City of San Jose

Residential Seismic Safety Program

August 1998

The Apartment Owner's Guide to Earthquake Safety

A Handbook for Owners to Identify Seismic Hazards in Low Rise Apartment Buildings

Steven M. Vukazich, S.E., Ph.D.
San Jose State University

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Purpose of this Handbook

When building owners think about the seismic safety of their buildings, several questions come to mind:

- How does a building resist earthquake forces?
- How safe is my building?
- If my building has seismic weaknesses, how can I fix them?
- How much will it cost?

This handbook is intended to be used by building owners to attempt to answer these difficult questions as accurately as possible by identifying structural weaknesses and understanding how to mitigate these weaknesses.

It should be obvious that the rapid visual screening procedures outlined in this handbook cannot provide highly reliable estimates of seismic performance and are intended only to identify those buildings where reasonable doubts exist. **If any questions exist in applying these techniques, you should err on the side of requiring the building to be investigated in further detail by a design professional. A design professional is a licensed Architect, Civil Engineer, or Structural Engineer with wood frame retrofit experience.**

If you identify a seismic weakness after using this handbook and would like to pursue retrofitting your building, you should first contact a design professional to perform a detailed analysis and, if necessary, create a design for your specific building. Guidelines for hiring design professionals can be found in the *Commercial Property Owner's Guide to Earthquake Safety* published by the California Seismic Safety Commission.

***The Apartment Owner's Guide to Earthquake Safety* is intended to provide information to building owners and is not a design guide for engineers or contractors. A permit is required for all seismic retrofit work, including all work described in this guide.**

I. Introduction

Recent seismic events such as the Loma Prieta, Northridge, and Kobe earthquakes have shown that in addition to loss of human life and property damage, these events can have far reaching political and economic effects on their respective communities. Identifying and reinforcing buildings that lack adequate seismic resistance can reduce this risk to the community. Wood framed apartment buildings, particularly those with first story tuck-under parking, have proven to be vulnerable to earthquake damage. Owners of low-rise apartment buildings in San Jose should be concerned for the following reasons:

A major earthquake is likely to occur in San Jose. San Jose is located in an active seismic region, and is vulnerable to severe ruptures on both the Southern Hayward Fault and the Peninsula Segment of the San Andreas Fault. The United States Geological Survey (USGS) estimates that the combined chance of a major earthquake from either fault is 46% in the next 30 years.

Apartment buildings constructed similarly to those that collapsed in recent earthquakes can be found in San Jose. The Northridge earthquake was the first major disaster where extensive residential damage data was systematically collected, and the results are sobering. Due to the Northridge earthquake there were 2700 multi-family dwellings (30,000 living units) that were vacated or had significant structural damage. Due to the similarities of the housing stock, it is reasonable to expect similar damage in San Jose. In fact, recent studies performed by the Association of Bay Area Governments (ABAG) and EQE International estimate that a major earthquake on the Hayward Fault will result in major structural damage to San Jose's residential housing. The Northridge earthquake has finally dispelled the myth that wood construction is largely immune to earthquake shaking. Although the 1971 San Fernando and 1989 Loma Prieta earthquakes provided evidence of the weakness of some wood buildings, the $10 billion of damage to wood buildings and loss of life in a moderate earthquake like Northridge is final proof.

Apartment owners may be held liable for the safety of residents. California Law makes the owner responsible for building safety even if the owner is unaware of structural deficiencies. One prominent example is the lawsuit against the owner of the Northridge Meadows Apartments whose collapse resulted in the death of sixteen people. Many apartment owners in Los Angeles are currently looking toward strengthening their buildings to both improve resident safety and prevent economic loss.

In the opinion of most structural engineers, a significant amount of the damage to multi-unit structures observed in the Northridge earthquake could have been prevented. In order to reduce the risk to human life and property, the City of San Jose Office of Emergency Services (OES) has implemented a Residential Seismic Safety Program (RSSP) funded by the Community Development Block Grant program. The goal of this program is to provide greater seismic resistance for the existing housing stock, an activity that is of special importance in the current San Jose housing market. One of the objectives of the RSSP is to provide an educational program to encourage multi-unit residential building owners to evaluate the seismic safety of their buildings.

II. Understanding Earthquake Behavior of Residential Buildings

Most of the multi-unit residential buildings in San Jose are predominantly wood frame construction, ranging in height from one to three stories. This section provides a simple overview of how these buildings are designed to resist earthquake forces.

In order to design simple structures like low rise residential buildings, engineers idealize earthquake ground accelerations as horizontal forces applied at the elevated floor and roof levels. These horizontal forces are carried to the foundation by specially designed walls called shearwalls. Figure 1 illustrates this lateral force idealization for a two-story structure. Note that only the walls parallel to the seismic load act as shearwalls and so walls perpendicular to the load are not shown in the figure. Figure 2 shows the forces on the individual elements of the building in order to illustrate how horizontal seismic loads are transmitted through the building down to the foundation. The seismic forces are carried by the floors and roof to the shearwalls. The floor and roof framing specially designed to carry seismic loads to the walls is termed a diaphragm by structural engineers. The diaphragms and shearwalls act together to carry seismic load to the foundation. Since this particular type of system looks like a box, the system is often called a box system. This box system is the most common lateral force resisting system for low rise multi-unit residential construction.

For the building to effectively carry the seismic loads, both the diaphragms and the shearwalls must be strong enough and stiff enough to resist excessive deformation. From examining the behavior of structures in recent earthquakes, by far the most effective method for providing strength and stiffness to diaphragms and shearwalls is to sheath them with structural grade plywood securely nailed to the wood framing. One of the primary reasons that older multi-unit buildings have performed poorly in past earthquakes is due to shearwalls being sheathed with inadequate materials such as gypsum wallboard or stucco instead of plywood.

Another concept that is important in understanding the behavior of buildings in earthquakes is the idea of a "soft" story. It is advantageous in multi-unit construction to provide parking for the residents on the first floor of the building. Unfortunately, this practice often creates what is termed a soft story by structural engineers. A soft story building is one in which one level (usually the first story) is significantly less rigid than any of the other levels above. Since residential units contain many walls to separate rooms and individual units, the upper levels of multi-unit construction tend to be very rigid. A first floor parking area, commonly called tuck-under parking, creates a first floor which is almost entirely free of walls, and thus is much softer (less rigid) than the residential units above.

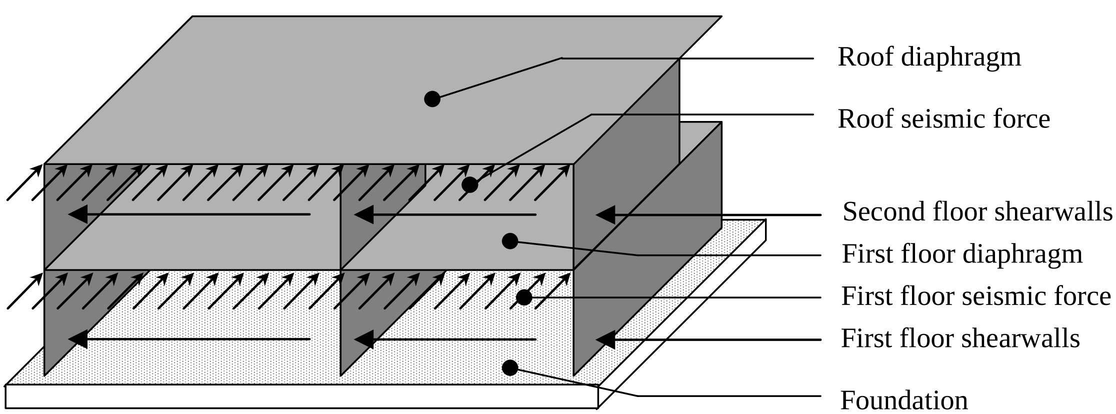


Figure 1. Seismic force resisting system for a box structure.

