthquakes are estimated to cause 50-90% of soft-story multi-family dwellings to be red-tagged or collapse (see Table 9-5). The CAPSS Project Engineering Panel concluded that these figures represent an upper bound and interpreted them to produce a range of outcomes that they considered to be reasonable; these results are shown in Table 9-6.

Table 9-5 Estimated Damage to Housing Among *all* 2,800 Buildings in the Study, Based on Modeling

Scenario	Retrofit	SPUR Performance Level Among 2,800 Buildings (%)				
		A	B	C	D	E
Magnitude 6.9 Hayward Fault	As-is	15%	18%	19%	30%	18%
	1	50%	22%	18%	8%	2%
	2	68%	16%	10%	6%	0.3%
	3	72%	16%	9%	3%	0.2%
Magnitude 6.5 San Andreas Fault	As-is	9%	13%	17%	39%	22%
	1	38%	23%	23%	13%	4%
	2	56%	20%	15%	9%	1%
	3	59%	20%	15%	6%	0.3%
Magnitude 7.2 San Andreas Fault	As-is	2%	5%	9%	54%	31%
	1	17%	19%	28%	28%	8%
	2	35%	22%	24%	18%	1%
	3	44%	23%	21%	12%	0.7%
Magnitude 7.9 San Andreas Fault	As-is	0%	1%	2%	62%	35%
	1	4%	8%	21%	52%	14%
	2	10%	14%	26%	47%	3%
	3	13%	15%	26%	44%	3%

Note: SPUR performance levels are color-coded to indicate an equivalency with the ATC-20 UNSAFE placard/tag (red), RESTRICTED USE placard/tag (yellow), and INSPECTED (apparently safe) placard/tag (green).

Table 9-6 Estimated Damage Based on CAPSS Project Engineering Panel Interpretation of Modeling Results

Scenario	Retrofit	SPUR Performance Level Among 2,800 Buildings (%)			
		A/B	C	D	E
Magnitude 6.9 Hayward Fault	As-is	33 – 49%	19 – 27%	18 – 30%	6 – 18%
	1	72 – 75%	18 – 20%	4 – 8%	1 – 2%
	2	84 – 86%	10 – 11%	3 – 6%	0.2 – 0.3%
	3	88 – 89%	9 – 10%	2 – 3%	0.1 – 0.2%
Magnitude 6.5 San Andreas Fault	As-is	22 – 42%	17 – 27%	23 – 39%	8 – 23%
	1	61 – 66%	23 – 26%	6 – 13%	2 – 4%
	2	76 – 79%	15 – 17%	4 – 9%	0.3 – 0.5%
	3	79 – 81%	15 – 16%	3 – 6%	0.2 – 0.3%
Magnitude 7.2 San Andreas Fault	As-is	6 – 35%	9 – 23%	32 – 54%	11 – 31%
	1	36 – 48%	28 – 34%	14 – 28%	4 – 8%
	2	57 – 64%	24 – 27%	9 – 18%	0.5 – 1%
	3	67 – 71%	21 – 23%	6 – 12%	0.3 – 0.7%
Magnitude 7.9 San Andreas Fault	As-is	1 – 33%	2 – 18%	37 – 62%	12 – 35%
	1	13 – 35%	21 – 32%	26 – 52%	7 – 14%
	2	23 – 40%	27 – 35%	24 – 47%	1 – 3%
	3	28 – 44%	26 - 33%	22 - 44%	1 – 3%

Note: SPUR performance levels are color-coded to indicate an equivalency with the ATC-20 UNSAFE placard/tag (red), RESTRICTED USE placard/tag (yellow), and INSPECTED (apparently safe) placard/tag (green).

Here, SPUR performance level E means that at least a portion of the building, most likely the ground story, is likely to collapse during the hypothetical earthquake. SPUR performance level D (colored red in the table to indicate red-tag equivalency) means that after the hypothetical earthquake, the ground story of the building would be leaning at least two inches, which would tend to cause building safety inspectors to post the building as unsafe to enter or occupy under the ATC-20 post-earthquake inspection procedures (ATC, 1989). Under current City of San Francisco policy, these buildings would have to be repaired, unless they actually collapsed. SPUR performance level C (colored yellow, indicating a yellow tag equivalency) means that restricted use of the buildings would be allowed. SPUR performance levels A and B (color coded green to indicate a green tag equivalency) means that the buildings would be labeled "Inspected," and it would therefore be lawful to occupy these buildings, even if some repairs were required.

As discussed in Appendix 7, the HAZUS®-MH software (FEMA, 2003a) estimates building repair costs by using probabilistic damage states and associated mean damage factors for three aggregate components—the structural system, drift-sensitive non-structural components, and acceleration-sensitive nonstructural components. As

used in this study, "mean damage factor" refers to the expected value of repair cost as a fraction of the total facility replacement cost. There is a mean damage factor for each component, each damage state, and each occupancy classification.

The HAZUS®-MH mean damage factors for multi-family dwellings were used, realizing that the assumptions about structure type embedded in these damage factors might not accurately represent losses in the particular building types examined in this CAPSS study. In other words the HAZUS®-MH damage factors for large wood-frame buildings might not reflect damage so concentrated at the ground story, which is the typical damage pattern anticipated for buildings addressed in this CAPSS study.

It is not known whether this is a significant concern or not, or whether the potential error is great or small. It was beyond the resources of this project to reexamine the basis for the default HAZUS®-MH mean damage factors (which, in any case, is not documented in sufficient detail in FEMA 2003a for such a purpose) or to determine whether the factors ought to be adjusted for the particular building types examined here.

However, because the primary interest of the CAPSS project was comparison between different shaking scenarios and retrofit options, the HAZUS®-MH damage factors seem reasonable to produce comparative results. Regardless, as discussed elsewhere in the CAPSS reports, calculation of economic losses associated with building damage for a large number of buildings has high levels of uncertainty, perhaps as great as ± 50% or more.

For this project, economic losses were calculated using typical HAZUS®-MH damage factors (see Table 7-2 in Appendix 7). Several rounds of analysis were conducted using varying fragility parameters. The repair costs are based on fragility parameter values near or at the lower bound presented in the column labeled "CAPSS" of Table 7-7 of Appendix 7, from an early round of analysis. The estimated damage presented in Table 9-5 in terms of SPUR performance categories was calculated using values at the upper bound of the same column and table, in a later round of analysis. If the upper-bound fragility values were used to estimate repair costs, then the results would show lower repair costs. The repair costs would be slightly lower than shown for pre-retrofit conditions, ranging from $2.5 to $4.4 billion for the four scenarios. After retrofit, repair costs would be significantly lower than those shown. The significance is that the savings from retrofit would be greater than reported in Table 2 of the main report, *Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco, Earthquake Safety for Soft-Story Buildings* (ATC, 2009), resulting in savings of $900 million to $2.5 billion, depending on the earthquake scenario and retrofit scheme.

9.7 Validation

Treadwell and Rollo estimated two to four times greater shaking intensities in the four scenarios examined here, compared with the USGS's ShakeMap estimates of intensities in the San Francisco Marina District in the 1989 Loma Prieta earthquake. It seems reasonable, therefore, that the scenarios examined here would cause greater damage on average to soft-story buildings than occurred in the Marina District in the 1989 Loma Prieta earthquake. The same methodology presented above was applied to corner apartment buildings using estimates of ground shaking in the San Francisco Marina District during the 1989 Loma Prieta earthquake. The official USGS estimate

of shaking in this area was S_a(1.0 sec, 5%) ≈ 0.17g. Based on this CAPSS study, Index Buildings 1 and 2 would have on average 39% probability of being in the "complete" structural damage state, including those buildings with some fraction of their floor area collapsed.

Table 9-7 provides a comparison, on an aggregated basis, of damage experienced by corner apartment buildings on all soil profiles in the Marina District in the 1989 Loma Prieta earthquake, versus a hindcast estimate of Loma Prieta earthquake damage considering only corner buildings (Index Buildings 1 and 2, this CAPSS study). The 1989 "observed" figures are calculated from Harris and Egan's (1992) estimates of the damage state to 74 corner apartment buildings in the San Francisco Marina District after the 1989 Loma Prieta earthquake. Agreement is reasonable, with the figures generally agreeing within ±50%. This CAPSS study does not reflect ground failure, but the "observed" figures do not change substantially by excluding buildings in the region that had ground failure in the 1989 earthquake.

Table 9-7 Comparison of Actual 1989 Damage and Hindcast Damage Estimates to Corner Buildings in the Marina District

HAZUS®-MH Structural Damage State	Approximate ATC-13 Damage State	1989 Estimate*	1989 Observed
None	None	5%	3%
Slight or moderate	Slight, light, moderate	56%	74%
Extensive or complete	Heavy, major, destroyed	39%	24%

**Hindcast, based on this CAPSS study.*

9.8 Summary and Conclusions

Analytical Framework. A study was undertaken to estimate the effects of several large, hypothetical but realistic earthquakes on some of the most seismically vulnerable buildings in San Francisco: wood-frame buildings of three or more stories with five or more housing units and soft-story conditions on the first floor. The study used the HAZUS®-MH analytical framework (FEMA, 2003a) to estimate the risk, but the analysis effort is implemented outside of HAZUS®-MH, in order to avoid a programming flaw in the HAZUS®-MH AEBM software (FEMA, 2003b) and to make the methodology more transparent. Several enhancements over the basic HAZUS®-MH methodology were made, such as adding new fragility information about particular components of San Francisco housing (e.g. straight sheathing and brick veneer). While this approach offers less fidelity than PEER-style dynamic nonlinear multi-degree-of-freedom (MDOF) analyses, the HAZUS®-MH framework is much simpler, more practical for these purposes, and has been shown in several instances to produce realistic aggregate results.

Large Soft-Story Wood-Frame Residential Buildings in San Francisco. Index Buildings were selected that approximately represent the range of existing soft-story wood-frame buildings in San Francisco. This selection was made in consultation with several DBI engineering staff and experienced consulting structural engineers. The study employed a house-by-house DBI database of important features and related the Index Buildings to the buildings in the DBI database through key observable parameters: corner vs. mid-block, and pre-1950 versus post-1950 construction. The

buildings in the DBI database are approximately equally distributed among the four Index Buildings.

Soil and Hazard Information. The study's soil and shaking hazard model is based on results from Treadwell and Rollo's study during the initial stages of the CAPSS project (see Appendix 6 for additional information). Roughly three-fourths of the buildings addressed by this CAPSS study are estimated to be situated on soil of NEHRP site class D.

Structural and Component Fragility Models. Structural and component fragility models were developed for each of the as-is and retrofit configurations. The fragility functions were peer-reviewed, and are based on experimental data and observed earthquake performance of the dominant components of the Index Buildings: straight sheathing, lath and plaster walls, stucco exterior finish, and masonry veneer (Porter, 2009b). The benefit of adjacency (where buildings abut each other within inches or less and thus, may support each other in earthquakes) was addressed approximately, by making mid-block buildings one-third as likely to collapse as corner buildings, given that they experience complete structural damage.

Seismic Retrofits. The retrofit schemes for the four Index Buildings, as described in Appendix 4, are intended to meet enhanced performance objectives defined by SPUR (2008), ranging from safe but not repairable (performance category D, using "retrofit 1") to safe and usable during repair (performance category B, using "retrofit 3"). The estimated costs for these retrofit schemes, as developed in Appendix 5, are generally in the range of $10,000 to $20,000 per dwelling unit.

Loss Calculations. This CAPSS study employs a loss-calculation procedure ("cracking an open safe," Porter 2009c,d) that honors all HAZUS®-MH methodologies, while avoiding the iteration and a programming error recently discovered in AEBM (FEMA, 2003b). In addition to the peer-reviewed stepwise validation or quality assurance at each stage, the overall alternative procedure was validated by hindcasting with reasonable accuracy the damage to corner apartment buildings in the San Francisco Marina District during the 1989 Loma Prieta earthquake. The results therefore seem valid for the limited purposes of assessing community-wide retrofit policy alternatives. Losses were calculated for the entire stock of 2,800 buildings under as-is conditions and again for each retrofit scheme, i.e., assuming all the buildings were upgraded to retrofit 1, then 2, then 3. Losses were calculated for each of four earthquake scenarios, focusing on a magnitude 7.2 earthquake on the Peninsula segment of the San Andreas fault.

Results. The large but highly realistic magnitude 7.2 earthquake is estimated to be capable of causing half of the 2,800 large soft-story wood-frame dwellings in San Francisco to be red-tagged (after the earthquake), and 30% more to collapse. Most of the collapses are estimated to occur in corner buildings. There is a tendency to higher damage on softer soil, but three-fourths of the subject buildings are on NEHRP site class D. Seismic retrofit, involving new steel cantilever columns and shearwalls at the ground-floor level, could reduce collapses to fewer than 1 in 100 buildings, at a total cost throughout the City on the order of $260 million.

APPENDIX 10: COMMUNITY AND ECONOMIC IMPACTS OF SOFT-STORY RISK AND MITIGATION

10.1 Introduction

This appendix describes an effort under the San Francisco Community Action Plan for Seismic Safety (CAPSS) project to evaluate the socio-economic impacts of a retrofit policy for soft-story wood-frame residential buildings. Specifically addressed are the potential socio-economic impacts of a major earthquake on residential tenants, businesses, and building owners.

The study was developed to aid the CAPSS project team, the CAPSS Advisory Committee, City staff, the Board of Supervisors, and other stakeholders, as they formulated a seismic retrofit policy for San Francisco's residential soft-story buildings.

10.2 Methodology Overview

The study included the development of residential and business profiles that draw on a San Francisco Department of Building Inspection (DBI) database of wood-frame buildings in San Francisco with three or more floors and five or more units. The database identifies structures with an open-wall condition, defined here as (1) an opening of 80 percent or more in a ground floor exterior wall, or (2) openings of 50 percent or more on two ground floor exterior walls. These open-wall structures represent a major subset of soft-story buildings. The firm that conducted the study (Bay Area Economics) cross-referenced the DBI database with 2008 demographic data from Claritas, Inc. and 2008 data from Dun and Bradstreet to characterize residents and businesses in open-wall buildings.

To assess the socio-economic consequences of a mandatory seismic retrofit ordinance and major earthquake, Bay Area Economics (BAE) conducted a literature search of studies that evaluate the impacts of comparable ordinances on owners, occupants, and neighborhood character. The literature review also researched community impacts associated with Hurricane Katrina and the 1989 Loma Prieta and 1994 Northridge earthquakes.

In addition, BAE interviewed various individuals with expertise on these issues, including representatives from the San Francisco Apartment Association, the San Francisco Rent Board, members of the insurance industry, commercial lenders, the Federal Emergency Management Agency (FEMA), and building engineers on the CAPSS project team.

Finally, BAE conducted research on local rental market conditions, the San Francisco Rent Stabilization Ordinance, and economic factors that affect the city's residential rental market.

The following sections contain descriptions of the activities and findings of the efforts to develop a Residential Profile, a Business Profile, Impacts of a Seismic Retrofit Policy, and Impacts of a Major Earthquake.

10.3 Residential Profile

This section examines the demographic characteristics of residents of soft-story buildings, and compares these households to residents citywide. Specifically, the section outlines the distribution of soft-story units across San Francisco neighborhoods, and examines the homeownership rate, income, and ethnicity of households in these buildings.

As noted earlier, soft-story structures represent one of the most seismically vulnerable building types in San Francisco. Various characteristics can lead to a soft-story condition, the most common of which occurs when exterior structural walls contain a significant number of doorways, garage openings, and storefronts. This analysis focuses on these "open-wall" buildings as a major subset of all soft-story structures. An open-wall condition is defined here as (1) an opening of 80 percent or more in a ground floor exterior wall, or (2) openings of 50 percent or more on two ground floor exterior walls.

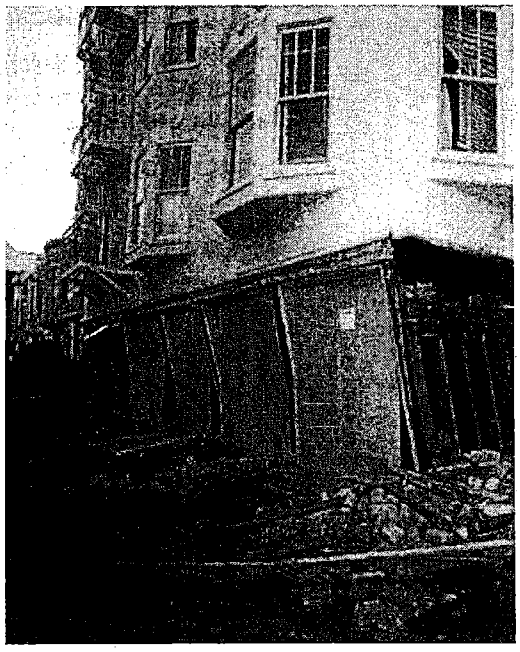


Figure 10-1 Earthquake-damaged soft story building.

10.3.1 Methodology

BAE utilized the following methodology to characterize households and residents currently residing in open-wall buildings in San Francisco. The resulting demographic profile offers a general perspective on residents of soft-story structures throughout the city.

Step 1: Cross-reference DBI database of wood-frame buildings with Census block groups.[2] The DBI maintains a database of wood-frame buildings in San Francisco with three or more floors and five or more units. Based on a sidewalk survey, the database identifies structures with an open-wall condition as defined above. BAE used a Geographic Information System (GIS) to map the open-wall buildings in the database and to identify the Census block groups in which they are located.

Step 2: Classify Census block groups according to their share of total units in open-wall buildings in San Francisco.[3] Through the GIS analysis discussed above, BAE calculated each Census block group's share of the total open-wall units in San Francisco. The city's 575 Census block groups were then placed into one of four categories according to their respective number of open-wall units for every 1,000 open-wall units in San Francisco (see Table 10-1). This study refers to these areas as "low," "medium," and "high" concentration areas.

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[2] A "block group" is a US Census-defined geography that includes roughly two to six blocks in San Francisco. Block groups are the smallest geography that can be used to analyze demographic data such as ethnicity and household income.