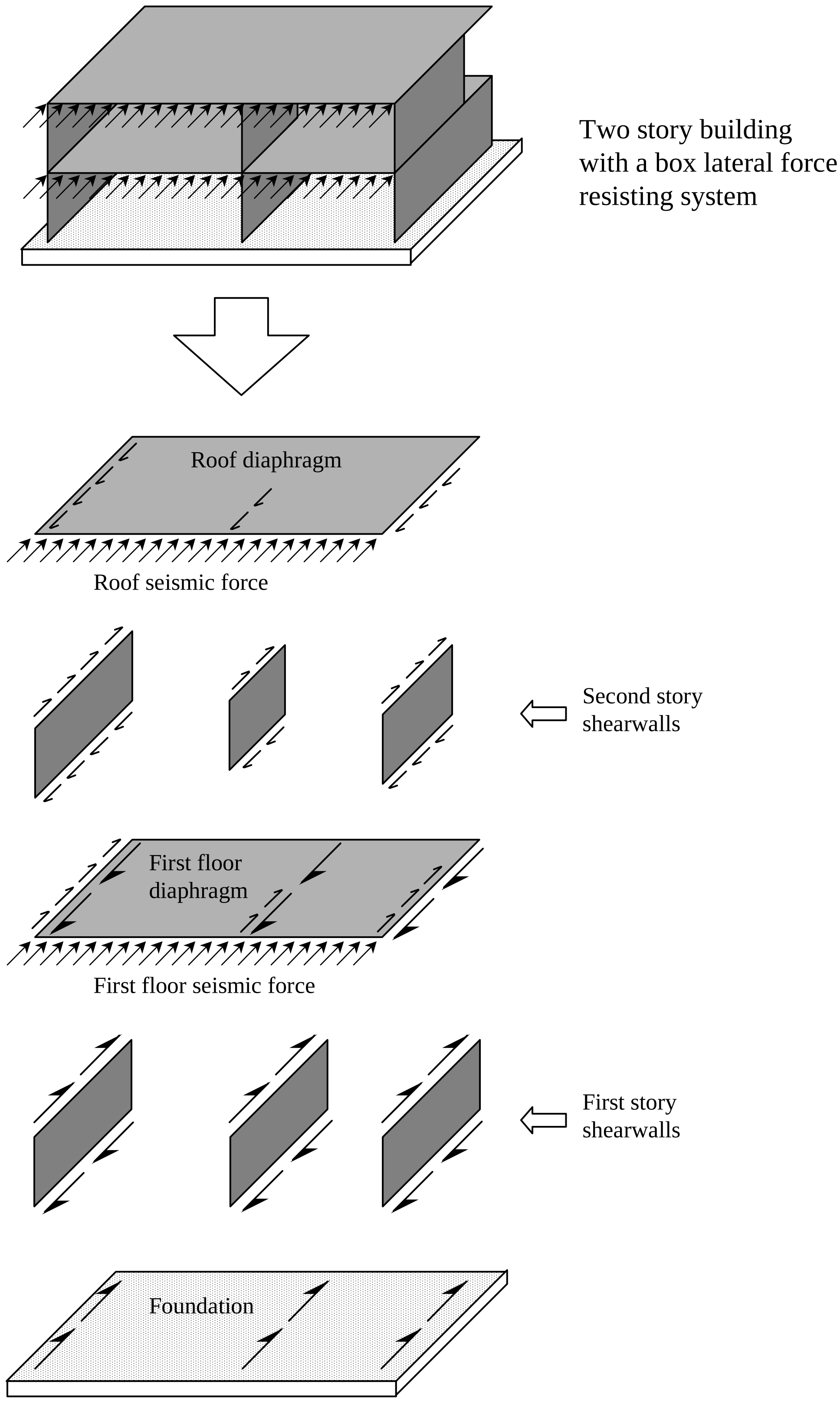


Figure 2. Seismic forces on the elements of a box structure

Expected Seismic Performance of Residential Buildings

Predicting the performance of buildings subjected to earthquakes is difficult, if not impossible, due to uncertainties in the earthquake motion, soil conditions, workmanship, and many other factors. Performance of similar structures in past earthquakes is the best indication of future performance. Nearly all of the residential buildings in California are designed according to guidelines set forth by the Uniform Building Code (UBC) which is revised every three years. A building designed according to code provisions should be able to:

- Resist minor level earthquake without damage;
- Resist a moderate level earthquake without structural damage, but possibly experience some nonstructural damage;
- Resist a major earthquake without collapse, but possibly with some structural and nonstructural damage.

Due to the evolution of building codes, there will always exist older structures that will not be able to achieve expected seismic performance. Wood buildings with tuck-under parking and buildings with unbraced cripple walls have now been identified as performing worse than expected. Seismic retrofit is the term given to procedures that strengthen these structures to improve seismic performance.

Performance History of Multiunit Residential Construction

Wood is the most popular construction material in California and accounts for the majority of residential buildings as well as many commercial buildings. In the past, earthquake damage to wood construction has been much less than that of unreinforced masonry and nonductile concrete buildings. In recent years, three types of wood building construction have proven to be vulnerable to earthquakes:

- Buildings with unbraced cripple walls;
- Buildings with soft first stories due to tuck-under parking areas;
- Hillside homes inadequately supported on steep foundations.

Because of their predominance in San Jose, this handbook addresses seismic weaknesses for the first two types of buildings, with particular emphasis on tuck-under parking buildings. The poor performance of these structures can be attributed primarily to the following:

- The presence of a very flexible first level due to tuck-under parking or unbraced cripple walls;
- The failure of shearwalls constructed from timber studs sheathed with stucco or gypsum board.

Stucco and gupsum board shearwalls coupled with tuck-under parking are present in many wood framed apartment buildings built prior to 1976. The primary reason for this is that the 1976 edition of the UBC contained revisions due to observed performance of buildings in the 1971 San Fernando earthquake. The most significant of these revisions was to decrease the allowable strength of both stucco and gypsum board shearwalls and to increase the seismic load by forty percent. The direct result was the increased use of plywood shearwalls in wood construction and while tuck-under parking was not eliminated it was discouraged. Figure 3 shows damage to stucco shearwalls in a tuck-under parking building following the San Fernando Earthquake. All of the damaged multi-unit buildings inspected after the Northridge earthquake had failed stucco or gypsum board shearwalls. The performance of these weak shearwalls was often made worse by sloppy construction and poor quality control.

Unbraced Cripple Walls

Most buildings that have a crawl space beneath the first floor level are supported by "cripple" walls. Figure 4 shows the view from the interior of the crawl space of an unbraced cripple wall building. The short (1-5 foot tall) walls between the exterior foundation and the first floor level are called cripple walls because they are shorter than full height walls. These cripple walls usually carry a significant portion of the weight of the building. The seismic vulnerability of buildings with cripple walls is that if these walls are not braced adequately to act as shearwalls, the upper portion of the building can fall off of its foundation due to the lateral shifting of the cripple walls. Figure 5 is a good illustration of an unbraced cripple wall failure in the Northridge earthquake. Many buildings with unbraced cripple walls were damaged in both the 1971 San Fernando earthquake and the 1994 Northridge earthquake. It should be noted that cripple wall construction is more common for single family residential construction than for multi-unit residential construction, but in San Jose there are many subdivided buildings with unbraced cripple walls. In particular, Victorian style buildings often have this type of foundation.