[3] For the sake of brevity, residential units in open-wall buildings are referred to as "open-wall units."

Table 10-1 Block Group Categories by Open-Wall Unit Concentration

Category	Number of Open-Wall Units in Block Group for every 1,000 Open-Wall Units in San Francisco
No Open-Wall Units	0.00 units
Low Concentration	0.01 – 1.99 units
Medium Concentration	2.00 – 4.99 units
High Concentration	5.00 units or more

Source: Bay Area Economics.

Step 3: Describe residents and households in block groups with different concentrations of open-wall buildings. Using 2008 demographic data from Claritas, Inc., a private data vendor, BAE characterized residents and households in low, medium, and high concentration areas.

10.3.2 Findings

Wood-frame buildings with three or more stories and five or more units contain a significant portion of the city's residential units. The DBI database records 4,600 of these structures in San Francisco, which house approximately 45,200 units or 13 percent of the city's housing stock. An estimated 88,600 residents live in these buildings, or 11 percent of the city's total population.

A notable percentage of San Francisco residents live in open-wall buildings. The DBI survey identified 2,900 buildings[4] with an open-wall condition, which comprise 63 percent of all buildings in the DBI database. These buildings contain 29,200 residential units, or over 8 percent of San Francisco households. Based on the average household size of the Census block group in which each open-wall unit is located, an estimated 58,000 residents live in these open-wall buildings, or 8 percent of San Francisco's total population.

The Western Addition, Mission, Pacific Heights, Marina, and Richmond neighborhoods have the highest concentration of residential units in open-wall buildings. The presence of open-wall buildings varies significantly by neighborhood. As shown in Table 10-2, these five neighborhoods contain over 70 percent of San Francisco's open-wall units.

Households in areas with the highest concentration of open-wall units generally have higher incomes than the city as a whole. Conversely, households in areas with no open-wall units have lower median incomes. As shown in Table 10-3, high concentration areas have a median household income of $74,700, compared to $61,800 in areas with no open-wall units and $68,300 among households citywide.

The geographic distribution of open-wall units throughout the city explains, in part, these trends. As noted above, more affluent neighborhoods such as Pacific Heights, the Marina, and North Beach contain a major portion of San Francisco open-wall

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[4] The sample set of buildings used in this socio-economic analysis was slightly larger than the set of 2,800 buildings used in the engineering and loss estimation analysis (i.e., approximately 100 buildings used in this analysis were not included in the engineering and loss estimation analysis). The CAPSS Project Team believes the slight difference in size of the number of buildings analyzed does not skew the analysis results.

Table 10-2 Units and Residents in Open Wall Buildings by Neighborhood

Neighborhood	Units in Open Wall Buildings		Residents in Open Wall Buildings	
	Number	Percent of Total San Francisco Open Wall Units	Number (a)	Percent of Total San Francisco Residents in Open Wall Buildings
Western Addition	5,779	19.8%	11,087	19.1%
Mission	4,633	15.8%	11,326	19.5%
Pacific Heights	3,515	12.0%	5,735	9.9%
Marina	3,440	11.8%	5,224	9.0%
Richmond	3,411	11.7%	7,782	13.4%
North Beach	3,231	11.1%	6,039	10.4%
Sunset	1,738	5.9%	4,103	7.1%
Downtown	1,436	4.9%	2,535	4.4%
Twin Peaks	1,078	3.7%	1,828	3.2%
Excelsior	293	1.0%	1,098	1.9%
Mission Bay	167	0.6%	302	0.5%
Ingleside	22	0.1%	81	0.1%
Bayview	0	0.0%	0	0.0%
Merced	0	0.0%	0	0.0%
No Neighborhood	494	1.7%	879	1.5%
TOTAL	**29,237**	**100.0%**	**58,019**	**100.0%**

Notes:

(a) Number of residents in open-wall units based on the average household size for the Census block group in which each open-wall building is located.

Sources: San Francisco Department of Building Inspection; MMI Engineering; Bay Area Economics.

units, while lower-income neighborhoods such as the Bayview and Ingleside have relatively few open-wall buildings.

Households in areas with higher concentrations of open-wall units are slightly younger than the city as a whole. Residents in high concentration areas have a median age of 39.2 years, compared to 40.2 years among citywide residents and 40.6 years among residents in low concentration areas (see Table 10-3).

Households in areas with higher concentrations of open-wall units have lower homeownership rates. Only 19 percent of households in high concentration areas are homeowners, compared to 44 percent among households in areas with no open-wall units. Citywide, 35 percent of households own their home (see Table 10-3).

Areas with a high concentration of open-wall units have greater proportions of White residents and fewer African American, Asian American, and Hispanic residents. Approximately 66 percent of residents in high concentration areas are White, compared to just 32 percent in areas with no open-wall units and 44 percent in San Francisco as a whole. Additionally, the proportion of African American, Asian American, and Hispanic residents in high concentration areas is substantially lower than in areas with no open-wall units and in the city as a whole (see Table 10-3).

Table 10-3 Demographic Characteristics of Block Groups by Concentration of Open Wall Units

Characteristic	No Units	Low Concentration	Medium Concentration	High Concentration	Citywide
Median Income	$61,823	$73,833	$68,980	$74,738	$68,309
Home Ownership Rate	43.9%	39.7%	23.3%	18.6%	34.6%
White	31.8%	44.5%	54.0%	65.7%	43.7%
African American	10.4%	3.8%	3.7%	3.2%	6.4%
American Indian/Alaska Native	0.2%	0.2%	0.2%	0.2%	0.2%
Asian American	38.9%	32.2%	24.0%	17.7%	31.6%
Native Hawaiian/Pacific Islander	0.8%	0.2%	0.2%	0.1%	0.4%
Some Other Race	0.3%	0.4%	0.3%	0.3%	0.3%
Two or More Races	3.3%	3.3%	3.0%	2.9%	3.2%
Hispanic	14.2%	15.4%	14.5%	9.8%	14.0%
Median Age	40.6	40.6	39.7	39.2	40.2

Sources: Claritas, 2008; Bay Area Economics.

Again, this finding is largely due to the underlying demographic profile of the neighborhoods that contain a large share of San Francisco's open-wall units. As Table 10-4 shows, the Marina, Pacific Heights, and the Western Addition have the highest proportion of White residents in San Francisco. These three neighborhoods contain 44 percent of the city's open-wall units. These same neighborhoods also have lower proportions of African American, Asian American, and Hispanic residents.

Neighborhood-specific demographic trends among areas with low, medium, and high concentrations of open-wall units can vary from citywide patterns. As noted above, underlying neighborhood demographics strongly influence the citywide analysis of low, medium, and high concentration areas. To examine trends on a more fine-grained level, BAE conducted detailed case studies of three neighborhoods that contain a large share of San Francisco's open-wall units. Table 10-5 presents the findings from these studies of the Mission, the Western Addition, and the Richmond District.

The analysis found that Western Addition trends parallel citywide findings, with high concentration areas having higher household incomes and a greater percentage of White residents than the neighborhood as a whole.

However, the analysis did reveal some variation between Mission and Richmond District trends and citywide demographic patterns. First, contrary to citywide findings, high concentration areas in both neighborhoods are less affluent than low concentration areas and the neighborhood as a whole.

Second, in both neighborhoods, areas with open-wall units have a larger share of racial minorities than areas with no open-wall units. In the Mission, areas with open-wall units have a larger percentage of Hispanic residents, while in the Richmond, more Asian Americans live in areas with open-wall units.

Table 10-4 Race and Ethnicity by Neighborhood

Neighborhood	White	African American	American Indian/Alaska Native	Asian American	Native Hawaiian/ Pacific Islander	Some Other Race	Two or More Races	Hispanic
Marina	83.7%	0.4%	0.1%	10.3%	0.1%	0.3%	2.0%	3.2%
Pacific Heights	82.4%	1.1%	0.1%	10.4%	0.1%	0.2%	2.0%	3.7%
Western Addition	66.3%	7.8%	0.2%	14.7%	0.2%	0.5%	3.5%	6.8%
North Beach	62.0%	1.3%	0.1%	30.1%	0.1%	0.2%	2.2%	3.9%
Mission Bay	56.4%	11.7%	0.4%	17.9%	0.5%	0.4%	3.5%	9.2%
Twin Peaks	56.0%	4.8%	0.2%	25.9%	0.2%	0.4%	3.8%	8.6%
Mission	51.3%	4.0%	0.3%	11.3%	0.2%	0.3%	3.3%	29.2%
Richmond	49.3%	1.2%	0.1%	41.3%	0.1%	0.4%	3.3%	4.3%
Downtown	45.5%	7.3%	0.4%	31.1%	0.3%	0.5%	4.1%	10.7%
Merced	42.6%	1.8%	0.1%	46.0%	0.2%	0.3%	3.0%	6.0%
Sunset	39.3%	1.0%	0.1%	51.4%	0.1%	0.3%	3.2%	4.5%
Ingleside	13.8%	16.6%	0.1%	52.3%	0.5%	0.2%	2.8%	13.6%
Excelsior	12.4%	3.5%	0.1%	54.3%	0.6%	0.2%	2.7%	26.1%
Bayview	5.4%	33.5%	0.2%	35.9%	2.1%	0.2%	2.6%	20.1%
Total	**59.5%**	**4.1%**	**0.1%**	**25.0%**	**0.2%**	**0.3%**	**3.0%**	**7.7%**

Sources: Claritas, 2008; Bay Area Economics.

10.3.3 Summary of Findings

San Francisco has approximately 4,600 wood-frame buildings with three or more stories and five or more units, containing approximately 45,200 units or 13 percent of San Francisco's housing stock. Of these buildings, approximately 2,900 have an open-wall condition, containing 29,200 residential units, or over 8 percent of all households in San Francisco. These open-wall structures represent a major subset of soft-story buildings, a highly vulnerable structural condition in a major earthquake.

The concentration of open-wall buildings varies significantly by neighborhood, suggesting that different areas of the city would be impacted more than others by an earthquake retrofit policy or seismic event. In particular, the Western Addition, Mission, Pacific Heights, Marina, and Richmond contain over 70 percent of the city's units in open-wall buildings.

The findings from a citywide demographic analysis of areas with a low, medium, and high concentration of open-wall units are largely driven by underlying neighborhood profiles. Households in high concentration areas generally are younger, have higher incomes, and are more likely to rent their homes. High concentration areas also have larger proportions of White residents and fewer African American, Asian American, and Hispanic residents. These patterns are consistent with demographic characteristics in neighborhoods such as the Marina, Pacific Heights, and North Beach, which have a large share of open-wall units.

Table 10-5 Demographic Characteristics of Block Groups by Neighborhood

Characteristic	No Units	Low Concentration	Medium Concentration	High Concentration	Neighborhood Wide
Mission District					
Median Income	$86,648	$88,022	$63,198	$66,696	$76,565
Homeownership Rate	51.4%	39.3%	21.2%	17.6%	33.6%
White	54.7%	50.9%	42.8%	51.4%	49.5%
African American	6.6%	2.0%	2.5%	3.3%	3.2%
American Indian/Alaska Native	0.3%	0.3%	0.3%	0.3%	0.3%
Asian American	14.5%	9.3%	9.5%	9.9%	10.4%
Native Hawaiian/Pacific Islander	0.3%	0.2%	0.2%	0.2%	0.2%
Some Other Race	0.4%	0.4%	0.2%	0.3%	0.3%
Two or More Races	3.6%	3.2%	2.8%	3.0%	3.1%
Hispanic	19.7%	33.6%	41.7%	31.6%	32.9%
Western Addition					
Median Income	$60,767	$67,132	$70,124	$75,250	$69,712
Homeownership Rate	26.6%	23.5%	18.8%	18.5%	21.1%
White	50.9%	60.6%	65.4%	70.8%	63.6%
African American	16.6%	10.5%	9.9%	8.2%	10.5%
American Indian/Alaska Native	0.1%	0.1%	0.3%	0.2%	0.2%
Asian American	20.6%	17.2%	12.8%	9.5%	14.2%
Native Hawaiian/Pacific Islander	0.1%	0.4%	0.2%	0.2%	0.2%
Some Other Race	0.5%	0.6%	0.4%	0.3%	0.5%
Two or More Races	4.1%	3.7%	3.5%	3.8%	3.7%
Hispanic	7.1%	6.8%	7.6%	7.0%	7.1%
Richmond District					
Median Income	$112,386	$79,266	$69,661	$69,850	$74,296
Homeownership Rate	63.6%	41.0%	32.7%	25.9%	36.2%
White	57.4%	47.9%	48.0%	54.1%	49.4%
African American	1.9%	1.2%	1.1%	1.5%	1.2%
American Indian/Alaska Native	0.2%	0.1%	0.1%	0.2%	0.1%
Asian American	33.1%	42.9%	42.1%	37.3%	41.1%
Native Hawaiian/Pacific Islander	0.0%	0.1%	0.1%	0.1%	0.1%
Some Other Race	0.2%	0.4%	0.4%	0.4%	0.4%
Two or More Races	2.3%	3.5%	3.5%	2.4%	3.2%
Hispanic	4.9%	3.9%	4.8%	4.1%	4.3%

Sources: Claritas, 2008; BAE, 2008

Case studies of the Mission, the Western Addition, and the Richmond indicate that neighborhood-level demographics can vary from citywide trends. Most notably, within the Mission and Richmond Districts, areas with a high concentration of open-wall units have lower household incomes than the neighborhood as a whole. In addition, in both the Mission and Richmond Districts, areas with open-wall units have a larger share of racial minorities than do areas with no open-wall units.

Notwithstanding the citywide trends expressed here, it is important to note that lower-income households do in fact reside in soft-story buildings. As discussed in subsequent sections on this report, these households would be more economically vulnerable in the event of a major earthquake.

10.4 Business Profile

This section describes the businesses occupying soft-story wood-frame buildings, analyzing their number of employees, location, and industry, and comparing these figures with businesses throughout the city.

10.4.1 Methodology

For this analysis, BAE cross-referenced a Dun and Bradstreet database of all San Francisco businesses with the DBI database of wood-frame buildings with three or more stories and five or more units. The Dun and Bradstreet database contained businesses' street address, size, and industry. Through GIS mapping, BAE determined which businesses were located in open-wall buildings in San Francisco. As the DBI database only includes residential and mixed-use structures, the businesses identified in this analysis likely operate on the ground floor of these buildings.

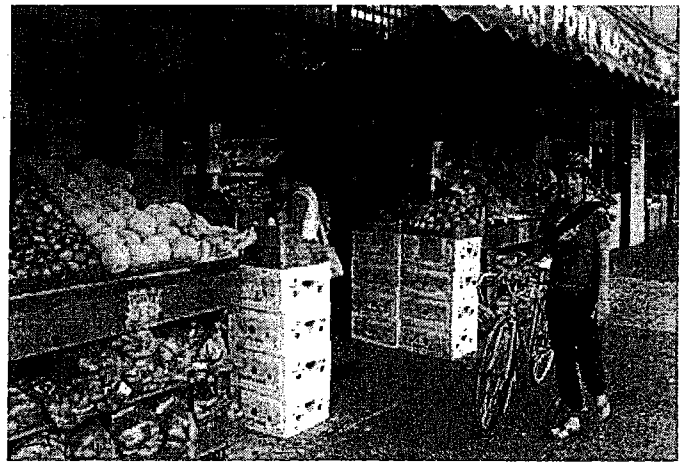

Figure 10-2 Example San Francisco street-side business

10.4.2 Findings

Just under one third of the city's open-wall buildings contain commercial uses. Businesses operate in approximately 900 of the 2,900 residential open-wall buildings in San Francisco.

Businesses and workers located in open-wall buildings represent a small percentage of all businesses and workers in San Francisco. Of the 73,000 businesses in San Francisco, 2,100 businesses, or just under 3 percent, operate in residential open-wall buildings. These businesses employ 6,900 people, accounting for 1 percent of jobs in the city.

The Western Addition, Mission, North Beach, and Pacific Heights contain the largest shares of San Francisco businesses operating in residential open-wall buildings.[5] As Table 10-6 shows, these four neighborhoods account for 68 percent of all open-wall businesses in the city. Not surprisingly, the neighborhoods that have a high concentration of San Francisco's open-wall units also contain a large proportion of the city's open-wall businesses.

Open wall businesses are concentrated in the retail, services, and food service industries. As shown in Table 10-7, 17 percent of open-wall businesses are in the retail trade industry, as compared to 12 percent of all San Francisco businesses. In addition, 13 percent of open-wall businesses are in the services industry, while 9 percent are in the accommodation and food service industry. These data reflect the

[5] For the sake of brevity, this report refers to businesses in open-wall buildings as "open-wall businesses."

Table 10-6 Open Wall Businesses by Neighborhood

Neighborhood	Number of Businesses		Employees (a)	
	Number	Percent of Total Businesses in Open Wall Buildings	Number	Percent of Total Employees in Open Wall Buildings
Western Addition	474	22.8%	1,456	21.2%
Mission	362	17.4%	1,257	18.3%
North Beach	308	14.8%	1,070	15.6%
Pacific Heights	264	12.7%	770	11.2%
Richmond	183	8.8%	518	7.5%
Marina	171	8.2%	598	8.7%
Sunset	118	5.7%	346	5.0%
Downtown	96	4.6%	446	6.5%
Twin Peaks	49	2.4%	227	3.3%
Excelsior	44	2.1%	166	2.4%
Mission Bay	7	0.3%	23	0.3%
Ingleside	1	0.0%	2	0.0%
Bayview	0	0.0%	0	0.0%
Golden Gate Park	0	0.0%	0	0.0%
Merced	0	0.0%	0	0.0%
Presidio	0	0.0%	0	0.0%
TOTAL	**2,077**	**100.0%**	**6,879**	**100.0%**

Notes:
(a) Represents the number of people employed at specific addresses, rather than throughout the company.
Sources: Dun and Bradstreet, 2008; MMI Engineering; Bay Area Economics.

fact that small retail shops and restaurants, along with professional and personal service establishments, often locate in mixed-use buildings along commercial corridors in San Francisco.