Tuck-Under Parking

As previously mentioned, multistory wood apartment or condominium buildings with open first-story parking and many upper-story walls are classic soft story structures. It is estimated that 200 of these buildings either collapsed or came close to collapsing in the Northridge earthquake. The mode of collapse generally followed the pattern of the first story parking level collapsing with the upper stories riding down remaining almost completely intact. The soft first story is often comprised of exterior shearwalls on three sides with very flimsy steel or timber posts on the fourth side. These posts are inadequate to resist the seismic forces and quate to resist the seismic forces and subsequent large deformation that they are subjected to in a major earthquake. Figure 6 shows a tuck-under parking building that collapsed during the Northridge earthquake. Note the collapsed steel posts indicated by the white arrows and the upper stories remaining almost completely intact. This figure illustrates the inherent weakness of the tuck-under parking configuration and the dangers to human life and property (16 people died in this particular building).

Figure 3. Damage to a tuck-under parking building with stucco shearwalls

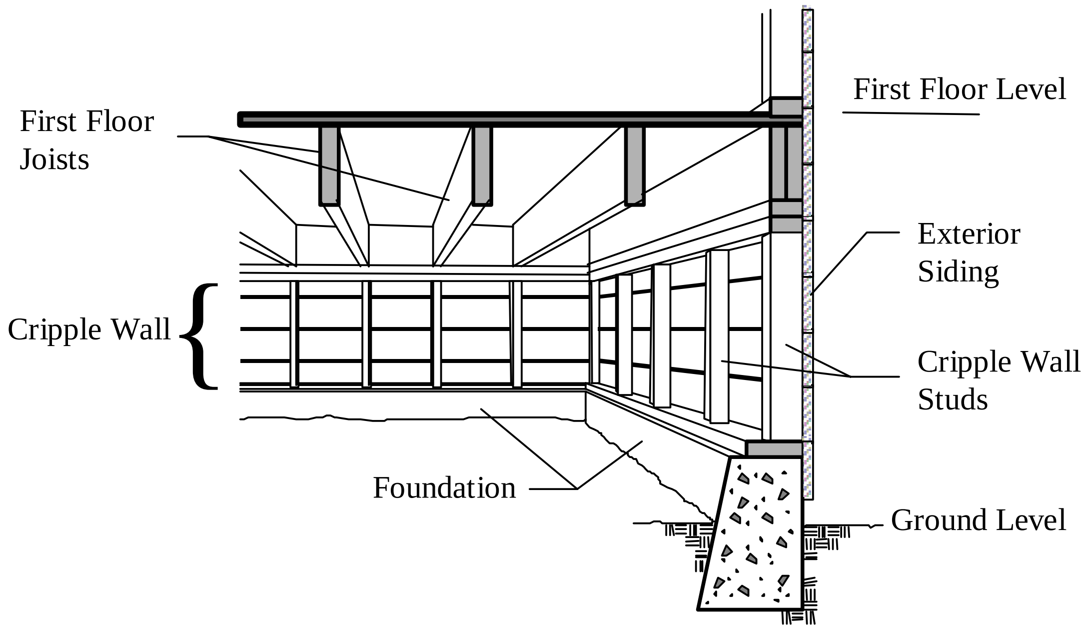


Figure 4. Unbraced cripple wall.

Figure 5. Cripple wall damage in the Northridge earthquake

Figure 6. Damage to a tuck-under parking building in the Northridge earthquake.

III. Rapid Screening Procedure to Evaluate Seismic Performance

The Rapid Screening Procedure (RSP) is intended to be an instrument for non-engineers to approximately evaluate the seismic performance of a building based on visual examination. This visual screening process is based on Applied Technology Council (ATC) guidelines. The final result of the RSP is to generate a Structural Score S which is related to the probability of the building sustaining life-threatening damage in the event of a severe earthquake. A low Structural Score indicates that the building requires additional study by a licensed design professional. A high Structural Score indicates that the building is probably adequate. Since this handbook is based on ATC guidelines set forth in the ATC-21 document, key terms such as Structural Score and Rapid Screening Procedure used in the original document are also used in this handbook.

This method is meant to give a fast and inexpensive measure of the seismic risk of a building and cannot replace a detailed analysis by a design professional based on review of structural drawings, examination of the building structure, and engineering calculations. If a detailed review is indeed performed by a design professional, the Data Collection Form provided in this handbook is designed to provide useful preliminary information.

Rapid Screening Procedure and the Data Collection Form

This section presents an overview of the RSP and contains detailed information on how to fill out the Data Collection Form shown in Figure 7. The result of this survey is a finding as to whether the building in question should or should not be subjected to a more detailed investigation as to its seismic adequacy. This survey is intended to be consistent with ATC guidelines and the following statement from the original document applies:

It should be obvious that no rapid visual examination can provide highly reliable estimates of seismic performance, and the RSP method is simply intended to identify those buildings where reasonable doubts exist. It should be recognized that the RSP is a simple screening procedure and as such is limited. In some cases the RSP may miss buildings that in reality are seismically weak, so that if questions exist in the surveyor's mind regarding a particular building, the surveyor should err on the side of requiring the building to be investigated in further detail.

The ATC-21 document categorizes 12 types of buildings and rates the relative seismic performance of each building type based on past performance. The relative seismic risk is summarized by a Basic Structural Hazard score that reflects the estimated likelihood of a typical building of that category sustaining major damage in the event of a strong earthquake. Major damage is defined by repairs that would cost 60 percent of the building's value. This value of 60 percent was selected because this much damage often results in the building being deemed a total economic loss, and also this is the approximate threshold where life safety (building collapse) begins to become a serious hazard. The Basic Structural Hazard scores for the 12 building types range from 1 to 8.5, where higher values indicate better seismic performance. Because this handbook is concerned with multi-unit residential structures, which are primarily wood framed in San Jose, the Basic Structural Hazard score prescribed by ATC-21 for wood buildings of 6.5 is used. **Note that if the building in question is not predominately wood construction, this handbook does not apply and ATC-21 should be used if the building is to be evaluated.**

In addition to the Basic Structural Hazard score there are significant factors, such as irregularities in the structural system, deterioration of the structural materials (e.g. dryrot in wood framing), and adverse soil conditions that can negatively affect a building's seismic performance. In order to account for these factors a series of Performance Modification Factors (PMFs) have been determined, which when subtracted from the Basic Structural Hazard score, result in the final Structural Score S for the building being surveyed. These PMFs are described in detail later in this section.

As mentioned previously, the Structural Score is an approximate measure of the adequacy of the building. A high Structural Score is good, and a low score indicates the possibility of poor seismic performance, and that the building should be

Address ______________________________________

______________________________ Zip Code __________

Number of Stories __________________ Year Built __________

Inspector ______________________ Date ______________

Total Floor Area (square feet) ____________

Photo

Structural Score and Modifiers

Basic Score	**6.5**
Pre 1990	-2.0
Tuck Under Parking (choose one)	
Wood Parking Level	-2.5
Concrete or Block Masonry Parking Level	-1.5
Unbraced Cripple Wall	-2.5
Plan Irregularity	-1.0
Poor Condition	-0.5
Soil Condition (from ABAG maps)	
MMI VIII	-0.3
MMI IX	-0.6
MMI X	-0.9

Final Structural Score:

NOTE: Detailed evaluation recommended for Final Scores of 2 or less

Sketch

Comments

Figure 7. Data Collection Form.

reviewed in detail by a licensed design professional. By the ATC-21 guidelines, a Structural Score of 2 or less indicates that the building may not meet modern seismic criteria and the building should be investigated further.

The remainder of this chapter is devoted to explaining each element of the data collection form. Detailed information is provided for each PMF and general instructions for filling out the form are given.

Survey Tools

The survey is designed to be simple with few tools needed to conduct the survey. The following is a list of items that may be needed in performing the survey as described in this handbook.

- Pen or pencil
- Clipboard for holding the survey form
- Camera, preferably instant (e.g., Polaroid)
- Tape to affix photo
- Straight edge to aid in sketching
- Copy of handbook

Building Age and Structural Information

Before performing the survey, as much information about the building should be gathered as possible. A very important piece of information is the age of the building. Obviously, the more information that can be gathered regarding the building, the more confidence the person conducting the survey has in the Structural Score. In addition, if the building is deemed to require further review by a design professional, any drawings or design information will aid in this review. The building owner's own files containing drawings and specifications are the most useful source of information. If the owner's files are incomplete, the following resources may provide information:

Assessor's files: Assessor's files usually contain information about ownership, the assessed value of the land, and improvements made. Useful information such as the age of the building, the square footage, and the number of stories can sometimes be found from assessor's files.

Building Department files: Building department files can vary greatly and can, in some cases, provide a great deal of information. In general, files (or microfilm) may contain permits, plans, and structural calculations required by the city for a building permit. It should be noted that building department files may have gaps or are discarded periodically and thus information for older buildings may be difficult to find.

Previous Studies: In some cases, buildings may have been a part of a previous building inventory or similar study. In these cases, useful building information may be contained in the study.

Information on Soil Condition

Because soil conditions can greatly affect the seismic performance of a building and due to the fact that soil information cannot be determined visually, collecting soil information should be one of the tasks performed prior to conducting the survey of the building. Fortunately, shaking intensity maps are available for the San Jose area neighborhoods from the Association of Bay Area Governments (ABAG). Figure 8 is an example of a shaking intensity map for Northeast San Jose due to a 7.0 Richter magnitude earthquake on the Southern Hayward Fault. Shaking intensity is measured by the Modified Mercalli Index (MMI) which measures damage intensity. The shaking intensity in the neighborhood that the building lies in can be found from these ABAG maps and the appropriate PMF can be found from the table below:

Shaking Intensity	PMF
MMI VII or below	0.0
MMI VIII	-0.3
MMI IX	-0.6
MMI X	-0.9

Shaking intensity maps for several faults are available, but the faults that are most critical for San Jose are the Southern Hayward, Hayward, Northern Calaveras, and San Andreas Faults. The shaking intensity maps can be purchased from ABAG at the following address:

Association of Bay Area Governments (ABAG)
P.O. Box 2050
Oakland, CA 94604
Tel: (510) 464-7900

Or can be downloaded free from the ABAG website at:

http://www.abag.ca.gov.

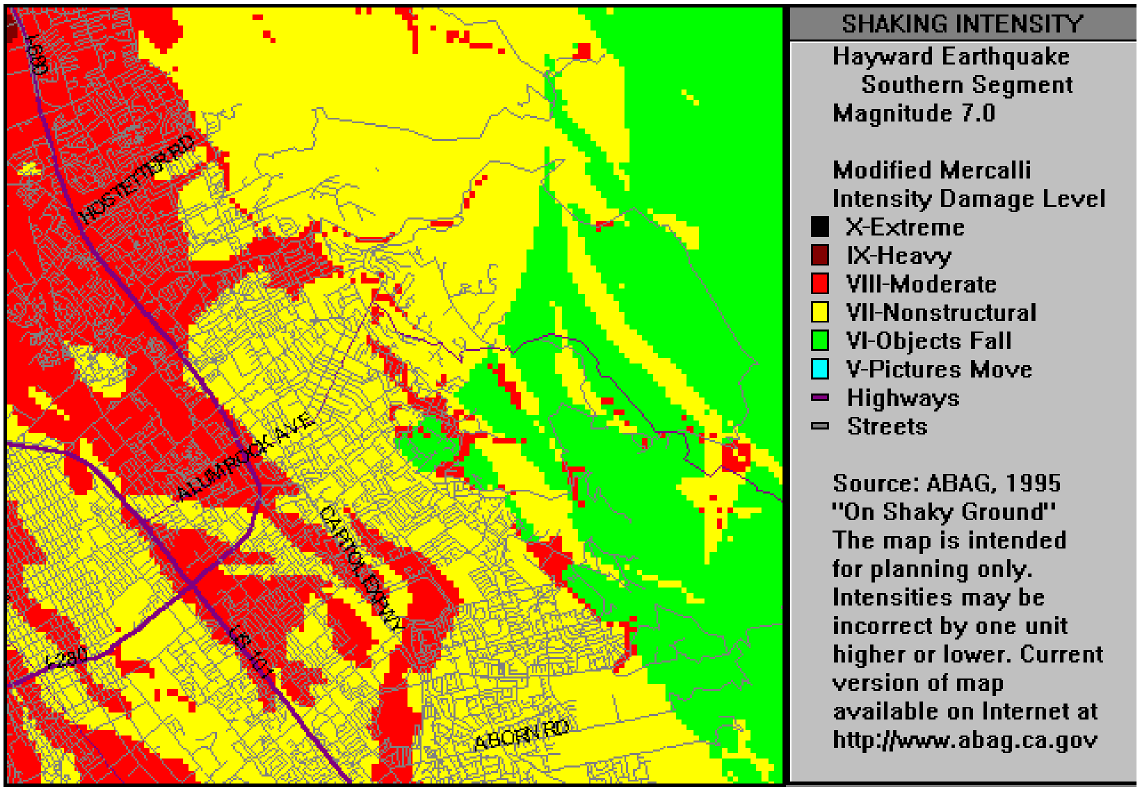


Figure 8. Shaking intensity map for Northeast San Jose from ABAG.

Filling Out the Data Collection Form

The following sections outline how to fill out the Data Collection Form section-by-section.

Basic Building Information

The person conducting the survey should include all of the information in this section (located in the upper left-hand corner of the Data Collection Form) which includes the address, number of stories, year built, approximate total floor area (in square feet), date of the survey, and the name of the inspector.

Photo

In order to provide a visual reference to the building and its surroundings, space is provided to affix a photo of the building on the Data Collection Form.

Sketch

Space is provided on the form for a sketch of the building which should include some approximate dimensions for the building.

Basic Structural Hazard Score

As mentioned in the preceding section, the basic structural score for a multi-unit wood frame buildings is 6.5. This value is based on guidelines set forth by the ATC-21. This basic score can be modified depending on factors such as year of construction, soil conditions, building configurations that have been known to affect the seismic performance of buildings. The following sections describe the factors that modify the Basic Structural Hazard Score.

Performance Modification Factors (PMFs) to the Basic Structural Hazard Score

All of the possible PMFs are listed on the Data Collection Form. Once the appropriate PMFs for the building are found they should be circled by the inspector on the Data Collection Form.

Building Constructed Prior to 1990 (PMF: –2.0)

The benchmark year for multi-unit timber construction in San Jose is 1990. Buildings built prior to this date may have seismic resisting elements that have proven to be inadequate in recent earthquakes. The justification for 1990 as the benchmark year lies in the fact that as a result of post-earthquake evaluation of structures and research, earthquake design loads have increased and allowable capacities for poorly performing materials, like stucco and gypsum wallboard, have been reduced. Significant changes in the 1976 and 1988 editions of the Uniform Building

Code (UBC) have had the effect of increasing the use of plywood shear walls in timber construction. The 1988 UBC was not fully adopted in San Jose until 1990, and so prior to 1990 the use of timber walls sheathed with gypsum wallboard, gypsum lath and plaster, and stucco for shear walls was common. Walls sheathed with these materials have performed poorly in earthquakes compared to walls sheathed with structural grade plywood.