Open wall buildings contain an extremely high proportion of small businesses. As shown in Table 10-8, 84 percent of open-wall businesses employ fewer than five people, compared to 76 percent of all San Francisco businesses. An additional 11 percent of open-wall businesses have between five and ten employees. The small size of businesses in open-wall buildings suggests that many are independent, locally-owned enterprises.

10.4.3 Summary of Findings

Approximately 31 percent of the 2,900 residential open-wall buildings in San Francisco are mixed-use buildings with a commercial use on the ground floor. These enterprises represent a small proportion of all businesses citywide; less than 3 percent of the city's firms operate in open-wall buildings, employing about 1 percent of all employees in San Francisco. The Western Addition, Mission, North Beach, and Pacific Heights neighborhoods contain a large share of these employers.

Table 10-7 Open Wall and San Francisco Businesses by Industry Sector

Industry Sector	Open Wall Businesses		All Businesses	
	Number	Percent	Number	Percent
Retail Trade	354	17.0%	8,546	11.7%
Professional, Scientific, and Technical Services	344	16.6%	14,331	19.5%
Other Services, except Public Administration	262	12.6%	7,033	9.6%
Administrative and Waste Services	211	10.2%	7,930	10.8%
Accommodation and Food Services	182	8.8%	3,933	5.4%
Health Care and Social Assistance	122	5.9%	6,334	8.6%
Real Estate and Rental and Leasing	117	5.6%	3,499	4.8%
Construction	84	4.0%	3,595	4.9%
Information	84	4.0%	3,054	4.2%
Wholesale Trade	80	3.9%	3,438	4.7%
Finance and Insurance	75	3.6%	4,448	6.1%
Manufacturing	57	2.7%	2,417	3.3%
Arts, Entertainment, and Recreation	50	2.4%	1,482	2.0%
Educational Services	28	1.3%	1,220	1.7%
Transportation and Warehousing	22	1.1%	1,077	1.5%
Agriculture, Forestry, Fishing and Hunting	2	0.1%	238	0.3%
Management of Companies and Enterprises	2	0.1%	313	0.4%
Public Administration	1	0.0%	368	0.5%
Mining	-	0.0%	28	0.0%
Utilities	-	0.0%	45	0.1%
TOTAL	**2,077**	**100.0%**	**73,329**	**100.0%**

Sources: Dun and Bradstreet, 2008; Bay Area Economics.

The data show that a large share of these firms are small retail shops, restaurants, and other personal and professional service businesses. In addition, almost 95 percent of open-wall businesses are small firms employing fewer than 10 people, suggesting they are independent, locally-owned enterprises.

10.5 Impacts of Seismic Retrofit Policy

This section addresses the impacts of a retrofit policy from the perspective of building owners, residents, and commercial tenants of open-wall buildings. To assess the socio-economic consequences of a mandatory seismic retrofit ordinance, BAE conducted a literature search of studies that evaluate the impacts of comparable ordinances on owners, occupants, and neighborhood character. While the literature on hazards mitigation is expansive, no single study has assessed the impacts on these affected groups in a systematic way.

Table 10-8 Distribution of Businesses by Size

Number of Employees	Open Wall Businesses		All Businesses	
	Number	Percent	Number	Percent
0 – 4	1,742	83.9%	55,793	76.1%
5 – 10	224	10.8%	9,285	12.7%
11 – 25	88	4.2%	4,742	6.5%
26 – 50	19	0.9%	1,959	2.7%
51 – 75	3	0.1%	509	0.7%
76 - 125	1	0.0%	494	0.7%
126 +	0	0.0%	547	0.7%
Total	**2,077**	**100.0%**	**73,329**	**100.0%**

Sources: Dun and Bradstreet, 2008; BAE, 2008

BAE also interviewed various stakeholders and individuals with expertise on this issue, including representatives from the San Francisco Apartment Association, the San Francisco Rent Board, members of the insurance industry, commercial lenders, and building engineers on the CAPSS project team.

Finally, BAE conducted research on local rental market conditions, the San Francisco Rent Stabilization Ordinance, and economic factors that affect the city's residential rental market.

10.5.1 Impacts on Building Owners

The San Francisco Rent Stabilization Ordinance governs owners' ability to pass seismic retrofit costs through to residential tenants. The Ordinance allows landlords to pass through the full cost of any seismic retrofit required by law, with a maximum increase of 10 percent of the tenant's base rent in any 12 month period, amortized over 20 years.

Capital improvements that are not required by law are subject to a different set of pass-through regulations. For properties with one to five residential units, 100 percent of the certified capital improvement costs may be passed through to tenants. For properties with over five units, only 50 percent of the certified capital improvement costs may be passed through to tenants. Therefore, under the current Ordinance, landlords of buildings with six or more units would only be able to recoup 50 percent of total retrofit costs, if it were not a mandatory requirement by the City.

Approximately 97 percent of the open-wall buildings identified in the DBI database were built prior to 1980 and would therefore be subject to the Ordinance, which applies to buildings built before July 1979.

The Rent Stabilization Ordinance pass-through allowance appears sufficient to cover the cost of seismic retrofits. Table 10-9 compares the monthly debt service of a seismic retrofit to the permitted capital improvement pass-through to tenants. The analysis assumes a retrofit cost of $132,000, based on the cost estimates prepared by the CAPSS team, as well as a 20 year amortization period, 8.0 percent interest rate,

Table 10-9 Allowable Rent Increase for Retrofit vs. Monthly Debt Service

Cost Category	Amount
Average monthly rent in San Francisco (a)	$2,400
Maximum allowable increase (10% of base rent) (b)	$240
Estimated retrofit cost (c)	$132,031
Monthly debt service (amortized over 20 years @ 8% interest)	$1,104
Monthly debt service per unit (6 unit building)	$184

Notes:

(a) Average rent for third quarter 2008.

(b) Assumes Rent Stabilization Ordinance allows 100% of qualified retrofit costs may be passed through to renters.

(c) Conservatively assumes highest cost estimate from Young & Associates. Estimates range from $49,100 to $132,000.

Source: Young & Associates; RealFacts; San Francisco Rent Board; Bay Area Economics.

and six-unit building.[6] This analysis also assumes that the Rent Stabilization Ordinance will be amended to allow 100 percent of all qualified seismic upgrades to be passed onto tenants. Rent data is drawn from RealFacts, a private subscription data service. Under these assumptions, the building owner would have a monthly debt-service of $184, which falls well within the $240 monthly pass-through allowance.

However, in many cases, building owners will be unable to pass through retrofit costs, because the units are already offered at market rate rents. Under San Francisco's Rent Stabilization Ordinance, the Rent Board sets a maximum annual rent increase, based on changes to the San Francisco Bay Area Consumer Price Index. Since 1998, this maximum increase has ranged from 0.6 to 2.9 percent. However, when the unit is vacated, the owner may raise rents to market rate levels. Under this system, the more often that units turn over, the more likely it is that rents will be at market rates.

Census data suggests that a significant portion of the city's rental units are at or near market rents due to ongoing tenant turnover. The 2000 Census reports that 24 percent of rental units are re-occupied every year, 43 percent turn over every two years, and 61 percent turn over every five years.[7]

Basic real estate economic principles dictate that the market sets the maximum rent that a landlord can charge. Therefore, when rents in a building are already at market rates, a landlord who attempts to pass through seismic retrofit costs risks greater vacancies. Assuming occupancy of up to three years allows for a rent that is at or close to market rates, this analysis suggests that landlords have a limited ability to pass through costs to 40 to 60 percent of the city's apartments. As such, landlords may choose to forgo a capital improvement pass-though petition with the Rent Board

[6] The amortization period and interest rate are based on Rent Stabilization Ordinance requirements.

[7] In the Mission, Western Addition, Marina, and Pacific Heights, neighborhoods with a large share of open-wall units, the annual turnover rate ranges from 20 percent to 31 percent.

if roughly half of the units in any given multifamily building cannot absorb a rent increase.

In part due to this dynamic, few building owners petition the Rent Board for capital improvement pass-throughs. Interviews with experienced Rent Board staff indicate that as few as 400 owners a year might apply for a capital improvement pass-through of any kind.[8] In fact, a 1992 study of LA Earthquake Hazard Reduction Ordinance found only 25 percent of owners who completed a unreinforced masonry (URM) building retrofit sought a rent increase, in part because rents were already at market rates (Comerio, 1993).

The financial impact of seismic retrofit costs on building owners will vary according to each owner's particular economic circumstances. A major property owner with a diversified investment portfolio would be able to absorb these costs over time. By contrast, a "mom and pop" owner that relies on the property as a major source of income, has a significant amount of outstanding debt, or is heavily invested in the property, would be more negatively impacted by additional retrofit costs, assuming that he or she could not pass through these costs to tenants.

In general, San Francisco building owners do not rely on their properties as a primary income source. In 2003, the San Francisco Board of Supervisors commissioned a survey of owners and tenants of multifamily rental building in San Francisco[9] (BAE, 2003) The survey revealed that building owners were employed and tended to be in executive or professional occupations working in San Francisco. Most of the respondents did not work primarily as property owners or managers. Owners had relatively high household incomes in comparison with San Francisco tenants, all San Francisco households, and property owners nationwide. For the owners, median annual household income was estimated at $90,900, compared to $44,800 for tenants, and $55,200 for San Francisco households overall. Most owners received the majority of their income from sources other than their rental properties in the city; only one-fourth relied on these properties for half or more of their income. The most frequently stated reason for purchasing property was for income from rents, and only 16 percent reported purchasing the property for retirement security. Less than one-fifth of the owners indicated that they were only breaking even or losing money on their properties, nearly the same as nationwide rates, where a far lower proportion of units are covered by rent control.

Notwithstanding these survey results, it is important to note that a significant portion of San Francisco landlords do in fact rely on their properties as a major source of income. These owners, along with smaller-scale landlords, would be potentially negatively impacted by a mandatory retrofit ordinance. Programs such as affordable loan pools and adjustments to the Rent Stabilization Ordinance would help to mitigate the financial effects of the retrofit requirement.

In the short term, restrictive credit markets may limit the ability of landlords to secure financing for seismic improvements. Due to ongoing turmoil in the national and international credit markets, landlords will encounter difficulty in securing

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[8] Interview with Joe Grubb, former Director of San Francisco Rent Board, November 11, 2008.

[9] Survey respondents totaled 693 multifamily rental building owners, representing six percent of the total rental housing stock in San Francisco.

affordable financing for seismic improvements. Literature reviews also indicate that lenders often provide less favorable financing terms for seismic improvements, which do not increase the property's value (i.e., allow for higher rents). In fact, experience in other cities has shown that when seismic upgrading is required, owners use the retrofit as an opportunity to repair other code violations and do cosmetic rehabilitation work, in order to command higher rents as turnover occurs (Comerio, 1987).

To the extent that a retrofit policy initially targets one class of buildings, these owners will remain at a financial disadvantage relative to other owners. However, in the long run, as the retrofit policy is implemented by more building owners and expanded to address other building types, the market can be expected to reach a new equilibrium and to create a "level playing field" for all owners. Moreover, as seismic safety eventually becomes a more recognized standard, and as demand increases for seismically-sound homes, tenants may actually assign a premium to these units, conferring an advantage to owners of retrofitted buildings.

10.5.2 Impacts on Residential Tenants

Seismic retrofits to address a soft-story condition can be limited to the ground floor of residential and mixed-use buildings. Therefore, residential tenants living above the ground floor are protected from displacement during construction. However, CAPSS team engineers estimate that construction will likely affect ground floor parking and storage for two to four months. To compensate tenants for these losses, landlords may have to pay for alternate parking and storage and/or reduce rents, until the retrofit is complete.

Under San Francisco Rent Stabilization law, eviction can occur only if the improvement and/or rehabilitation work makes the unit hazardous, unhealthy, and/or uninhabitable while work is in progress.[10] If these criteria are present and tenants are evicted, then they have the right to reoccupy the unit after the work is complete. Should the owner choose to "recover possession of the unit" (i.e., prevent re-occupancy), he or she is required to pay a relocation fee. The current relocation payment set by the Rent Stabilization Board is $4,744 per tenant and an addition $3,164 for disabled, elderly, or tenants with minor children, up to $14,234 for capital improvements. However, because seismic retrofits can be limited to the ground floor, it appears unlikely that tenants will be forced to relocate during construction.

In rare cases, landlords may use the retrofit as an opportunity to remove existing occupants and replace them with higher-income tenants. A report on the 1981 Los Angeles URM Earthquake Hazards Reduction Ordinance found that several landlords did in fact use rehabilitation work in this manner (Alesch and Petak, 1983). The study also reported that in some cases, the cost of seismic retrofitting was illegally passed through to the renters. In these instances, building owners ignored the rent stabilization law and increased rents among tenants who were afraid to complain or did not know their rights.

These practices remain a threat in lower-income San Francisco neighborhoods and in situations where long-term tenants rely on the Rent Stabilization Ordinance to continue living in their unit at below-market rents. Landlord and tenant education,

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[10] Chapter 37, San Francisco Administrative Code, San Francisco Rent Stabilization Ordinance, Rules and Regulations, Section 12.15.

the ongoing participation of tenants-rights advocates, and active enforcement of the City's Rent Stabilization Ordinance will help to mitigate these impacts. Ultimately, however, illegal rent pass-throughs and evictions will be relatively limited, simply because a significant share of San Francisco units are already at or close to market rate rents, as discussed above.

10.5.3 Impacts on Commercial Tenants

Because San Francisco's Rent Stabilization Ordinance does not apply to commercial tenants, lease rates are already at market, and landlords have a limited ability to pass through seismic retrofit costs. A 1990 study reporting on the impacts of the Los Angeles Earthquake Hazard Reduction Ordinance found that few owners were able to pass through costs to commercial tenants, because rents were already as high as the market could bear (Blair-Tyler and Gregory, 1990). In the few cases where rents were raised, the increase did not cover the full cost of seismic rehabilitation. Long-term leases will also prevent landlords from passing costs on to commercial tenants.

The proposed retrofits will have a negative impact on ground-floor businesses during construction. During construction, which generally lasts for two to four months, businesses can expect a substantial amount of noise, space constraints, visual disturbance, and dust, disrupting normal operations and customers. In the 1990 Los Angeles study, building owners commented that it was in their best interest to retain tenants and rental income and thus, they tried to do the work in phases so as not disturb business. Despite these efforts, however, the retrofit activity did force many businesses to close during construction.

Small businesses will have difficulty recovering from any closure or relocation. As noted earlier, small businesses make up a major share of commercial tenants in soft-story buildings; almost 95 percent of these businesses have up to ten employees. With limited savings, small profit margins, and reliance on a steady revenue stream to pay for inventory and debt, many small businesses, particularly in the retail and food service industry, do not have the resources to withstand a prolonged closure or relocation.

Seismic retrofit ordinances have a limited impact on the mix of local land uses. The 1990 Los Angeles study developed detailed case studies of four different neighborhoods, to examine the effect of the Earthquake Hazard Reduction Ordinance on local land uses. The study ultimately viewed the shifts in occupancy as a normal pattern of land use change in these neighborhoods, rather than a direct impact of the Ordinance. Building owners reported that when tenants moved out permanently, new tenants with similar businesses moved in. In some neighborhoods, the rate of turnover represented approximately the same rate of turnover for non-URM buildings. To the extent that local businesses were supplanted with national tenants, this trend was already occurring throughout the neighborhood, and the seismic work provided an opening for changes that might have been destined to occur under normal circumstances.

The likelihood of displacement can be viewed as a factor of the existing strength of businesses. The 1990 Los Angeles study indicated that the Earthquake Hazard Reduction Ordinance affected businesses to a greater degree in neighborhoods where the existing commercial tenants were already *underperforming.*

Once completed, the retrofits will have a minimal impact on leasable area. The CAPSS team engineers report that the proposed retrofit solutions do not occupy a

significant amount of space and only require the installation of steel posts at key points of the structure. Plywood shear wall will also have no effect on the leasable commercial area. Therefore, building owners can expect the commercial space to return to full use, once construction is complete.

10.5.4 Summary of Findings

This study finds that the proposed seismic retrofits can be confined to the ground floor and that construction will generally not lead to tenant displacement. In cases where a long-term tenant occupies the unit, and the Rent Stabilization Ordinance has kept rents below market-rate levels, landlords may raise rents to cover the retrofit costs. In fact, based on citywide average rents, the San Francisco Rent Stabilization Ordinance appears to provide a sufficient allowance for landlords to cover the cost of seismic retrofits. This finding assumes that the Ordinance is amended to allow 100 percent of qualified seismic retrofit costs, as defined by DBI, to be passed through to tenants.

However, because 40 to 60 percent of San Francisco apartments have rents that are at or close to the market rate (i.e., the maximum rent that may be charged), landlords have a limited ability to pass through additional costs to tenants. Under these constraints, landlords are less likely to submit a capital improvement petition to the Rent Board and will have to absorb a notable portion of costs themselves. As another financial impact, building owners may need to reduce rents and/or compensate tenants for lost parking and storage space during the course of construction.

Commercial tenants can expect to experience a greater impact than their residential counterparts. The seismic work will significantly disturb operations for two to four months, and many small businesses that occupy soft-story buildings lack the financial wherewithal to recover from this interruption and/or relocate to another space. However, studies suggest that while the retrofits may displace tenants, they are generally replaced by similar businesses. To the extent that changes do occur among commercial tenants, these are viewed as part of the normal pattern of land use change, and the retrofit activity may simply provide an opening for larger market dynamics to affect a neighborhood.

10.6 Impacts of Major Earthquake

This section highlights the potential socio-economic impacts of a major earthquake on San Francisco tenants, businesses, and building owners, absent a citywide retrofit policy. These findings draw on a literature review of the community impacts associated with Hurricane Katrina and the 1989 Loma Prieta and 1994 Northridge earthquakes.