Tuck-Under Parking

Tuck-under parking is a common term given to multi-story structures whose first level consists of parking spaces located directly below the upper level residential units. An approximate guideline is a building whose first story consists of greater than 40% open parking area, can be characterized as a tuck-under parking building.

Wood Parking Level (PMF: -2.5)

Figure 9 represents a generic tuck-under parking building typical of those that can be found in San Jose. The construction is primarily of wood with steel beams or posts sometimes visible at the ground floor parking level. Note that the upper floors are entirely comprised of residential units while the parking level is comprised of 40% to 60% open parking area. Note that Figure 9 is meant as an illustrative guideline, and that many other possible configurations are possible.

Concrete or Block Masonry Parking Level (PMF: -1.5)

Figure 10 shows another tuck-under parking configuration that may be found in San Jose where the parking level is built from concrete or concrete block masonry. As shown in the figure, the parking level is usually below the street level with two or three levels of wood constructed residential units above. This configuration usually performs better than the previously mentioned all timber construction, but is still vulnerable to damage, particularly if the concrete is in poor condition.

Unbraced Cripple Wall (PMF: -2.5)

In order to identify if cripple walls are adequately braced, the inspector needs to go into the crawlspace of the building and look for plywood panels sheathing the interior of the cripple walls. If no plywood sheathing is present (see Figure 3) the cripple walls are not adequately braced.

Plan Irregularity (PMF: -1.0)

Seismic weaknesses can be exacerbated by building configurations that are irregular in that they contain significant projections from the main building. Buildings that are “L”, “T”, “U”, or “E” shaped in their plan shape can incur additional damage at the sharp re-entrant corners. If the length of any projection is greater than 15 percent of the plan dimension in the given direction, the structure can be considered to have a plan irregularity. Figure 11 illustrates this criterion for plan irregularity and the location of vulnerable areas for several irregular configurations. For example, for the “L” shaped building in Figure 11: if L = 150 ft then the projection would classify as a plan irregularity if it were longer than 0.15*(150 ft) = 22.5 ft.

Poor Condition (PMF: -0.5)

The effect of poor condition or maintenance on seismic behavior is difficult to quantify. Poor condition affects the seismic behavior when it results in building materials that are weaker than those originally called for in the structural design. Examples of poor condition include the following:

- Excessive or uneven ground settlement, usually detected by cracking on the exterior of the building;
- Main member rotting due to water damage (dryrot), pest damage (e.g. termite), or rusting of metal connectors (bolts, nails).
- Concrete surfaces that exhibit rust stains and/or exposed steel reinforcement.

Soil Condition (PMF: 0.0 to –0.9)

Soil conditions can greatly affect earthquake ground motion intensity. For this reason the RSP includes a PMF for soil type based on Modified Mercalli Index shaking intensity. The shaking intensity in the neighborhood that the building lies in can be found from the ABAG maps mentioned previously, and the appropriate PMF can be found.

Structural Score

The final Structural Score is obtained by subtracting all of the PMFs that apply to the building from the Basic Structural Hazard score. The Structural Score should be recorded it in the space provided on the Data Collection Form. Note that final scores of 2 or less indicate that further detailed evaluation of the building is recommended.

Comments

Space is provided for the inspector to write any additional information that may be valuable in assessing the seismic performance of the building. If the inspector is uncertain of any PMFs used or in data collection (such as the age of the building) an explanation of the uncertainty may be noted here.

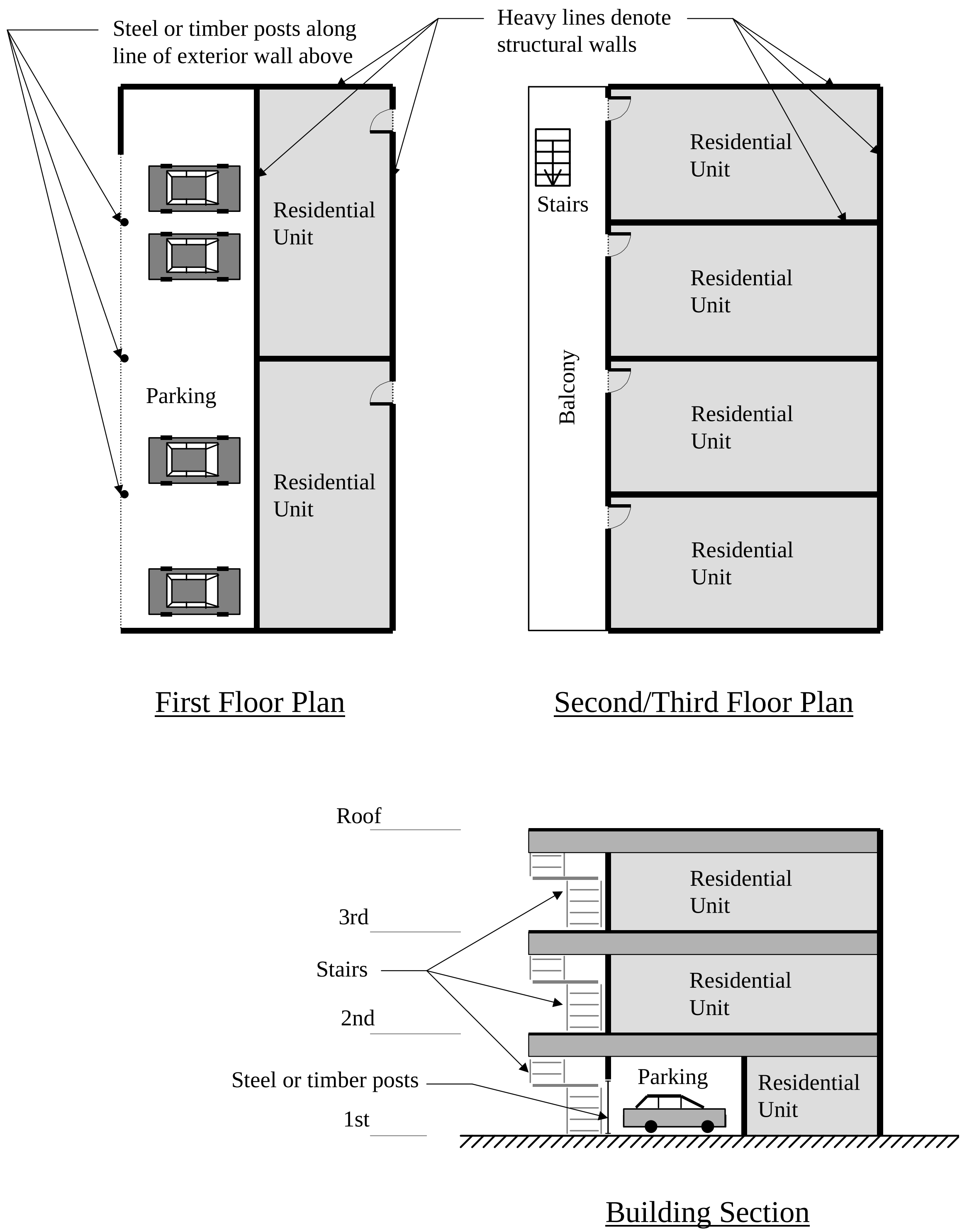


Figure 9. Generic tuck-under parking building.