10.6.1 Impacts on Building Owners

Multifamily housing is slow to recover following an earthquake. A 1994 study on residential rebuilding efforts after the Loma Prieta Earthquake found that one year after the earthquake, 90 percent of the multifamily units destroyed or rendered unserviceable were still out of service. Four years later, 50 percent of these units remained unrepaired or unreplaced (Comerio, Landis, and Rofe, 1994).

The federal government offers limited resources for rebuilding rental housing. The Federal Emergency Management Agency (FEMA) and Small Business Administration (SBA) offer grants and loans to homeowners for the rebuilding their properties following a disaster. In general, FEMA offers more financial assistance to

homeowners than to renters, simply due to the added cost of reconstructing or repairing their homes. Homeowners also may qualify for additional months of rental assistance while repairing their property.[11]

For owners of rental properties, the SBA represents the primary source of financial assistance for rebuilding. The SBA offers Business Physical Disaster Loans with interest rates ranging from 4.0 to 8.0 percent, and a maximum term of 30 years, though applicants with credit available elsewhere have a maximum three-year term. Loans are limited to $2.0 million, and cannot exceed the verified uninsured disaster loss.

Following Hurricane Katrina, smaller building owners could also access forgivable loans through the Department of Housing and Urban Development's (HUD) Small Rental Repair Program. In contrast to the upfront grants available to homeowners for property reconstruction, the Program reimburses owners after repairs are completed and tenants are in place. A recent study found that due to the difficulty in accessing private financing for repairs, building owners have had difficulty taking advantage of the Small Rental Repair Program's reimbursements (Rose, Clark, and Duval-Diop, 2008).

In addition to assisting building owners, the federal government can also provide resources to developers of affordable multifamily rental housing in the form of Low Income Housing Tax Credits and Community Development Block Grant (CDBG) funds, as modeled by the Hurricane Katrina "Large Rental Program."

The private market also favors the rebuilding of ownership housing over rental housing. An owner of a single-family home or condominium can directly link the value of the property to its condition and therefore, has an immediate incentive to rebuild in the aftermath of a disaster. Conversely, for an owner of an apartment building, the incentive to rebuild is connected to the ability to enhance cash flow and to service debt (Comerio, Landis, and Rofe, 1994). Owners have little incentive to rebuild, if construction costs cannot be recovered through rents. With units serving lower-income households, access to construction financing is even less feasible. In sum, if the building owner is carrying a large debt load relative to the building value, is making little or no profit from rental income, and the cost to repair is high, then incentives to re-construct the property as condominiums are greater.

When multifamily properties are demolished after an earthquake, the market favors reconstruction as condominiums, rather than apartments. Development economics generally find that condominiums generate greater financial returns to developers than do apartments, even in high-priced rental markets such as San Francisco. Demolished apartments are not subject to the City's Condominium Conversion Lottery and may be replaced as ownership units. Similarly, new apartments replacing demolished units are not subject to the City's Rent Stabilization Ordinance.

The current credit market will limit access to construction financing for any new residential development in the short-term. As noted earlier, lenders continue to apply tight underwriting criteria and more stringent financing terms for new construction of any kind in the current economic climate. Interviews with developers suggest that

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[11] E-mail correspondence with Jo Ann Zwicky, Individual Assistance Program Specialist, DHS-FEMA Region IX. 1/7/09.

lenders are currently offering loans up to 50 percent of the building value, compared to 70 to 90 percent historically.

10.6.2 Impacts on Residents

Natural disasters have a particularly negative effect on lower-income households and other vulnerable populations, such as seniors and the disabled. Lower-income households typically have fewer resources to manage their losses, recover from economic and geographic displacement, and return to their homes. Furthermore, many lower-income residents live in multifamily buildings, which historically have been rebuilt at slower rates than single-family units, as discussed above.

A 2006 study of New Orleans following Hurricane Katrina suggests that lower-income areas have been slower to repopulate, due to a lack of transportation among poor households, fewer resources to repair damaged property, and the ongoing absence of employment prospects in the city's disrupted economy. The study also states that lower-income households may not be able to afford the higher rents in reconstructed buildings in New Orleans. As a result, the study expects major demographic and socioeconomic disparities in the city's repopulation (McCarthy et al., 2006).

Research on the impacts of the Loma Prieta earthquake in Santa Cruz County shows that seniors are similarly affected by natural disasters. The elderly are less mobile, and need to be near social services, grocery stores, pharmacies, shopping, entertainment, and existing community networks (Phillips, 1998). These factors, combined with the general loss of affordable housing, make it particularly difficult to find replacement housing for lower-income seniors, as well as disabled individuals, who lose their homes after a disaster.

Affordable housing stock is slow to recover following natural disasters. For example, following Hurricane Katrina, Federal and State allocations will only replace two out of five affordable rental units in State, and one out of three in New Orleans. Moreover, of the 24,600 units projected to receive assistance, only 11 percent are currently open for occupancy (Rose, Clark, and Duval-Diop, 2008).

The Loma Prieta Earthquake particularly impacted lower-income housing stock. The 1994 study of the Loma Prieta earthquake found that of the 6,300 San Francisco units destroyed or damaged after the earthquake, 75 percent were rental units, and 66 percent were rented by low- and moderate-income households (Comerio, Landis, and Rofe, 1994). The study also showed that Federal recovery assistance was less effective at meeting repair needs for multifamily buildings and affordable housing, in particular. While owners of multifamily buildings in strong San Francisco submarkets could rely on rental income to access rebuilding loans, owners of marginal properties had little cash flow to secure financing.

Evidence suggests that major earthquakes can have significant impacts on neighborhood transition. A study of the 1996 Northridge earthquake reported that an estimated 60,000 people migrated out of the San Fernando Valley as a result of the damage to homes and businesses (Petak and Elahi, 2000). The area had been suffering an economic decline due to contraction of the defense industry and falling home values. In the years following the disaster, approximately 20,000 new residents moved into the area. Most of the newcomers were younger and poorer than the previous population. These new residents had different spending habits and needs, greatly changing the retail fabric and overall social structure of neighborhoods.

In some Los Angeles neighborhoods, the Northridge earthquake had an even greater impact on neighborhood transition. In many areas that were once middle-income neighborhoods, the damage made structures uninhabitable and forced some to abandon their units. These neighborhoods subsequently became targets for looters, squatters, and street gangs, further degenerating the quality of the neighborhood. In the midst of an already weak housing market, it was not economically viable to reconstruct the housing stock, and low-income units were especially difficult to finance. Overall, this led to a spiraling decline in the affordable housing stock and an overall decline in property values (Petak and Elahi, 2000).

10.6.3 Impact on Businesses

Small businesses are more vulnerable than large firms following a natural disaster. Small businesses seldom carry insurance, and are rarely diversified in terms of products and services. They also lack the resources to address equipment and inventory damage, interruptions in utility and transportation lifelines. Small and locally-owned businesses are therefore less likely to recover from disasters compared to their chain competitors, whose profits are not dependent on a single store.

For small businesses located in older areas, structural damage can cause a number of problems that further delay and hamper recovery. Small businesses often lack the resources to address the damage that can occur in older buildings. Structural damage may also cause failure of older utility pipes, ducting, and sprinkler systems, which can cause flooding and interior damage. Similar damages to other nearby businesses and residences may reduce customer traffic, further compounding the economic hardship.

Small retailers appear to be the most vulnerable to withstanding major earthquakes. In the case of the Northridge earthquake, businesses reported that for some time after the earthquake, residents changed their spending patterns, further disrupting operations. The highest job loss resulting from the Northridge earthquake was in the retail industry (24 percent of total losses). Some small businesses failed as a result of the Northridge earthquake two years after the event (Petak and Elahi, 2000).

A study of the 2001 Nisqually Earthquake in Washington State also highlighted the vulnerability of small retailers (Meszaros and Fiegener, 2002). Of the 13 industries surveyed, retail businesses reported not only higher rates of both direct physical losses (buildings and equipment), but also higher rates of reduced revenue as a result of lost inventory. This was attributed to the fact that retailers have a higher portion of their assets invested in inventory than do most businesses.

*Even businesses that qualify for federal lending assistance eventually bear the full losses themselves (*Committee on Assessing the Costs of Natural Disasters, National Research Council, 1999). The SBA offers loans to businesses for the repair or replacement of real estate, inventories, machinery, equipment, and all other physical losses following a disaster. Business Physical Disaster Loans have interest rates ranging from 4.0 to 8.0 percent, and a maximum term of 30 years, though applicants with credit available elsewhere have a maximum three-year term. Loans are limited to $2.0 million, and cannot exceed the verified uninsured disaster loss. The SBA does not provide disaster grants.

While small businesses are generally more affected by natural disasters, the financial strength of some businesses will make some more resilient than others. A study of the Northridge Earthquake found that businesses in an unstable financial position

before the earthquake suffered the same losses, but lacked the resources for a strong recovery (Tierney et al., 1997). The study also found that many business owners underestimated the financial risks associated with earthquakes and that most were unaware, unwilling, or unable to invest in earthquake preparedness.

10.6.4 Summary of Findings

Natural disasters have a disproportionate impact on multifamily housing, particularly rental units. Both Federal assistance programs and development economics favor the reconstruction of ownership units over apartments.

This loss of affordable rental housing, coupled with the lack of personal financial resources for recovery and relocation, makes lower-income households particularly vulnerable in a natural disaster. These findings do not necessarily contradict the demographic profile of residents discussed earlier. Because households in soft-story buildings may in fact have higher incomes than San Francisco as a whole, they may be able to rebound from a major earthquake more easily than lower-income households, despite potential damage to their buildings.

In terms of impacts on local businesses, small firms also have difficulty returning to operation following a major earthquake, due to a lack of financial resources. The retail industry is especially vulnerable to seismic events, due to its reliance on a steady customer base and a large investment in inventory. Given the overwhelming number of small businesses in soft-story buildings and in San Francisco as a whole, the city's economic recovery following an earthquake depends on a well-organized and prepared business community, and a seismically-sound commercial and mixed-use building stock.

10.7 Summary

10.7.1 Residential Profile

San Francisco has approximately 4,600 wood-frame buildings with three or more stories and five or more units, containing approximately 45,200 units or 13 percent of San Francisco's housing stock. Of these buildings, 2,900 have an open-wall condition, containing 29,200 residential units, or over 8 percent of all households in San Francisco.

The concentration of open-wall buildings varies significantly by neighborhood, suggesting that different areas of the city would be impacted more than others by an earthquake retrofit policy or seismic event. In particular, the Western Addition, Mission, Pacific Heights, Marina, and Richmond contain over 70 percent of the city's units in open-wall buildings.

The findings from a citywide demographic analysis of areas with a low, medium, and high concentration of open-wall units are largely driven by underlying neighborhood profiles. Households in high concentration areas generally are younger, have higher incomes, and are more likely to rent their homes. High concentration areas also have larger proportions of White residents and fewer African American, Asian American, and Hispanic residents. These patterns are consistent with demographic characteristics in neighborhoods such as the Marina, Pacific Heights, and North Beach, which have a large share of open-wall units.

Case studies of the Mission, the Western Addition, and the Richmond indicate that neighborhood-level demographics can vary from citywide trends. Most notably, within the Mission and Richmond Districts, areas with a high concentration of open-

wall units have lower household incomes than the neighborhood as a whole. In addition, in both the Mission and Richmond Districts, areas with open-wall units have a larger share of racial minorities than do areas with no open-wall units.

Notwithstanding the citywide trends expressed here, it is important to note that lower-income households do in fact reside in soft-story buildings. As discussed in subsequent sections on this report, these households would be more economically vulnerable in the event of a major earthquake.

10.7.2 Business Profile

Approximately 31 percent of the 2,900 residential open-wall buildings in San Francisco are mixed-use buildings with a commercial use on the ground floor. These enterprises represent a small proportion of all businesses citywide; less than 3 percent of the city's firms operate in open-wall buildings, employing about 1 percent of all employees in San Francisco. The Western Addition, Mission, North Beach, and Pacific Heights neighborhoods contain a large share of these employers.

The data show that a large share of these firms are small retail shops, restaurants, and other personal and professional service businesses. In addition, almost 95 percent of open-wall businesses are small firms employing fewer than 10 people, suggesting that they are independent, locally-owned enterprises.

10.7.3 Impacts of Seismic Retrofit Policy

This study finds that the proposed seismic retrofits can be confined to the ground floor, and that construction will generally not lead to tenant displacement. In cases where a long-term tenant occupies the unit, and the Rent Stabilization Ordinance has kept rents below market-rate levels, landlords may raise rents to cover the retrofit costs. In fact, based on citywide average rents, the San Francisco Rent Stabilization Ordinance appears to provide a sufficient allowance for landlords to cover the cost of seismic retrofits. This finding assumes that the Ordinance is amended to allow 100 percent of qualified seismic retrofit costs, as defined by DBI, to be passed through to tenants.

However, because 40 to 60 percent of San Francisco apartments have rents that are at or close to the market rate (i.e., the maximum rent that may be charged), landlords have a limited ability to pass through additional costs to tenants. Under these constraints, landlords are less likely to submit a capital improvement petition to the Rent Board and will have to absorb a notable portion of costs themselves. As another financial impact, building owners may need to reduce rents and/or compensate tenants for lost parking and storage space during the course of construction.

Commercial tenants can expect to experience a greater impact than their residential counterparts. The seismic work will significantly disturb operations for two to four months, and many small businesses occupying soft-story buildings lack the financial wherewithal to recover from this interruption and/or to relocate to another space. However, studies suggest that while the retrofits may displace tenants, they are generally replaced by similar businesses. To the extent that changes do occur among commercial tenants, these are viewed as part of the normal pattern of land use change, and the retrofit activity may simply provide an opening for larger market dynamics to affect a neighborhood.

10.7.4 Impacts of Major Earthquake

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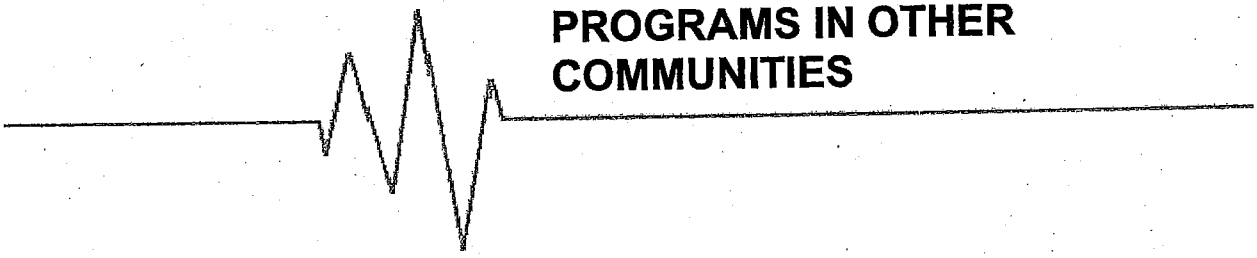
In terms of impacts on local businesses, small firms also have difficulty returning to operation following a major earthquake, due to a lack of financial resources. The retail industry is especially vulnerable to seismic events, due to its reliance on a steady customer base and a large investment in inventory. Given the overwhelming number of small businesses in soft-story buildings and in San Francisco as a whole, the city's economic recovery following an earthquake depends on a well-organized and prepared business community, and a seismically-sound commercial and mixed-use building stock.

APPENDIX 11: SOFT-STORY MITIGATION PROGRAMS IN OTHER COMMUNITIES



11.1 Overview

The CAPSS program has been asked to identify policy options to reduce the risk of wood-frame buildings with soft or weak first stories in San Francisco. As part of this process, the CAPSS team has researched the activities of other California communities relating to this high-vulnerability type of building. San Francisco can learn from the successes and failures of other communities.

This appendix describes mitigation programs and activities related to soft-story buildings for four California cities (See Table 11-1). Details of the soft-story programs of the City of Berkeley, City of Freemont, City of Santa Monica, and the City of Los Angeles are provided in Tables 11-2. 11-3, 11-4, and 11-5, respectively.

Table 11-1 Summary of Programs by Jurisdiction

Jurisdiction	Summary of Program
City of Berkeley	Requires an engineering study and informing tenants; retrofit not required.
City of Fremont	Requires an analysis and retrofit of buildings that do not meet the minimum standard; few buildings affected
City of Santa Monica	Requires an analysis and retrofit of buildings that do not meet the minimum standard; enforced for several years, but not supported in recent years
City of Los Angeles	Retrofit is not required

In addition, activities of a number of other communities are described: Oakland, San Jose, Burbank, San Leandro, and Campbell. These communities are taking or have taken some steps towards addressing the risk of soft-story buildings but did not have specific ordinances requiring retrofit of these buildings in place, at the time when this information was gathered and documented.

Table 11-2 City of Berkeley Soft-Story Program

Item	Information Provided by Jurisdiction
Jurisdiction	City of Berkeley, Building and Safety Division, Planning and Development Department
	Nature of Ordinance
Ordinance	Soft-Story Ordinance (Berkeley Municipal Code 19.39)
Date Enacted	October 2005
Approach	Berkeley's ordinance requires owners of buildings on the City's soft-story inventory to conduct engineering studies to identify structural retrofit solutions and their costs, in accordance with standards defined by the city. A notice and order is sent to owners of buildings on the City's Inventory of Potentially Hazardous Soft-Story Buildings. The notice and order provides six months to challenge the inclusion on the Inventory, before the notice becomes final. Once final, owners are required to post the building with a warning sign and notify tenants within 30 days. Within two years from the notice date, owners must file an engineer-prepared "Soft-Story Engineering Evaluation" report that compares the building with designated technical standards and defines a plan to fix any weakness. The report deadline is accelerated under certain events, including when title is transferred, the building is refinanced, or work of $75,000 or more is done. As notices become final, the ordinance requires recording notices of Inclusion on the Inventory with the County Recorder's Office. Retrofit is not required.
Scope	Residential buildings with five or more residential units with an apparent soft, weak and open front story
Priorities	Buildings with a wood ground floor are addressed first. The next phase will probably focus on high occupancy buildings with concrete podia at the ground floor.
Fees	Berkeley requires a review fee of $583.
Implementation Period	Owners have 6 months to contest inclusion in the soft-story inventory, before the notice becomes final. After notice becomes final, owners have 30 days to post a sign and notify tenants. Owners have two years to comply with the notice requirement for an analysis. Building owners can apply for time extensions.
Incentives	Once retrofitted, the owner enjoys a 15-year period during which additional requirements cannot be imposed. The City provides a report framework to guide report preparation and a roster of engineers who attended the City's training session. Retrofitting or a favorable analysis results in the building being removed from the list of soft-story buildings. Owners can forgo the cost of the review of the engineering report, if they choose to retrofit directly.
Penalties	There are sanctions or fees and fines for non-compliance and for the staff to bring buildings into compliance with the ordinance. So far, the program has relied on the voluntary compliance of owners.
Performance Objectives/ Technical Standards	Engineering reports compare buildings to Appendix Chapter A4 of the 2003 *International Existing Building Code* (IEBC). There is concern that the IEBC Appendix Chapter A4 requires work beyond addressing the soft, weak and open condition. The City might waive these requirements.