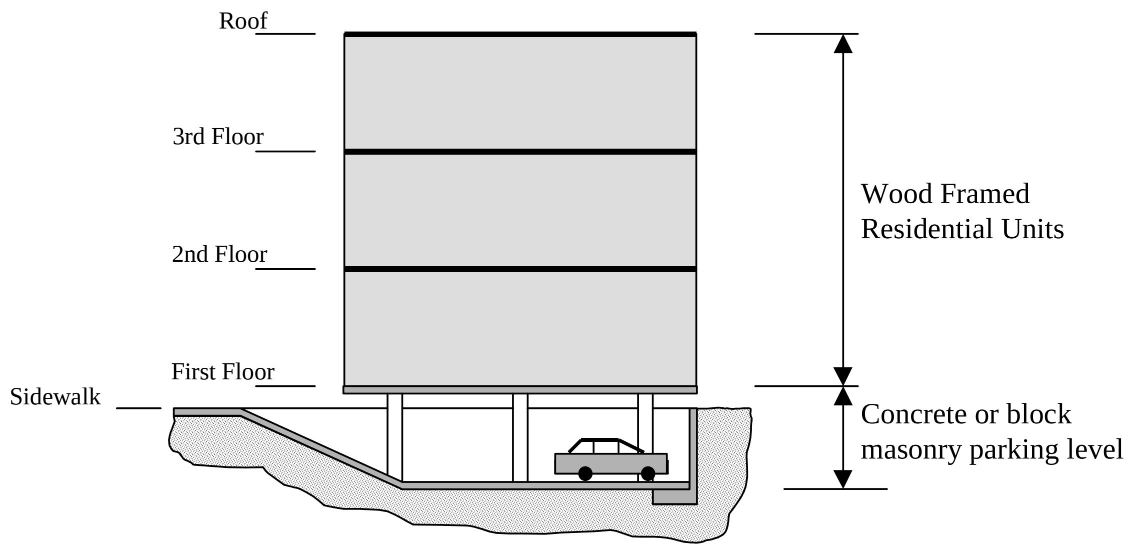


Figure 10. Tuck-under parking building with concrete parking level.

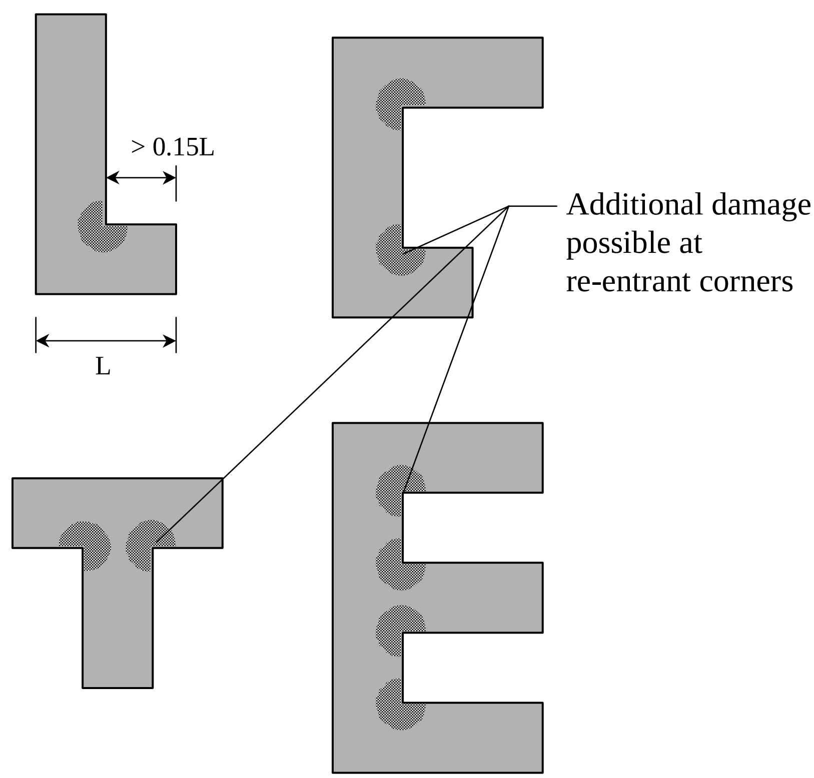


Figure 11. Examples of buildings with plan irregularities.

Interpretation of Structural Scores

Once the survey has been performed, the natural question that arises is what does this score mean. As previously mentioned, the structural score is linked to the likelihood of the building sustaining major life-threatening damage given the occurrence of an earthquake that is reasonable to expect in that community.

The question of what constitutes an acceptable seismic score still remains. In many ways it is up to the community to weigh the cost of safety versus the benefits. The City of San Jose has taken the approach that the identification of potentially hazardous buildings and the mitigation of their hazards will not only save lives and prevent injuries to the residents of the community, but will minimize economic losses and disruption to the daily lives of the people in the community. The “cut-off” value of 2 used by the City of San Jose in this handbook is based on the value recommended by ATC-21.

IV. Example RSP Evaluation of a Building

In order to illustrate the RSP and how to fill out the Data Collection Form, the following example is presented. A photo of the example building is shown in Figure 12 and the completed Data Collection Form for this building is shown in Figure 13.

Pre Field Data Collection

The age of the building is a very important factor that determines the standard as to which the building is designed. From review of the owners records, it is determined that this building was constructed in 1968. Also, from the ABAG maps, the building lies in a neighborhood that has a maximum shaking intensity of VIII on the Modified Mercalli Index.

Rapid Screening Procedure (RSP)

From a visual inspection, the owner determines that:

- This building is predominantly wood framed;
- The first floor is over 40% open parking area;
- The building is regular in its plan dimension (rectangular);
- There are no signs of dryrot or faulty construction.

In addition, the owner has sketched the plan and elevation view of the building including approximate dimensions.

From the visual survey and data collection, the PMFs that apply to this building are circled on the Data Collection Form. The circled PMFs as indicated on Figure 13 are:

- Building Constructed prior to 1990 (PMF: –2.0);
- Tuck-Under Parking, wood framed parking level (PMF: –2.5);
- Shaking Intensity of MMI VIII (PMF: –0.3).

Thus, the Final Structural Score is calculated by subtracting the PMFs from the Basic Hazard Score:

6.5 –2.0 –2.5 –0.3 = **1.7**

The Final Structural Score of 1.7 is less than 2.0 and it is noted in the comment section that for this building a detailed evaluation by a design professional is recommended.

Figure 12. Photo of building for RSP example.

City of San Jose Multiunit Residential Building
Seismic Hazard Checklist

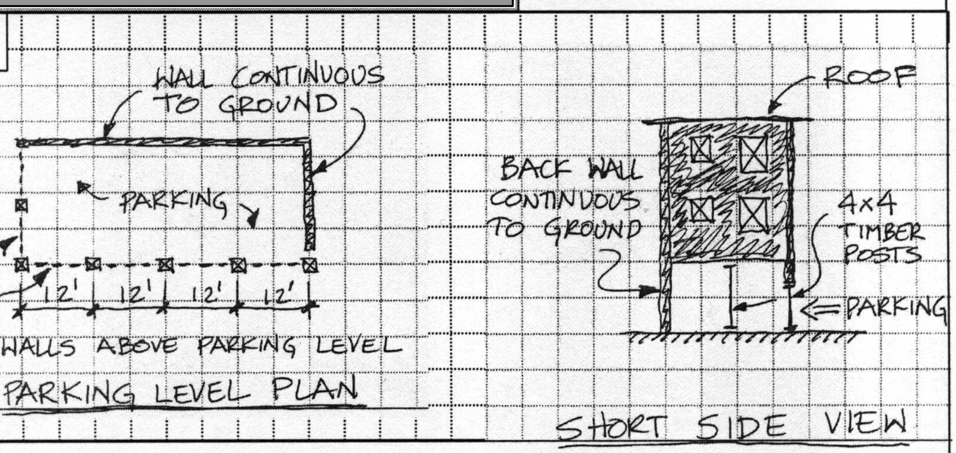
Address 525 MEADOW AVE.
OURTOWN Zip Code 98888
Number of Stories 3 Year Built 1968
Inspector S. VUKAZICH Date 11/11/97
Total Floor Area (square feet) 1920

Structural Score and Modifiers

Basic Score	**6.5**
Pre 1990	(-2.0)
Tuck Under Parking (choose one)	
Wood Parking Level	(-2.5)
Concrete or Block Masonry Parking Level	-1.5
Unbraced Cripple Wall	-2.5
Plan Irregularity	-1.0
Poor Condition	-0.5
Soil Condition (from ABAG maps)	
MMI VIII	(-0.3)
MMI IX	-0.6
MMI X	-0.9
Final Structural Score:	1.7

NOTE: Detailed evaluation recommended for Final Scores of 2 or less

Sketch



Comments

FINAL SCORE => 1.7 < 2
DETAILED EVALUATION IS RECOMMENDED

Figure 13. Example of completed Data Collection Form.

V. Retrofit Strategies and Costs

This section outlines retrofit strategies for buildings that have seismic weaknesses that can be identified by the RSP. It should be noted that it is usually not economically possible to bring existing structures to a performance level equal to that of new construction. However it is almost always possible to greatly improve the seismic performance of older buildings by means of seismic retrofit. The following case study is a good example of the economic effectiveness of retrofitting a tuck-under parking building.

Case Study: Friday Apartments in Sylmar California

One case study that can be used to base retrofit strategies on is the Friday Apartments, a 200-unit apartment complex located in Sylmar California. The complex consists of several buildings with two stories of wood residential units above first floor tuck-under parking. The complex was built in 1964 and was damaged in the 1971 San Fernando earthquake. The damage was mostly confined to the tuck-under parking units which deformed excessively with some of the units permanently shifted more than three inches out of plumb. The reason for the damage can be attributed to the use of stucco and gypsum board shearwalls in the first story parking level. The damage resulted in the entire complex being shut down for one year for necessary repairs and retrofitting. In 1971, the following repairs were made:

- The permanently deformed buildings were jacked up and moved back over their original foundations;
- Plywood was added to all first story walls;
- New 5/8-inch diameter anchor bolts were added to anchor the new first floor plywood shearwalls.

The cost of the aforementioned repairs and retrofitting was $3,500,000 in 1995 dollars. The retrofitted complex was subjected to almost identical ground motions in the 1994 Northridge earthquake and was "green-tagged" and fully functional after the earthquake. The cost of all needed repairs after the Northridge earthquake and complete painting of the exterior of the building was performed at a cost of $100,000. Thus, seismic retrofitting of multi-unit tuck-under parking buildings can be effective from both a life safety and financial perspective.

Retrofit Strategy for Tuck-Under Parking Buildings

In order to retrofit a tuck-under parking building to performance levels near that of modern construction, significant work must be performed throughout the building. This "full" seismic retrofit would probably result in significant portions of the building being shut down, tenants being temporarily displaced, and loss of some of the first floor parking spaces. Because this full seismic retrofit is not economically practical, the City of San Jose is proposing a "life-safety" retrofit designed to concentrate on retrofitting the obviously vulnerable first story parking level first, and then to develop a long-range program to determine if strengthening in the upper stories is needed. The reason for this strategy is twofold; first the parking level has shown to be the most vulnerable, and secondly the first level can be retrofitted with minimal disruption and displacement of the tenants.

The performance objective for the life safety retrofit is to prevent a catastrophic collapse that can endanger the lives of the tenants. This retrofit probably cannot control excessive deflection at the parking level and thus significant structural damage may still occur in the case of a moderate earthquake, but building performance will be improved.

The life safety retrofit procedure for a typical tuck-under parking building is illustrated in Figure 14. The recommended steps are as follows:

- Remove all existing first story wall coverings and sheath the walls with structural plywood and add special shearwall hardware;
- Add a rigid steel frame to control deflection at the entrance to the parking area;
- Replace any framing members that are damaged or deteriorated;
- Check existing foundations.

It should be noted that every building will have a different set of circumstances and requirements. Thus, it is very difficult to determine exactly what measures will be needed for an individual building. Figure 14 is meant as a guide to give building owners an idea of what type of strengthening is typically required.

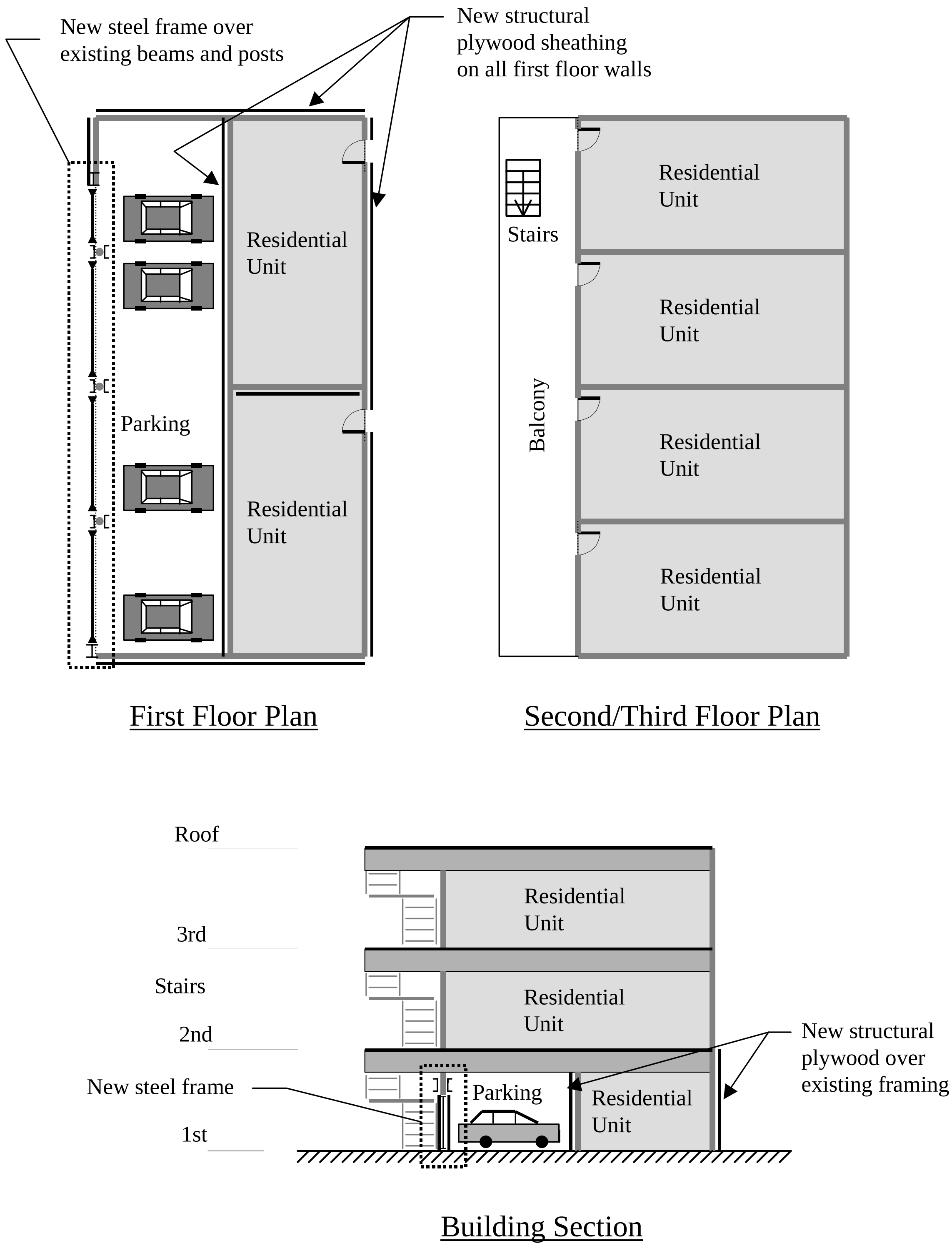


Figure 14. Life Safety retrofit strategy for a tuck-under parking building.