Table 11-2 City of Berkeley Soft-Story Program (continued)

Item	Information Provided by Jurisdiction
Implementation	
Number of Buildings, Types, Size	The city's survey identified 317 potential soft-story buildings with wood frames at the ground level. About 140 more buildings with concrete podia were also identified as having potential soft or weak open front conditions.
Progress	All wood-frame buildings identified in the survey have been noticed, most between March and September 2006. As of October 2008, engineering reports had been submitted for about 130 buildings. As of April 2008, about 10 buildings on the building inventory were found not to have soft-story weaknesses. A further 20 buildings were removed from the inventory because they have fewer than 5 residential units. Currently, about 33 buildings have been seismically retrofitted or have building permits to conduct retrofits. The Building Official reported on progress to Council in the winter of 2009 and planned, at that time, to recommend an ordinance mandating retrofit of buildings not meeting IEBC Appendix Chapter A4.
Cost	Engineering surveys have been in the range of $3,000 to $12,000 per building. Retrofit costs are not yet available. Staff will collect and analyze this information at some point.
Problems	The costs of retrofits are an allowable expense for building owners to pass through to tenants. However, most building owners may not actually be able to pass through these costs, due to having increased Net Operating Income, which is used as an offset to costs under Berkeley's rent control regulations.
Background	Berkeley's program emerged as the result of a long process involving the city's voters, discussions with building owners and community members, and review by the many boards that advise the city's lawmaking process. Initially, the city attempted to raise funds to assist in the structural strengthening of soft-story buildings through a ballot measure, but this was rejected by voters. Discussions followed to create legislation mandating that owners retrofit their buildings, but this was deemed too challenging as the community's initial step. This led to the city's current approach. The city is considering a more assertive approach.
Administration	
Number of staff for program, qualifications and duties	One staff member works on this program about half time. The building official uses normal procedures to check plans and inspect the work during construction.
Do you use consultants?	Engineering reports are reviewed by consultants: Bureau Veritas and Telesis Engineers.
Workload Metrics	The program is tracked by the key staff member, and information is stored in the city's central database in the Code Enforcement Module.
Any Lawsuits or Legal Opinions?	There have been no lawsuits. The City Attorney was involved during the program's development.
Other Matters	
Give Advice?	
Web Page	www.ci.berkeley.ca.us/ContentDisplay.aspx?id=622
Sources	Joan MacQuarrie, Building Official, personal communication. Dan Lambert, Senior Management Analyst, personal communication. www.ci.berkeley.ca.us/ContentDisplay.aspx?id=622.

Table 11-3 City of Fremont Soft-Story Program

Item	Information Provided by Jurisdiction
Jurisdiction	City of Fremont, Building and Safety Division, Community Development Department
Nature of Ordinance	
Ordinance	Fremont Municipal Code, Title VII (Building Regulations) Chapter 10 *Minimum Mandatory Earthquake Hazard Reduction Requirements and Standards for Existing Wood Frame Residential Buildings with Soft or Open-Front Walls*
Date enacted	May 1, 2007
Approach	Mandatory program requiring owners of apartment buildings with soft-story deficiencies to seismically retrofit. Building owners are required to complete a survey checklist to determine if the building meets minimum earthquake performance standards. If the building does not meet these standards, then building owners must retrofit according to a specified timetable.
Scope	Covers apartment buildings with soft-story deficiencies built before 1978. Condominiums and townhouses are not covered by the mandatory ordinance at this time.
Priorities	Apartment buildings with 10 or more units must seismically retrofit first. Apartment buildings with 10 or fewer units are also mandated to retrofit, with a longer deadline. Condominiums and townhouses have no mandates to retrofit.
Fees	Fees are rebated to owners, once the work associated with seismic retrofits is completed successfully.
Implementation Period	Building owners have 30 days to appeal, after receiving notice that they are covered by the ordinance. Buildings with more than 10 units must submit engineering plans within 24 months of notice and complete construction within 48 months. Buildings with 10 or fewer units must submit engineering plans within 36 months of notice and complete construction within 60 months. Building owners can apply for time extensions due to financial hardship.
Incentives	Plan check and building permit fees are returned for earthquake retrofits of soft-story apartment buildings, when the work is completed within the specified timetables.
Penalties	Apartment buildings not in compliance are deemed a public nuisance and could potentially be demolished.
Performance Objectives/Technical Standards	The ordinance, when adopted, was based on the 2001 version of the California Building Code. Buildings are required to resist a base shear of 75 percent of the code. The goal is to reduce the collapse hazard of buildings in the event of a major earthquake. The mandatory program only requires analysis and strengthening of the soft-story portion of the structure, the ground floor.
Implementation	
Number of Buildings, Types, Size	Fremont has identified fewer than 30 complexes or owners with apparent soft-story buildings, some with multiple buildings. This includes 19 apartment complexes with soft-story deficiencies. Two of these complexes were seismically retrofitted under a previous voluntary program. Seventeen complexes, some with multiple buildings and with an estimated 726 apartment units, have yet to be retrofitted. All buildings have wood-frame construction. Three condominium complexes with soft-story deficiencies have also been identified, but are not covered by the mandatory retrofit ordinance.

Table 11-3 City of Fremont Soft-Story Program (continued)

Item	Information Provided by Jurisdiction
Progress	The city allows owners to appeal the identification of their buildings and inclusion in this program; however, none have appealed. Three, perhaps four, owners have submitted drawings to the City for review. None were under construction as of October 1, 2008.
Cost	When the ordinance was enacted, city staff estimated that it would cost building owners $2,500 to $3,500 per parking space at the ground level. A better estimate of the cost of engineering and construction might be received from design professionals working in the City. The estimated cost to the City in terms of lost permit fees was $22,000 to $40,000.
Problems	There were no particular "problems" with the program as of the time of this writing. Owners and their design engineers ask questions regarding the extent of required work.
Background	Fremont had a voluntary ordinance, enacted in 1999, to encourage building owners to strengthen multi-residential soft-story buildings. Owners of soft-story buildings were notified and the city adopted standards for seismic retrofits. Only two buildings, containing 96 rental units, performed seismic retrofits under this program.
Administration	
Number of staff for program, qualifications and duties	One structural engineer is responsible for monitoring the soft-story program and answering questions. This assignment takes less than 5 percent of his/her time. Plan review is conducted using the normal process for reviewing all permit requests and is done by the engineer assigned at the time of submittal.
Do you use consultants?	Consultants are not used.
Workload Metrics	
Any Lawsuits or Legal Opinions?	None
Other Matters	
Give Advice?	Plan check engineers do not give advice on retrofitting. Plans prepared for the owner are checked against code requirements, and deficiencies are noted on a list of comments. Plan checkers do not engage in design. Special inspection and construction observation by the engineer of record are required during construction. Retrofit solutions include steel frames, horizontal diaphragm braces to transfer loads to the back wall, and buttresses, if planning department set back requirements allow this solution.
Web site	http://www.fremont.gov/CityHall/Departments/BuildingSafety.htm http://www.fremont.gov/Construction/Ordinances/default.htm
Sources	Jack Chen, City of Fremont Building Department. http://www.fremont.gov/Construction/Ordinances/default.htm.

Table 11-4 City of Santa Monica Soft-Story Program

<table>
<tr><th>Item</th><th>Information Provided by Jurisdiction</th></tr>
<tr><td>Jurisdiction</td><td>City of Santa Monica, Planning and Community Development Department, Building and Safety Division</td></tr>
<tr><td colspan="2">Nature of Ordinance</td></tr>
<tr><td>Ordinance</td><td>Original ordinance number unknown.

Additional Ordinance: Ordinance 1945, adding Chapter 8.72 to the City's Building Regulations, "Seismic Strengthening Provisions for Soft, Weak or Open Front Walls in Light, Wood framed Buildings".</td></tr>
<tr><td>Date enacted</td><td>Original ordinance passed in mid-90's after the 1994 Northridge earthquake.

Ordinance 1945 passed in June 1999</td></tr>
<tr><td>Approach</td><td>The city requires owners of wood-frame soft-story buildings to seismically retrofit within a given timetable.

The process began when the Building Officer sent a written notice to building owners that they are subject to this ordinance.

Building owners must have their building evaluated by a licensed civil or structural engineer and submit a report to the City. Buildings that do not meet the required standards must seismically retrofit. No additions, alterations, or remodels are allowed until seismic retrofit has occurred. Owners can seek permits to demolish their building instead of retrofitting.</td></tr>
<tr><td>Scope</td><td>The ordinance applies to all wood-frame buildings designed to a code in effect before December 12, 1995 that have soft, weak or open front line walls as defined in the building regulations.</td></tr>
<tr><td>Priorities</td><td>Buildings used as essential facilities must retrofit first. Buildings with more occupants must retrofit before buildings with fewer occupants.</td></tr>
<tr><td>Fees</td><td>Permit fees are waived for retrofits.</td></tr>
<tr><td>Implementation Period</td><td>Owners must submit an engineering report within four months of receiving notice from the city.

Buildings with soft-story deficiencies must retrofit within the following time periods after submitting an engineering report:
<table>
<tr><th>Type</th><th>Submit Plans</th><th>Begin Construction</th><th>Complete Construction</th></tr>
<tr><td>Essential facilities</td><td>60 days</td><td>150 days</td><td>1 year</td></tr>
<tr><td>More than 100 occupants</td><td>180 days</td><td>270 days</td><td>3 years</td></tr>
<tr><td>20 to 99 occupants</td><td>1.5 years</td><td>1 year, 8 months</td><td>3 years</td></tr>
<tr><td>Fewer than 20 occupants</td><td>2 years, 5 months</td><td>2 years, 8 months</td><td>4 years</td></tr>
</table></td></tr>
<tr><td>Incentives</td><td>Permit fees are waived for retrofits.

Owners are not required to compensate tenants, if temporary relocation is required. Tenants must be allowed to return to their units at rent-controlled rates.</td></tr>
<tr><td>Penalties</td><td>Information can be attached to building titles that they are potential soft-story buildings subject to this ordinance.</td></tr>
</table>

Table 11-4 City of Santa Monica Soft-Story Program (continued)

Item	Information Provided by Jurisdiction
Performance Objectives/ Technical Standards	Santa Monica developed its own technical standards (Chapter 8.72 of Santa Monica Municipal Code), based on work in Los Angeles. The goal of these standards is to substantially improve the performance of retrofitted buildings.
Implementation	
Number of Buildings, Types, Size	Approximately 2,100 buildings were identified as potential soft-story buildings by City staff during a field survey. These buildings were given notices to comply with the ordinance during or prior to March 1995. As of May 1997: • Seismic retrofits had been completed for over 1,000 buildings; • Owners of more than 200 buildings had submitted engineering reports that showed their buildings were not soft-story buildings; • Approximately 200 buildings had permits, current or expired, to conduct retrofits but had not received final inspection; • Owners of over 400 buildings had submitted engineering reports but had not yet requested permits for retrofits; and • Owners of more than 600 buildings had not responded to the City's notices.
Progress	Santa Monica's program has not been enforced since the late 1990's due to lack of resources and internal support by some key City staff. Recently, there have been staff changes within the city, and it is moving forward to enforce the ordinance. However, current city staff appear to be unaware of the progress that this program made a decade ago. The city has plans to hire a consultant to develop a new inventory of soft-story buildings and to review permits for retrofit status. Some elements of the original ordinance are likely to be altered, such as including an appeals process for building owners who believe that they should not be covered by the program.
Cost	No data on costs of seismic retrofits are available.
Problems	Santa Monica's soft-story ordinance has no real penalties for owners who do not comply. There may be institutional "memory loss" due to significant staff turnover. Current staff members seem unaware of the activities, reports and databases that were used to enforce this program.
Background	This ordinance was passed quickly after the Northridge earthquake. Santa Monica experienced significant damage in that event, which raised public concern about building safety. Santa Monica has required the retrofit of unreinforced masonry (URM) buildings, soft-story buildings, tilt-ups, non-ductile concrete buildings, and steel frame buildings. To date, only the URM and soft-story requirements have been enforced. Other types have not yet been inventoried. Owners of single-family homes are encouraged, but not required, to retrofit.
Administration	
Number of staff for program, qualifications and duties	Santa Monica had one staff member for approximately three years who was supposed to spend significant time on this program. However, this staff member was not able to spend as much time as hoped on this program due to a sizeable increase in the overall department workload. After this staff member left, the program apparently had no staff support.

Table 11-4 City of Santa Monica Soft-Story Program (continued)

Item	Information Provided by Jurisdiction
Do you use consultants?	A consultant will help the city resume this program.
Workload Metrics	
Any Lawsuits or Legal Opinions	
Other Matters	
Give Advice?	It is important to include penalties and enforcement mechanisms in an ordinance of this type.
Web site	http://www.qcode.us/codes/santamonica/ (Chapter 8.72)
Sources	Loretta Duvall, Mel Green and Associates, Torrance, CA (formerly Santa Monica Code Enforcement) Edwin Hacopian, Santa Monica Code Enforcement Timothy McCormick, Director of Building Services, County of Monterey (formerly Building Officer for the City of Santa Monica)

Table 11-5 City of Los Angeles Soft-Story Program

Item	Information Provided by Jurisdiction
Jurisdiction	City of Los Angeles, Department of Building and Safety
Nature of Ordinance	
Ordinance	Voluntary Earthquake Hazard Reduction in Existing Wood Frame Residential Buildings with Soft, Weak or Open Front Walls (Division 93, Article 1, Chapter IX of LA Municipal Code)
Date enacted	May 1998
Approach	The city developed technical standards for building owners who wish to voluntarily seismically retrofit their buildings.
Scope	The standards apply to apartment buildings, condominium buildings, hotels and other "congregate residences." It applies to wood-frame buildings with an open ground floor designed to codes prior to the 1995 code.
Priorities	None
Fees	No fee reductions
Implementation Period	None
Incentives	There may have been limited low-interest loans through the Housing Department, but no details are known.
Penalties	None
Performance Objectives/ Technical Standards	Their own standards are defined in the ordinance, developed with a task force of the Structural Engineers Association of Southern California (Chapter 93 of the Los Angeles Building Code). This was the first effort to define technical standards for retrofit of this type of building.

Table 11-5 City of Los Angeles Soft-Story Program (continued)

Jurisdiction	City of Los Angeles, Department of Building and Safety
Implementation	
Number of Buildings, Types, Size	The City has no inventory of potential soft-story buildings. According to information developed under the CUREE-Caltech Wood-Frame Project, there are an estimated 20,000 wood-frame apartment or condominium buildings in the LA area with "tuck under" parking at the ground level.
Progress	As of June 2006, owners of 106 wood-frame soft-story buildings had conducted voluntary retrofits that met the city's standard, or were in the process of doing so.
Cost	No data.
Problems	
Background	After the 1994 Northridge earthquake, the city developed technical standards for retrofits of: • wood-frame buildings with weak cripple walls and unbolted sill plates; • hillside buildings; • reinforced concrete and reinforced masonry wall buildings with flexible diaphragms; and • reinforced concrete buildings and concrete frame buildings with masonry infills.
Administration	
Number of staff for program, qualifications and duties	Retrofit plans are checked through normal procedures.
Do you use consultants?	
Workload Metrics	
Any Lawsuits or Legal Opinions	
Other Matters	
Give Advice?	
Web site	
Sources	Andrew Adelman, General Manager, Department of Building and Safety, Personal communication and written materials Victor Cuevas, staff, LA Department of Building and Safety

11.2 Activities of Additional Communities

11.2.1 City of Oakland

Oakland has no ordinances requiring soft-story retrofits.

The City of Oakland is currently developing an inventory of its soft-story buildings. The inventory focuses on buildings with five or more units, from two to seven stories. Some buildings with concrete podia are included. The inventory effort was scheduled to be completed by the end of 2008.

The Association of Bay Area Governments (ABAG) is organizing the inventory process, supported by a FEMA grant. The Structural Engineers Association of Northern California (SEAONC) and the Northern California Chapter of the Earthquake Engineering Research Institute (EERI-NC) are providing volunteers to assist in surveying nearly 4,000 parcels.

Source: Jeanne Perkins, consultant to ABAG

11.2.2 City of San Jose

San Jose has no ordinances requiring soft-story retrofits.

The City completed an inventory of apartment buildings with apparent soft-stories, prepared maps with locations identified, and conducted an outreach program including education and training for owners.

The city staff recommended preparation of a program to require retrofit with priority given to 460 addresses (some with multiple buildings and units) that were considered to be of poor construction and located on poor soil. The program was to be modeled after the City's program for unreinforced masonry (URM) buildings. The City would waive permit fees, provide some engineering services, and a special "opt in" district would be created for owners wishing to borrow funds. The URM program created a special district in about 1992, when interest rates were high and money tight. However, the economy improved, and owners preferred to rely on traditional sources for funds; the potential use of the district funds was abandoned in about 1995.

The City Attorney opposed releasing the inventory information and moving ahead with a program, and the City Manager was concerned with the political implications of a program. The effort was dropped, but the City developed some helpful information for apartment owners and others.

Between 1998 and 2000, the City of San Jose created several publications about soft-story buildings:

- *The Apartment Owner's Guide to Seismic Safety: A Handbook for Owners to Identify Seismic Hazards in Low Rise Apartment Buildings* was prepared by Vukazich, Department of Civil Engineering, San Jose State University, San Jose, California;
- *Practical Solutions for Improving the Seismic Performance of Buildings with Tuck-under Parking*, a publication of pre-engineered typical solutions, was prepared by Rutherford and Chekene; and
- Two other technical reports analyzing costs and technical approaches to retrofit soft-story buildings;

Sources:

- http://www.sjsu.edu/cdm/projects/inventory.html
- quake.abag.ca.gov/mitigation/PR-Soft-Story-11-17.pdf
- http://www.sanjoseca.gov/emergencyServices/brochures.asp
- Francis Edwards, San Jose State University, former director of Emergency Services for San Jose.

11.2.3 City of Burbank

Burbank has no ordinances requiring soft-story retrofits.

Burbank held public hearing in Spring 2008 on a concept proposal to address the risk of soft-story buildings. These proposals were put on hold due to stiff opposition.

11.2.4 City of San Leandro

San Leandro has no ordinances requiring soft-story retrofits.

The City's Building Department has conducted a preliminary "draft" inventory of about 330 multi-family residential, commercial/office, and mixed-use buildings containing approximately 4,000 units. All buildings with two or more stories were surveyed. City staff met with the Apartment Owners Association and the Chamber of Commerce while conducting this inventory. City staff are now working to further validate which buildings have soft-story conditions by conducting an in-house survey for each building based on the screening form provided in FEMA 154, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, Second Edition* (FEMA, 2002). City Council will be approached soon to discuss the appropriate policy for reducing risk in these buildings

Sources:

- William Shock, Chief Building Official
- http://www.quake06.org/quake06/best_practices/IMSSB.html

11.2.5 City of Campbell

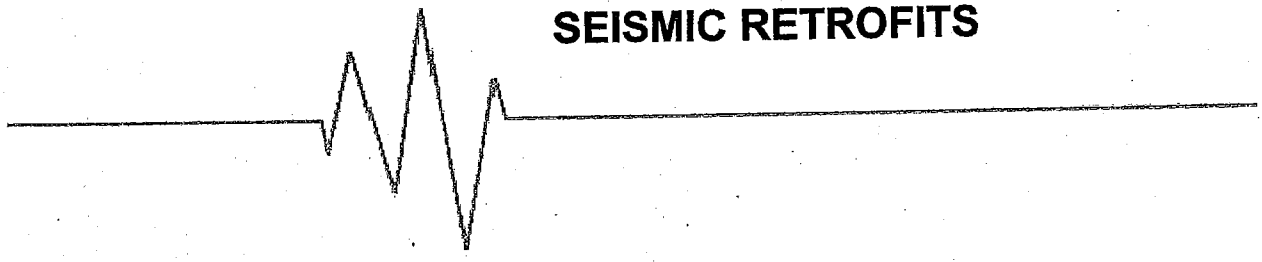
Campbell has no ordinances requiring soft-story retrofits.

The City worked with a consultant to develop an inventory of soft-story buildings in the city. All building owners were mailed a copy of San Jose's *The Apartment Owner's Guide to Seismic Safety*.

Consultants developed the inventory of soft-story buildings in the City of Campbell (Disaster Mitigation Collaborative, a non-profit based at San Jose State).

Source: http://www.sjsu.edu/cdm/projects/inventory.html

APPENDIX 12: INCENTIVES TO ENCOURAGE SEISMIC RETROFITS



12.1 Introduction

The purpose of this appendix is to provide San Francisco's decision makers with a range of incentives that could be offered to encourage seismic retrofits. Some of these incentives will make sense for San Francisco; others will not. Some of the ideas mentioned here have more details than others. Many are not fully fleshed out. Undoubtedly there are additional incentives that could be offered, which are not described here.

12.2 Background

A significant earthquake could destroy more than a quarter of the building stock in San Francisco. This level of damage would injure thousands, cripple the city's economy, cause a housing crisis, devastate tourism, and irrevocably change the character and affordability of the city. Some argue that the damage could reach a "tipping point," causing recovery challenges that would persist for years. These are compelling reasons to consider earthquake losses to privately-owned buildings as a community issue, more than simply a collection of many private losses experienced by building owners and their tenants. If avoiding these consequences is a community priority, then it could make sense for the community to invest in encouraging private building owners to seismically retrofit.

Over time, San Francisco could work to reduce its vulnerability by seismically upgrading the weakest buildings. Designing a program to improve the earthquake performance of buildings involves many variables and elements:

- *Scope:* Which buildings should be addressed?
- *Priorities:* Should any particular building type, use or occupancy be addressed before other buildings?
- *Approach:* What is the proper degree of government intervention? Should building retrofits be required or encouraged?
- *Implementation Period:* How many years is the City willing to wait until the building stock is strengthened?
- *Incentives:* To what degree should the City encourage compliance with a program, given that there are benefits to retrofitting that accrue to the general public and not just to owners?
- *Performance Objectives:* How much damage is acceptable in privately-owned buildings after an earthquake, and are there different levels of acceptable damage for buildings with different uses?

This appendix provides options for one of these elements: incentives to encourage building owners to seismically retrofit their buildings. These options have been collected from efforts in other communities, previous efforts in San Francisco, and ideas that have not yet been tried in any community. Not all of these ideas will be appropriate for San Francisco.

12.3 Incentives

Incentives for seismic retrofits could be offered to encourage voluntary retrofits or to ease the impact of mandated seismic upgrades. For example, the City could develop a policy to require owners of vulnerable buildings to upgrade to a minimal standard that would save lives, and could also incentivize them to retrofit to a higher standard that would ensure that buildings could be occupied and would be repairable after earthquakes, thereby preserving post-earthquake housing and improving resilience.

The most effective approach might be to offer multiple incentives, because no single incentive or combination of incentives will serve the interests of every building owner. The decision of a building owner to seismically retrofit is complex and occurs within a context of many competing needs. Building owners vary significantly, ranging from a city resident who owns one apartment building that he or she lives in to a corporation, and these diverse owners have varying knowledge, resources and motivation. A variety of incentives would allow owners to assemble unique combinations to satisfy their particular needs.

Building retrofit incentives can be divided into the following categories:

- *Financial incentives:* grants, rebates, credits, loans, loan interest reductions, deferred loans, donated and reduced-rate labor, insurance premium savings, fee waivers;
- *Policy incentives:* expedited processing of permit applications and loan applications, waiver of property restrictions;
- *Technical assistance incentives:* advice on retrofitting, standard details, help with garnering incentives, assistance with contracting questions; and
- *Information incentives:* information and materials.

Examples from each of these categories are discussed below.

12.4 Options for Incentives to Encourage Seismic Retrofits

12.4.1 Financial Incentives

Financial incentives reduce the costs of seismic retrofits for owners. It could make sense for communities to offer financial incentives because, while many of the benefits of retrofits go directly to building owners, there are also larger societal benefits, such as safety for tenants and preserved affordable housing and neighborhood character.

The California Constitution (Article XVI, Section 6) prohibits gifts of public funds for private purposes. However, seismic retrofits of privately-owned buildings have been supported by programs such as loans, grants to low income residents and non-profit organizations, and tax rebates, in recognition of their public benefits. Whether or not the City could subsidize private owners who retrofit their buildings, voluntarily or because of a mandate, should be considered by the City Attorney. Conflicting

opinions have been voiced, but there seems to be flexibility in interpreting the law when the public will benefit in ways such as improved public safety.

Grants, Credits and Rebates

San Francisco could provide grants or rebates to pay for a portion of qualified expenditures on building evaluation, design drawings and/or construction.

Communities have used redevelopment funds and Community Development Block Grant (CDBG) funds to provide grants to cover costs associated with retrofitting vulnerable buildings. CDBG funds could only be used for low- and moderate-income homeowners. Small Business Administration Certified Development Corporation CDC/504 loans might be available for small businesses.

The following communities provided grants or rebates for their unreinforced masonry building (URM) retrofit programs (EERI, 1998, p 39):

- Inglewood, California: City reimbursed up to $3,000 of cost of engineering studies and 100 percent of plan check fees, permits and taxes using redevelopment money;
- San Jose, California: City provided redevelopment fund grants for engineering design work;
- Sonoma, California: City reimbursed owners for a portion of engineering fees;
- Tustin, California: City used CDBG grants of up to $2,000 to cover engineering costs; and
- West Hollywood, California: City used CDBG grants of up to $7,100 per building and housing rehabilitation program of $10,000 per building.

Property Tax

Existing state tax law (Section 74.5 California Revenue and Taxation Code) provides that the cost of an earthquake retrofit should not increase the property assessment used to determine the amount of property taxes. However, it could be challenging for building owners to secure this benefit, because they must submit specific information to their County Assessor's Office prior to conducting retrofit work. Due to lack of state support, many Assessor's Offices around the state do not have forms for this purpose, and their staff are not trained to process this benefit.

At this time, it is not known whether and how San Francisco manages this issue. In a few jurisdictions, city officials have worked with the County Assessor's Office to facilitate this process for building owners. San Francisco could make sure that this benefit is truly available to building owners and could advertise and explain it to homeowners, so that they follow proper procedures.

Further incentives involving property tax are possible, such as deferred or reduced property taxes for building owners who have seismically retrofitted. Currently, we are unaware of other communities that have offered this type of incentive for seismic upgrades.

Real Estate Transfer Tax Rebate

San Francisco currently has a real estate transfer tax of 0.68 percent of the purchase price for properties sold for under $1 million and 0.75 percent for properties sold for over $1 million. In November 2008, San Francisco voters approved a measure

(Measure N, "Changing Real Property Transfer Tax Rates") to rebate one-third of San Francisco's transfer tax to properties for conducting seismic upgrades or installing active solar systems, as well as doubling the transfer tax for properties sold for $5 million or more. At the time of writing, it is not clear how the transfer tax rebate program will be implemented.

The City of Berkeley rebates up to one-third of its transfer tax amount (1.5 percent of purchase price) for qualified earthquake retrofit on homes. This program, along with Berkeley's other retrofit incentives, has led to an estimated 45 percent of the private residences in Berkeley being made more seismically resistant. Over $6 million in transfer taxes have been rebated. In recent years, Berkeley has required retrofits to meet specified standards to qualify for a transfer tax rate. This was done because some retrofits were found to be ineffective at reducing a building's seismic risk.

In 2007, the City of Oakland followed in Berkeley's footsteps and developed a program to offer a rebate of up to one-third of its property transfer tax (1.5 percent of purchase price), if those funds are used for qualified seismic retrofit programs.

Fee Rebates

The City collects fees associated with property taxes and charges for certain services. It could compensate owners who conduct qualified seismic safety upgrades by reducing relevant fees.

Reducing fees reduces existing City government resources. If there is no existing fee with a nexus to earthquake emergency management, then a new emergency management fee could be established, and then reduced, to compensate owners who spend their own money to reduce emergency response burdens on the City.

Loans

The City could assist building owners to pay for seismic retrofits by:

- offering loans with rates lower than commercial rates;
- providing loan guarantees;
- reducing or "buying down" loan interest rates; or
- making market-rate loans available to those who might not otherwise qualify for them.

The City could provide these loan services or assist building owners to get loans from other sources. Loans could be repaid through assessment liens paid along with property taxes. Loan payments could be deferred for a period of time, or until the sale of the property for hardship cases.

To reduce or "buy down" loan interest rates, the City, a contractor or another organization wishing to encourage retrofit could subsidize loans by "buying down" with cash the interest rate on a loan to a level below prevailing market rates. For example, a 3-2-1 buy down would reduce the interest by 3 percent the first year, 2 percent the second year and 1 percent the third year and would revert to market rate for the fourth and subsequent years. A 3 percent buy down of a $100,000 loan for one year would cost about $3,000.

In 1992, San Franciscans passed a bond measure to offer loans for mandated retrofits to unreinforced masonry buildings. Most of the funds were intended for market rate loans (7.5 percent rate), and a portion of the funds was for low-interest loans (2.5

percent rate) for qualified buildings housing low-income tenants. Very few building owners took advantage of the market rate loans, but the low-interest loans provided a useful source of financing for some affordable housing upgrades. To date, slightly over 15 percent of the $350 million has been used for loans; about 13 percent was used for low-interest loans and 2 percent used for market rate loans. Some building owners have stated that they chose not to seek these loans, because there were complex conditions attached to the loans and it was easier and more cost-effective to deal with commercial lenders.

In general, many building owners prefer conventional loans from commercial lenders to loans offered by a government entity. Commercial second mortgages are not common and when offered, generally have high interest rates. Note that if borrowers default on mortgages, government liens often are paid before loans from other financial institutions. This reduces the equity that covers the private loans and could affect existing mortgages or make new or refinanced mortgages unattractive, because mortgage lenders generally do not offer "second place" loans, and if they do, then the interest rates will reflect the risk.

The City could fund loan programs for seismic retrofits in a variety of ways, including, but not limited to, those listed below:

- The remaining funds authorized for unreinforced masonry building loans could be repurposed to provide loans to other building types through a ballot measure.
- The City could raise funds for loans to property owners by creating a special city-wide tax district that collects funds from the property owners who voluntarily opt-in to use it as a financing mechanism for seismic safety upgrades. Those that opt-in would pay for the cost of their own loan, plus fees necessary to administer the program. Payment could be via property tax assessment over a set period.
- CDBG funds could be used for retrofit loans on homes owned by persons with low or moderate incomes.
- City funds or bond proceeds could be used to fund a retrofit loan loss guarantee fund or to purchase insurance on retrofit loans, to reduce risk of default and the interest rate. A City department could create a revolving fund for this purpose. Guidance from the City Attorney would be needed in order to do this.
- Financing for seismic retrofits might be available to eligible non-profit organizations through programs including the Association of Bay Area Governments (ABAG) Authority for Non-Profit Corporations.

Permit Fee Waivers

The City could waive or reduce fees charged for building permits, plan checking, planning review and/or variance applications or other permits required for seismic retrofit work.

The City considered but did not pass legislation to waive such fees for voluntary retrofits in the Fall of 2008. Waiving these fees would reduce City revenues.

Pass Through of Retrofit Costs to Tenants

Building owners who seismically retrofit their buildings could be allowed to pass through the costs of these retrofits to renters in rent-controlled units.

For the City's unreinforced masonry building program, building owners were allowed to pass through 100 percent of seismic retrofit costs to rent-controlled tenants over a 15-year period, with a maximum increase of 10 percent of the base rent in any one year. This was coupled with a daily stipend for temporary relocation and other protections for tenants. Some, but not all, building owners took advantage of this benefit. Presumably, many buildings had turnover in their tenants, allowing them to rent units at market rate and negating the need to seek pass-throughs for retrofit expenses.

In 2002, the City passed a law allowing 100 percent pass-through of any code mandated seismic or energy upgrades. When this work is voluntary, however, only 50 percent of costs can be passed through to tenants. The City could alter this to allow 100 percent of expenses for voluntary seismic retrofits to be passed through.

Tax Reductions for Historic Properties

There are two existing incentive programs that could be used to reduce taxes for historic properties that conduct seismic upgrades: the state Mills Act and the creation of a federal historic district.

The Mills Act (California Government Code, Article 12, Sections 50280 - 50290, California Revenue and Taxation Code, Article 1.9, Sections 439 - 439.4) gives local governments the authority to enter into contracts with owners who restore and maintain historic properties. In exchange, the property owners could get significant property tax savings (approximately 50%). Only buildings that are listed on the National Register or are located in a National Register District can qualify for this incentive. The process to apply for this program is expensive and cumbersome. The City limits its annual loss to a maximum of $1 million per year due to the Mills Act.

Creating a National Register Historic District could provide a federal income tax credit for qualifying work on contributing historic properties within the district.

The City of St. Helena used both of these tools to assist owners of unreinforced masonry buildings to seismically retrofit. Creating a federal historic district was a successful incentive, giving owners a 20 percent federal tax credit. Many building owners found the Mills Act less appealing because of its cumbersome process.

Insurance Incentives

Most, but not all, earthquake insurance for single-family homes and renters in California is offered through the California Earthquake Authority (CEA), a publicly managed, largely privately funded organization. CEA policies are offered through participating private insurance companies. The CEA was started in 1996, after the southern California Northridge earthquake, which caused major losses to insurance companies and restricted their willingness to offer earthquake policies. CEA policies reflect the risk of earthquake damage and have higher premiums, higher deductible limits, and more limited content and living expenses coverage than policies prior to Northridge. Private insurance companies offer earthquake insurance on commercial properties, such as multi-unit residential properties.

The ability of property insurers to offer incentives is limited by market competition, federal tax law, state regulation and the nature of insurance working best when covering large numbers of predictable losses and dispersed over time and location. Risks that are infrequent, unpredictable and concentrated in time and space by a single event are hard to cover by actuarially based reserves.

Currently, the CEA offers a 5 percent rate credit to those who retrofit their homes. This discount is offered for wood-frame construction dwellings built before 1979, if the frame is tied to the foundation, has cripple walls braced with plywood or its equivalent, and if the water heater is secured to the building frame. The retrofit discount is not available for houses built on concrete-slab foundations, and insurance is not offered by the CEA for multi-unit residential housing.

Other possible incentives associated with earthquake insurance are possible but not currently available. These include further discounts on premiums for homeowners who have retrofitted, lower deductibles and coinsurance percentages, and increased availability of coverage.

Action by the CEA, non-participating insurance companies, and the Insurance Commissioner would be needed in order to enact these incentives. Insurance premiums are regulated by the Department of Insurance to assure that rates charged are fair, actuarially justified and that reserves are sufficient to pay losses. Because insurance companies compete for market share, they could use retrofit-based reduced premiums to attract more policies. However, this is a double-edged sword: increased customers result in increased exposure to losses concentrated in the area affected by earthquakes.

Insurance agents could be enlisted in efforts to explain the risk of earthquake damage to residential and commercial policyholders. Property insurance policies exclude damage due to earthquake shaking, but they do cover fire losses. Because of the direct link between earthquake and fire in San Francisco, there might be an incentive to insurance companies to encourage retrofitting measures that also reduce the risk of fires following earthquakes.

Insurance companies that provide owners with liability coverage should have an interest in retrofitting. See incentive 4.5.

FEMA Grants

Grants from FEMA are not an incentive *per se*, but because they could be used in a variety of ways to help fund incentive programs, they are briefly mentioned here.

FEMA offers a variety of grants to state and local agencies to reduce the risk from hazards. Hazard Mitigation Grants (Section 404 of the Federal Stafford Act) provide matching grants from a fund established from a percentage of post-disaster repair grants (Section 406 of the Federal Stafford Act). The amount available under Section 404 depends on the magnitude of Section 406 grants to the state following disasters declared by the President and the percentages established at the time. These grants could be used in communities not affected by the declared disaster (e.g., San Francisco could apply for grant funds after an earthquake in Los Angeles).

FEMA also provides grants from the Pre-Disaster Mitigation Program to state and local governments. The amount appropriated by Congress varies each fiscal year. San Francisco could apply for grants to fund some of the costs of administering mitigation programs and providing incentives.

Federal, State or Private Sector Incentives

There are a number of frequently mentioned potential financial incentives that would require action by federal or state level government or private sector institutions. It is not within the power of the City to offer these incentives. They are mentioned here for completeness.

These include:

- Preferable mortgage rates for earthquake resistant structures, provided by lending institutions such as Fannie Mae or private banks;
- Income tax credits and/or homeowner deductions for the costs of seismic retrofits, or accelerated depreciation rates for retrofit improvements. The value of deductions varies with taxpayer's adjusted gross income, while tax credits provide a specific tax reduction to all taxpayers;
- Removal of financial disincentives for retrofitting, by removing programs that subsidize post-disaster losses through casualty tax deductions of disaster losses, and disaster assistance that subsidizes losses of owners who chose not to retrofit. This policy could have unintended implications on recovery and be perceived as callous; and
- Companies that provide building materials could offer a discount or rebate on materials used for retrofitting deficient properties. There would have to be compensating factors such as increased volume or market share due to favorable publicity.

12.4.2 Policy Incentives

There are many incentives that are not directly financial that could be powerful motivators to encourage seismic retrofit, such as allowing owners to make changes to a building that they would not otherwise be allowed to make, if they seismically upgrade their building. For example, Palo Alto granted density bonuses and waived parking set aside fees to encourage seismic strengthening. All of these policy incentives have social. if not financial, "costs,", because there are politically sound reasons for each aspect of how changes in buildings are currently regulated. Many of the ideas mentioned below might not be acceptable in San Francisco. However, City leaders might decide that seismic safety and preservation of affordable housing and neighborhood character after an earthquake are community priorities that outweigh some other needs.

Exemptions for Nonconforming Conditions

Many older buildings have nonconforming conditions that do not meet current code requirements, such as construction directly on the lot line, inadequate setbacks, or inadequate parking. If upgrade projects trigger changes to nonconforming conditions, such as when buildings are altered or enlarged, then the City could offer some exemptions to these requirements, if owners seismically retrofit.

Non-Permitted Work

Many buildings in San Francisco have made additions or alterations without permits and might avoid seeking permits for seismic retrofit in order to avoid detection and the associated cost of either removing the improvement or having it regularized. The City could establish a program to facilitate approvals, except for illegal developments that are unsafe.

Zoning Incentives

City land use policies and zoning ordinances could provide important value in return for retrofitting. The City could exempt homes that retrofit from selected zoning restrictions, such as allowing concessions regarding encroachment into set backs,

increased floor/area ratios, height limits, density bonuses, and on site parking requirements. These concessions would be more powerful, if owners who elect not to use them could sell them to others or transfer them to another location within the City (Transfer of Development Rights).

Palo Alto modified its zoning laws to encourage owners of unreinforced masonry buildings to retrofit. The zoning laws were modified to permit expansion of the floor area of downtown buildings included in the program, if the owner performed seismic upgrades. These buildings were also exempted from on-site parking requirements and fees for off-site parking.

Condominium Conversion

Converting multi-unit residential properties to condominiums buildings is a lengthy, complex process generally intended to limit the number of conversions. This process, which is driven by the difference in market value between rental and individually-owned units, could be used to trigger mandatory seismic retrofit, or could be eased as an incentive to those who retrofit voluntarily.

Exempt or Defer Triggered Work

Owners that choose to voluntarily seismically retrofit their buildings might trigger other required work, such as:

- Americans with Disabilities Act upgrades;
- Fire resistance upgrades and sprinklers;
- Title 24 energy analysis and upgrades; or
- Neighborhood notification.

The City could exempt owners from some triggered requirements. Note that owners cannot be exempted from triggered ADA upgrades, which can be costly. This is a federal requirement, and the courts have determined that seismic strengthening projects should not be exempted from this requirement.

Expedite Permits and Reviews

The City could provide over the counter permits without delay whenever possible. All permit reviews for seismic retrofits could be expedited. Planning Department review for most projects with seismic retrofits could be bypassed.

Discretionary Zoning Permits

The City could pass an ordinance linking discretionary zoning permits for building occupancy to seismic upgrades, if a building is designated potentially hazardous.

Rebuilding Restrictions

Currently, a rent-controlled apartment building that is demolished after an earthquake could be replaced by a building having a greater return on investment than apartments, such as condominiums. It can also be rebuilt maintaining non-conforming conditions of the previous building, such as proximity to the lot line and parking capacity. This potential could be viewed as a disincentive to seismically upgrade the city's worst buildings. Post-earthquake rebuilding policies could be changed to restrict this.

Transfer of Development Rights (TDR)

The City could allow owners to transfer unused development rights to another site. This incentive might be especially valuable for owners of historic properties. The value of the development rights to be transferred should be comparable to the cost of a seismic retrofit.

12.4.3 Technical Assistance Incentives

Many, maybe most, owners have never hired an engineer, sought permits or engaged a contractor and find the process daunting. Technical assistance incentives help building owners to navigate the complex engineering issues associated with building retrofits. City-offered technical review and advice would improve the chances that building owners would carry out effective retrofit projects.

Training Construction Professionals

The City could provide training to engineers and contractors in all stages of the retrofit process: building evaluation, retrofit design, and construction. A list with the names of those who complete the training successfully would be made available to building owners. However, training would not guarantee that those on the list are properly licensed and insured, or that they engage in good business practices.

Training could be provided free (FEMA grants could cover the cost), at a subsidized cost, or at-cost to prospective inspectors, civil engineers, architects, contractors and owners interested in developing a retrofit specialty. Training could be offered through existing organizations and training programs. A program name and logo could be copyrighted and trained individuals could be allowed to use it in advertising and business documents. The City's awareness literature could promote use of trained individuals.

The City of Berkeley provided training for civil engineers in preparation for its soft-story building program, and ABAG has provided training to contractors for retrofitting cripple walls.

Information for Building Owners

The City could provide publications or other materials about how to work with engineers and contractors for evaluations, design and contracting. These could include information that will help them to ask relevant questions and to evaluate proposed costs and activities.

Standard Plan Sets

The City could provide standard details and drawings to simplify and expedite approval of retrofit work. Buildings that are retrofitted according to the standard plan could receive expedited permit review and bypass engineering analysis. It might not be wise to eliminate engineering judgment on many buildings, and standardized solutions might not be possible for many buildings because of unique features.

Standard plan sets and details work best for single-family homes in standard configurations. They are probably not feasible for larger, complex, multi-family buildings. Standard plan sets exist for some configurations of single-family homes common in the East Bay, developed by the California Building Officials, but these are not applicable to typical San Francisco homes.

Independent Advice and Evaluations

Technical advice could be provided through intermediaries with no financial interest in the outcome. The Department of Building Inspection could inspect properties before approving construction drawings and critique plans. Partner organizations—private non-profits and professional associations—could provide technical advice through the auspices of the Department of Building Inspection. This type of program could be funded by a FEMA grant.

Assistance Navigating City Program

Owners of multi-unit buildings have a variety of characteristics. Some live in their buildings, some live out of state; some have cash available, others might have all of their assets in the property with little monthly income. Many owners have never hired an engineer or architect for a major project and have never engaged a contractor. The process of retrofitting would be daunting for many. The City could provide assistance on project financing and how to secure incentives. An ombudsman could be designated for all retrofit activities, guiding building owners though requirements, incentives, and financing options.

Tool Lending Library

The city could lend tools to building owners, so that they could do some retrofit work without purchasing or renting specialized tools. This could be a significant incentive to handy owners of small buildings or single-family homes, but of little importance when a contractor is needed to do specialized and difficult work.

Building Owner Training Programs

Building owners could be trained in:

- the City's retrofit program;
- the types of damage expected when buildings are retrofitted to different standards (performance objectives);
- how to select engineers to evaluate buildings and design retrofits, and contractors to conduct the work; and,
- how to do simple retrofit work themselves.

This could be integrated into an ongoing community-training program, such as the Fire Department's Community Emergency Response Team program.

12.4.4 Information Incentives

Many building owners and users do not know how their buildings will perform in an earthquake. Being better informed about risk can enable people to make informed choices about the level of risk they are willing to accept. Information can drive market-based decisions about seismic retrofitting. Owners choose to strengthen their buildings to protect their investments; tenants choose to occupy safer buildings; and retrofitted building could be more valuable when sold.

Real Estate Transfer Disclosures

Existing state real estate disclosure laws require building owners to disclose any known seismic deficiencies when a building is sold. Sellers are not required to evaluate the vulnerability of their building or to strengthen any known weaknesses.

The effectiveness of disclosure is compromised when owners often check the "do not know" option rather than speculating on deficiencies. Real estate earthquake vulnerability disclosure requirements could be amended to require an engineering evaluation of a building when sold. Existing state statutes would need to be amended to require this.

Possibly the City could note information about a building's seismic status as part of its tax assessor/official record. This could include a "certificate of retrofit" or documentation of whether the building is on a list of potentially vulnerable buildings.

Tenant Notification

Building owners can be mandated to notify tenants if their buildings are deemed to be potentially hazardous in earthquakes.

The City would need to identify hazardous or potentially hazardous buildings before such a program could occur. For some types of hazardous buildings (e.g., URM buildings), this is a relatively straightforward process. For others (e.g., older concrete buildings), this is challenging and could identify many buildings as potentially hazardous that actually pose little risk.

Building Ratings

Proposals to evaluate and rate the earthquake performance of buildings are discussed frequently. The objective would be to create an evaluation system that would be meaningful and that would be replicated closely by a variety of inspectors or engineers. The ratings would reflect the risk of earthquake loss, and the objective would be to influence market value, insurance premiums, and lending rates. Meaningful and replicable analysis methods are not yet available.

Placards

Owners of unreinforced masonry buildings are required to post signs warning occupants of the building's earthquake vulnerability. The objective is to give those who enter a chance to make an informed decision, and to warn those who might rent or purchase the building of its condition. These signs tend not to discourage persons from entering for limited periods but might have an impact on market or rental values. Owners of buildings found to have a weak first story could be required to post a notice and then be allowed to remove it upon completion of retrofit work.

Standard of Care

Owners have a responsibility to maintain their properties in a safe condition. Following earthquakes, those who are harmed might believe that the owner is responsible for damages. Although no case law on this matter was uncovered during this CAPSS effort, if a claim goes to court, the test will be determined by the standard-of-care, that is, whether the owner took reasonable steps appropriate to the location and time to provide an appropriately safe building. By establishing criteria for identifying vulnerable buildings, clear retrofit standards and compliance deadlines, the City could affect how the standard-of-care would be interpreted and applied. Those who comply are more likely to be found as having acted reasonably than those who have not. Clarifying liability in this fashion might encourage those who are concerned about liability and might encourage liability insurers to exert pressure on owners to retrofit.

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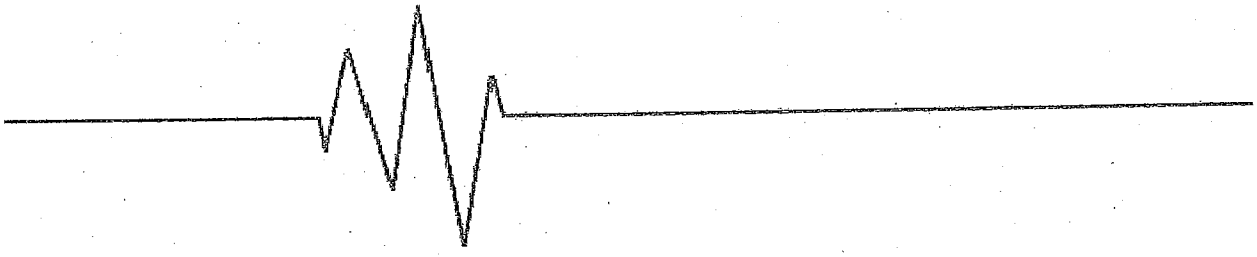
PROJECT PARTICIPANTS



The Applied Technology Council (ATC) gratefully acknowledges the significant contributions of the volunteer Community Action Plan for Seismic Safety (CAPSS) Advisory Committee, participants in the CAPSS Advisory Committee meetings and project workshop on soft-story buildings, the Project Consultants, the advisory Project Engineering Panel, and ATC staff. ATC also gratefully acknowledges the leadership and support provided by San Francisco Department of Building Inspection personnel and the Building Inspection Commission. Individuals who served in these various capacities are identified below.

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Vivian L. Day, Chief Building Official, DBI Director

Laurence Kornfield, Chief Building Inspector and DBI Project Officer

Raymond Lui, Manager, Plan Review Services

Hanson Tom, Principal Engineer

William Strawn, Communications Officer

Jimmy Cheung, Building Inspector

SAN FRANCISCO BUILDING INSPECTION COMMISSION

Frank Lee, President

Kevin B. Clinch (as of January 26, 2009)

Reuben Hechanova

Robin Levitt

Mel Murphy

Criss Romero

Vahid Sattary (until January 26, 2009)

Debra Walker

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Laura Samant (ATC Co- Project Manager), San Francisco, California

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*ATC Board Representative

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CAPSS VOLUNTEER ADVISORY COMMITTEE AND MEETING ATTENDEES

Mary Lou Zoback (Advisory Committee Co-Chair), Risk Management Associates

John Paxton (Advisory Committee Co-Chair), Real Estate Consultant

Aimee Alder

Jim Aldrich, Emergency management specialist

Alysabeth Alexander, La Voz Latina de la Ciudad Central

Robert Anderson, California Seismic Safety Commission/California Earthquake Authority

Thomas Anderson, Anderson Niswander Construction, Inc.

Alexandra Bevk, San Francisco Heritage

Jack Boatwright, U.S. Geological Survey

Bruce Bonacker, San Francisco Heritage

David Bonowitz, Structural Engineers Association of Northern California

Tom Brocher, U.S. Geological Survey

Tim Carrico, Property owner/manager

Ken Cleaveland, Building Owners and Managers Association

Jerry Cunningham, Mechanical Engineer

Anthony Demascole, Structural Engineer

Scott Dennis

Doug Diboll, North of Panhandle Neighborhood Association

Charles Duncan, Carey and Company

Rolf Erickson, CalQuake

J. Edgar Fennie, Fennie+Mehl Architects

Sig Freeman, Wiss, Janney, Elstner Associates

Lisa Fricke, San Francisco Apartment Association

Kurt Fuchs, Office of the Controller

Jack Gold, San Francisco Heritage

Vicki Hennessy, Department of Emergency Management

David Hoska, Lingruen Associates

Daniel Homsey, Office of City Administrator

Jonas Ionin, Planning Department

Judy Irvin, Historic preservationist

Whitney Jones, Chinatown Community Development Center

Ronald Kahn, Attorney

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John Keogan, San Francisco Citizens for Responsible Growth
Keith Knudsen, URS Corporation
Pius Lee, Chinatown Neighborhood Association
Reinhard Ludke, President, Structural Engineers Association of Northern California
Mark Luellen, Planning Department
John Lyong, San Francisco Citizens for Responsible Growth
Joan MacQuarrie, Building Official, City of Berkeley
Dave Massen, Renter
Betsy Mathieson, Exponent Failure Analysis
Janan New, San Francisco Apartment Association
Luke O'Brien, San Francisco Citizens for Responsible Growth
Ken Paige, Paige Glass
Jeanne Perkins, Association of Bay Area Governments
Lee Phillips, Code Advisory Committee, Disability representative
Dave Pritchard, Renter
Sean Pritchard, San Francisco Apartment Association
Badie Rowshandel, California Geological Survey/California Earthquake Authority
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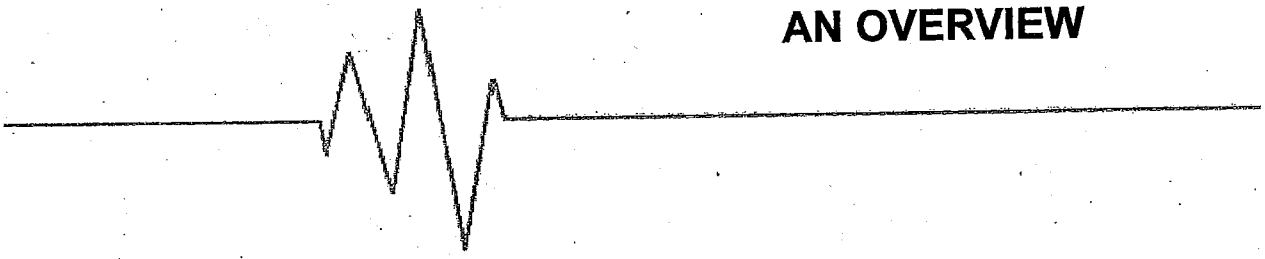
Steve Walter, U.S. Geological Survey
Paul Wermer, San Francisco Neighborhood Network
George Williams, San Francisco Planning and Urban Research
Malcolm Yeung

PARTICIPANTS OF THE DESIGN CHARETTE (SEPTEMBER 12, 2008)

Tom Anderson, Contractor, Anderson-Niswander Construction
Pat Buscovich, Structural Engineer, Pat Buscovich, Structural Engineer
Tony Demascole, Structural Engineer, A. Demascole, Consulting Engineer
Sig Freeman, Structural Engineer, Wiss, Janney, Elstner Associates
Laurence Kornfield, Building Official, SF DBI
Jimmy Cheung, Building Official, SF DBI
Chris Poland, Structural Engineer, Degenkolb
Vahid Sattary, Structural Engineer, Sattary Structural Engineering
Hanson Tom, Structural Engineer, SF DBI

APPLIED TECHNOLOGY COUNCIL: AN OVERVIEW



The Applied Technology Council (ATC) is a nonprofit corporation founded to protect life and property through the advancement of science and engineering technology. With a focus on seismic engineering, and a growing involvement in wind and coastal engineering, ATC's mission is to develop state-of-the-art, user-friendly resources and engineering applications to mitigate the effects of natural and other hazards on the built environment.

ATC fulfills a unique role in funded information transfer by developing nonproprietary consensus opinions on structural engineering issues. ATC also identifies and encourages needed research and disseminates its technological developments through guidelines and manuals, seminars, workshops, forums, and electronic media, including its web site (www.ATCouncil.org) and other emerging technologies.

Key Publications

Since its inception in the early 1970s, the Applied Technology Council has developed numerous, highly respected, award-winning, technical reports that have dramatically influenced structural engineering practice. Of the more than 100 major publications offered by ATC and its Joint Venture partners, the following have had exceptional influence on earthquake engineering practice:

ATC-3-06, *Tentative Provisions for the Development of Seismic Regulations for Buildings*, funded by the National Science Foundation (NSF) and the National Bureau of Standards and completed in 1978, provides the technical basis for seismic provisions in the current *International Building Code* and other model U. S. seismic codes.

ATC-14, *Evaluating the Seismic Resistance of Existing Buildings*, funded by NSF and completed in 1987, provides the technical basis for the current American Society of Civil Engineers (ASCE) Standard 31, *Seismic Evaluation of Existing Buildings* (the national standard for seismic evaluation of buildings).

ATC-20, *Procedures for Postearthquake Safety Evaluation of Buildings*, funded by the California Office of Emergency Services and the California Office of Statewide Health Planning and Development, is the *de facto* national standard for determining if buildings can be safely occupied after damaging earthquakes. The document has been used to evaluate tens of thousands of buildings since its introduction two weeks before the 1989 Loma Prieta earthquake in Northern California.

ATC-40, *Seismic Evaluation and Retrofit of Concrete Buildings,* funded by the California Seismic Safety Commission and completed in 1996, won the Western States Seismic Policy Council' s "Overall Excellence and New Technology Award" in 1997.

FEMA 273, *NEHRP Guidelines for the Seismic Rehabilitation of Existing Buildings,* funded by the Federal Emergency Management Agency (FEMA) and completed in 1997 under the ATC-33 Project, provides the technical basis for the current American Society of Civil Engineers (ASCE) Standard 41, *Seismic Rehabilitation of Existing Buildings* (the national standard for seismic rehabilitation of buildings).

FEMA 306, *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Basic Procedures Manual,* **FEMA 307,** *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Technical Resources,* and **FEMA 308,** *The Repair of Earthquake Damaged Concrete and Masonry Wall Buildings,* funded by FEMA and completed in 1998 under the ATC-43 Project, provide nationally applicable consensus guidelines for the evaluation and repair of concrete and masonry wall buildings damaged by earthquakes.

FEMA 352, *Recommended Post-earthquake Evaluation and Repair Criteria for Welded Steel Moment-Frame Buildings,* funded by FEMA and developed by the SAC Joint Venture, a partnership of the Structural Engineers Association of California, the Applied Technology Council, and California Universities for Research in Earthquake Engineering, provides nationally applicable consensus guidelines for the evaluation and repair of welded steel moment frame buildings damaged by earthquakes.

FEMA P646, *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis,* funded by FEMA and completed in 2008 under the ATC-64 Project, provides state-of-the-art guidance for designing, locating and sizing structures to resist the effects of tsunamis and thereby provide safe evacuation refuge in affected coastal areas.

Organization

With offices in California, Delaware, and Virginia, ATC's corporate personnel include an executive director, senior-level project managers and administrators, and technical and administrative support staff. The organization is guided by a distinguished Board of Directors comprised of representatives appointed by the American Society of Civil Engineers, the National Council of Structural Engineers Associations, the Structural Engineers Association of California, the Structural Engineers Association of New York, the Western Council of Structural Engineers Associations, and four at-large representatives.

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Projects are performed by a wide range of highly qualified consulting specialists from professional practice, academia, and research—a unique approach that enables ATC to assemble the nation's leading specialists to solve technical problems in structural engineering.

Funding for ATC projects is obtained through government agencies, and from the private sector in the form of tax-deductible contributions.

BOARD of SUPERVISORS

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NOTICE OF PUBLIC HEARING

LAND USE AND ECONOMIC DEVELOPMENT COMMITTEE

SAN FRANCISCO BOARD OF SUPERVISORS

NOTICE IS HEREBY GIVEN THAT the Land Use and Economic Development Committee will hold a public hearing to consider the following proposal and said public hearing will be held as follows, at which time all interested parties may attend and be heard:

Date: **Monday, March 18, 2013**

Time: **1:30 p.m.**

Location: **Committee Room 263, located at City Hall**
1 Dr. Carlton B. Goodlett Place, San Francisco, CA

Subject: **File No. 130119.** Ordinance amending the Building Code, to establish a Mandatory Seismic Retrofit Program for wood-frame buildings of three or more stories and containing five or more dwelling units where the permit to construct was applied for prior to January 1, 1978, and the building has not been seismically strengthened; establishing a fee for administering the program; adopting environmental findings, and findings of local conditions under California Health and Safety Code, Section 17958.7; establishing an operative date; and directing the Clerk of the Board to forward the legislation to specified State agencies.

If the legislation passes, an Administrative Fee for services provided under Building Code, Chapter 34B, Mandatory Earthquake Retrofit of Wood-Frame Buildings, by the Department of Building Inspection shall be codified at the standard hourly rate set forth in Building Code Table 1A-D: $187/hour for plan review; $170/hour for inspection or $180/hour for OSHPD inspection; and $104/hour for administration services, with a minimum charge of $52 for 30 minutes or less. When a Screening Form is required by Building Code, Section 3404B.2, a minimum fee equivalent to one hour for plan review and administration shall be charged, or two hours when a voluntary Evaluation Form is also submitted with the Screening Form. Additional fees may be charged for additional work and payable within 30 days of notice that payment is due. Monies collected shall be deposited into the Building Inspection Operating Fund.

In accordance with San Francisco Administrative Code, Section 67.7-1, persons who are unable to attend the hearing on this matter may submit written comments to the City prior to the time the hearing begins. These comments will be made a part of the official public record and shall be brought to the attention of the Members of the Committee. Written comments should be addressed to Angela Calvillo, Clerk of the Board, Room 244, City Hall, 1 Dr. Carlton Goodlett Place, San Francisco CA 94102. Information relating to the proposed fee is available in the Office of the Clerk of the Board. Agenda information relating to this matter will be available for public review on Friday, March 15, 2013.

Angela Calvillo, Clerk of the Board

DATED: February 26, 2013
POSTED: February 28, 2013
PUBLISHED: March 4 & 11, 2013

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SAN FRANCISCO, CA 94102

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NOTICE OF PUBLIC HEARING
LAND USE AND ECONOMIC DEVELOPMENT COMMITTEE
SAN FRANCISCO BOARD OF SUPERVISORS
MONDAY, MARCH 18, 2013 - 1:30 PM
COMMITTEE ROOM 263,C ITY HALL
1 DR. CARLTON B. GOODLETT PLACE, SAN FRANCISCO,C A

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Angela Calvillo,C lerk oft he Board

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BOARD of SUPERVISORS

City Hall
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San Francisco 94102-4689
Tel. No. 554-5184
Fax No. 554-5163
TDD/TTY No. 554-5227

MEMORANDUM

TO: Tom Hui, Acting Director, Department of Building Inspection
Sonya Harris, Secretary, Building Inspection Commission

FROM: Alisa Miller, Clerk, Land Use and Economic Development Committee
Board of Supervisors

DATE: March 13, 2013

SUBJECT: SUBSTITUTE LEGISLATION INTRODUCED

The Board of Supervisors' Land Use and Economic Development Committee has received the following *substitute* ordinance, introduced by Mayor Lee on March 12, 2013:

File No. 130119-2

Ordinance amending the Building Code to establish a Mandatory Seismic Retrofit Program for wood-frame buildings of three or more stories or two stories over a basement or underfloor area that has any portion extending above grade, and containing five or more dwelling units where the permit to construct was applied for prior to January 1, 1978, and the building has not been seismically strengthened; establishing a fee for administering the program; adopting environmental findings and findings of local conditions under California Health and Safety Code, Section 17958.7; establishing an operative date; and directing the Clerk of the Board to forward the legislation to specified State agencies.

The Building Inspection Commission held a public hearing on this matter on February 20, 2013, and provided their recommendation on the previous version. This matter is scheduled to be heard at the Land Use and Economic Development Committee next week on March 18, 2013.

If you have additional reports or comments to be considered with this matter, please forward them to me at the Board of Supervisors, City Hall, Room 244, 1 Dr. Carlton B. Goodlett Place, San Francisco, CA 94102.

c: William Strawn, Department of Building Inspection
Carolyn Jayin, Department of Building Inspection

BOARD of SUPERVISORS

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MEMORANDUM

TO: John Rahaim, Director, Planning Department

FROM: Alisa Miller, Clerk, Land Use and Economic Development Committee
Board of Supervisors

DATE: March 13, 2013

SUBJECT: LEGISLATION INTRODUCED

The Board of Supervisors' Land Use and Economic Development Committee has received the following *substitute* ordinance, introduced by Mayor Lee on March 12, 2013:

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Ordinance amending the Building Code to establish a Mandatory Seismic Retrofit Program for wood-frame buildings of three or more stories or two stories over a basement or underfloor area that has any portion extending above grade, and containing five or more dwelling units where the permit to construct was applied for prior to January 1, 1978, and the building has not been seismically strengthened; establishing a fee for administering the program; adopting environmental findings and findings of local conditions under California Health and Safety Code, Section 17958.7; establishing an operative date; and directing the Clerk of the Board to forward the legislation to specified State agencies.

The Planning Department issued an environmental review exemption for this matter on February 25, 2013.

This matter is being forwarded to your department for informational purposes. If you have any comments or reports to be included with the file, please forward them to me at the Board of Supervisors, City Hall, Room 244, 1 Dr. Carlton B. Goodlett Place, San Francisco, CA 94102.

c: Scott Sanchez, Zoning Administrator
Sarah Jones, Environmental Review Officer
AnMarie Rodgers, Legislative Affairs Manager
Joy Navarrete, Senior Environmental Planner
Monica Pereira, Environmental Planner

BOARD of SUPERVISORS

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February 19, 2013

File No. 130119

Bill Wycko
Environmental Review Officer
Planning Department
1650 Mission Street, 4th Floor
San Francisco, CA 94103

Dear Mr. Wycko:

On February 5, 2013, Mayor Lee introduced the following proposed legislation:

File No. 130119

Ordinance amending the Building Code, to establish a Mandatory Seismic Retrofit Program for wood-frame buildings of three or more stories and containing five or more dwelling units where the permit to construct was applied for prior to January 1, 1978, and the building has not been seismically strengthened; establishing a fee for administering the program; adopting environmental findings, and findings of local conditions under California Health and Safety Code, Section 17958.7; establishing an operative date; and directing the Clerk of the Board to forward the legislation to specified State agencies.

This legislation is being transmitted to you for environmental review, pursuant to Planning Code Section 306.7(c).

Angela Calvillo, Clerk of the Board
Alisa Miller
By: Alisa Miller, Committee Clerk
Land Use & Economic Development Committee

Attachment

c: Monica Pereira, Environmental Planning
Joy Navarrete, Environmental Planning

BOARD of SUPERVISORS

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Dr. Carlton B. Goodlett Place, Room 244
San Francisco 94102-4689
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MEMORANDUM

TO: John Rahaim, Director, Planning Department

FROM: Alisa Miller, Clerk, Land Use and Economic Development Committee
Board of Supervisors

DATE: February 6, 2013

SUBJECT: LEGISLATION INTRODUCED

The Board of Supervisors' Land Use and Economic Development Committee has received the following proposed ordinance, introduced by Mayor Lee on February 5, 2013:

File No. 130119

Ordinance amending the Building Code, to establish a Mandatory Seismic Retrofit Program for wood-frame buildings of three or more stories and containing five or more dwelling units where the permit to construct was applied for prior to January 1, 1978, and the building has not been seismically strengthened; establishing a fee for administering the program; adopting environmental findings, and findings of local conditions under California Health and Safety Code, Section 17958.7; establishing an operative date; and directing the Clerk of the Board to forward the legislation to specified State agencies.

This matter is being forwarded to your department for informational purposes. If you have any comments or reports to be included with the file, please forward them to me at the Board of Supervisors, City Hall, Room 244, 1 Dr. Carlton B. Goodlett Place, San Francisco, CA 94102.

c: Scott Sanchez, Zoning Administrator
Bill Wycko, Environmental Review Officer
AnMarie Rodgers, Legislative Affairs Manager
Joy Navarrete, Senior Environmental Planner
Monica Pereira, Environmental Planner

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MEMORANDUM

TO: Tom Hui, Acting Director, Department of Building Inspection
Sonya Harris, Secretary, Building Inspection Commission

FROM: Alisa Miller, Clerk, Land Use and Economic Development Committee
Board of Supervisors

DATE: February 19, 2013

SUBJECT: LEGISLATION INTRODUCED: BUILDING CODE AMENDMENT

The Board of Supervisors' Land Use and Economic Development Committee has received the following proposed ordinance, introduced by Mayor Lee on February 5, 2013:

File No. 130119

Ordinance amending the Building Code, to establish a Mandatory Seismic Retrofit Program for wood-frame buildings of three or more stories and containing five or more dwelling units where the permit to construct was applied for prior to January 1, 1978, and the building has not been seismically strengthened; establishing a fee for administering the program; adopting environmental findings, and findings of local conditions under California Health and Safety Code, Section 17958.7; establishing an operative date; and directing the Clerk of the Board to forward the legislation to specified State agencies.

The proposed ordinance is being transmitted pursuant to Charter Section D3.750-5 for public hearing and recommendation. It is pending before the Land Use & Economic Development Committee and will be scheduled for hearing upon receipt of your response.

Please forward me the Commission's recommendation and reports at the Board of Supervisors, City Hall, Room 244, 1 Dr. Carlton B. Goodlett Place, San Francisco, CA 94102.

c: Carolyn Jayin, Department of Building Inspection

OFFICE OF THE MAYOR
SAN FRANCISCO

EDWIN M. LEE
MAYOR

TO: Angela Calvillo, Clerk of the Board of Supervisors

FROM: for Mayor Edwin M. Lee

RE: Substitute Ordinance File No. 130119 - Building Code – Mandatory Seismic Retrofit Program for Wood-Frame Buildings; Optional Evaluation Form Fee

DATE: March 12, 2013

Attached for substitution to the Board of Supervisors is the ordinance amending the Building Code to establish a mandatory seismic retrofit program for wood-frame buildings of three or more stories or two stories over a basement or underfloor area that has any portion extending above grade, and containing five or more dwelling units where the permit to construct was applied for prior to January 1, 1978 and the building has not been seismically strengthened; establishing a fee for administering the program; adopting environmental findings and findings of local conditions under California Health and Safety Code Section 17958.7; establishing an operative date; and directing the Clerk to forward the legislation to specified state agencies.

Please note this item is cosponsored by Supervisors Chiu, Wiener, Yee, Farrell, Breed, Mar and Tang.

I request that this item be calendared in Land Use and Economic Development Committee on March 18, 2013.

Should you have any questions, please contact Jason Elliott (415) 554-5105.

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cc. Supervisor David Chiu
Supervisor Scott Wiener
Supervisor Norman Yee
Supervisor Mark Farrell
Supervisor London Breed
Supervisor Eric Mar
Supervisor Katy Tang

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SAN FRANCISCO, CALIFORNIA 94102-4681
TELEPHONE: (415) 554-6141

OFFICE OF THE MAYOR
SAN FRANCISCO

EDWIN M. LEE
MAYOR

TO: Angela Calvillo, Clerk of the Board of Supervisors
FROM: Mayor Edwin M. Lee
RE: Building Code – Mandatory Seismic Retrofit Program for Wood-Frame Buildings
DATE: February 5, 2013

Attached for introduction to the Board of Supervisors is the ordinance amending the Building Code to establish a mandatory seismic retrofit program for wood-frame buildings of three or more stories and containing five or more dwelling units where the permit to construct was applied for prior to January 1, 1978 and the building has not been seismically strengthened; establishing a fee for administering the program; adopting environmental findings and findings of local conditions under California Health and Safety Code Section 17958.7; establishing an operative date; and directing the Clerk to forward the legislation to specified state agencies.

Please note this item is cosponsored by Supervisors Chiu, Wiener, Yee, Farrell, Breed and Mar.

I request that this item be calendared in Land Use and Economic Development Committee on March 4, 2013.

Should you have any questions, please contact Jason Elliott (415) 554-5105.

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cc. Supervisor David Chiu
Supervisor Scott Wiener
Supervisor Norman Yee
Supervisor Mark Farrell
Supervisor London Breed
Supervisor Eric Mar

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