Approximate Cost of Retrofitting a Tuck-Under Parking Building

Table 1 represents approximate costs of retrofitting a generic tuck-under parking building to a life safety performance level and can be used as an approximate guideline. Note that actual costs can only be determined after a detailed analysis by a design professional and contractor. Also, circumstances like foundation replacement, ease of access, and replacement of damaged or deteriorated framing can add significant cost. The following cost analysis is based on a 25-unit complex with two stories above a first floor tuck under parking level. The total area of the living units is 17,360 square feet.

Table 1. Cost analysis for life safety retrofit of a 25-unit tuck-under parking building

Demolition	$5,746.00
Steel Frame	$26,500.00
Carpentry	$10,608.00
Finishes	$14,495.00
Subtotal	**$57,349.00**
General Conditions (12%)	$6,881.88
Overhead and Fee (15%)	$9,634.63
Contingency (5%)	$3,693.28
Total Cost	**$77,558.79**
Cost per square foot	**$4.47**
Cost per apartment unit	**$3,100.00**

The costs are based on 1995 dollars, and represent costs for one particular configuration. Note that this cost analysis does not include system improvements (mechanical, electrical, plumbing, fire), disabled access improvements, hazardous material removal, or architectural improvements.

The preceding cost analysis presented can be used as a guideline but the reality is that it is difficult to predict costs for multi-unit retrofits because there are very few examples to draw from. A realistic range for unit costs for tuck-under parking life safety retrofitting is $4 to $10 per square foot. Full seismic retrofitting is considerably more expensive, with unit costs in the range of $10 to $18 per square foot, not including possible additional costs due to loss of rent and tenant relocation.

Retrofit Strategy for Buildings with Unbraced Cripple Walls

Unbraced cripple walls are primarily a problem in single family homes, but there exist some multi-unit buildings in San Jose that have unbraced cripple walls. Buildings with unbraced cripple walls have a history of poor performance in many earthquakes with the building literally falling off of its foundation. Cripple walls are weak due to the inadequacy of exterior sheathing and stucco as bracing materials. Retrofit of unbraced cripple walls is a relatively simple procedure that involves installing structural grade

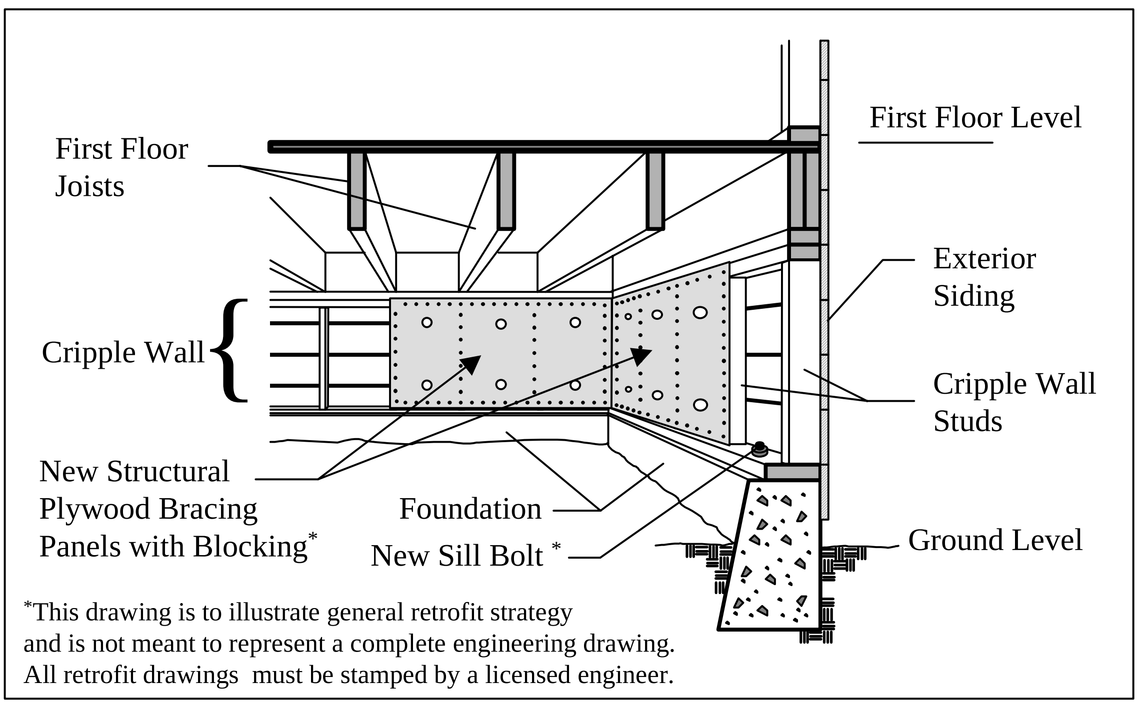


Figure 15. Retrofit strategy for an unbraced cripple wall building.

plywood bracing panels and connection hardware to the existing cripple wall studs. Figure 15 is a view from the crawlspace of a building with retrofitted cripple walls.

Because unbraced cripple wall retrofitting has been a recommended and relatively inexpensive procedure to perform, many buildings have been retrofitted in the Los Angeles area prior to the Northridge earthquake. There are well documented cases of retrofitted buildings performing very well in the Northridge earthquake in areas where unretrofitted buildings with similar construction sustained significant damage.

The recommended retrofit procedure for an unbraced cripple wall building is as follows:

- Check adequacy of existing foundation;
- Replace all damaged or deteriorated wood framing;
- Adequately bolt sill plate to the foundation;
- Provide structural grade plywood bracing panels on existing interior cripple wall studs;
- Install hardware to ensure positive attachment of the panels to the first floor level.

Note that the specific design for your building must be created by a design professional. Work must be completed by a licensed contractor under a City of San Jose building permit.

Approximate Cost of Retrofitting an Unbraced Cripple Wall Building

As previously mentioned, many retrofits of unbraced cripple wall buildings have been performed and the costs are well documented. One of the most important factors in the cost of retrofitting is the access and clearance available in the crawlspace work area. Crawl spaces of 10–18 inches in height can be considered difficult, 19-36 inches may be considered reasonable access, while crawlspaces with more than 36 inches of clearance can be considered excellent. In addition, if the work area is cluttered with plumbing, wiring, and ductwork will create extra work to relocate and/or work around them.

An unbraced cripple wall retrofit with a sound concrete foundation will have a unit cost in the range of $1.00 to $1.50 per square foot (based on total square footage of the building). A retrofit with a brick or unsound foundation that needs to be replaced with a new concrete foundation will have a unit cost in the range of $3.50 to $5.00 per square foot. Note that if the work area is cluttered or if less than reasonable access to the crawlspace is available, the aforementioned costs will increase between 20-50 percent.

VI. Should You Retrofit Your Building?

Obviously, the City of San Jose would like you to answer “yes” to this question if retrofit is recommended by a qualified design professional. Every building owner will have a different perspective as to whether the potential loss of income and perhaps human life in a future earthquake will justify the cost of seismic retrofit. Retrofitting programs for residential buildings are voluntary in nature and rely on building owners making educated choices as to what is best for them, their tenants, and the community. Currently, the City of San Jose is investigating the possibility of incentives that will help building owners offset the cost of retrofitting. Resources, such as tax credits and low interest loans, may already be available for some owners.

The damage and death that occurred in Northridge and other earthquakes has been well documented in the media and renters are choosing to avoid living in buildings that they perceive as unsafe. If you are reading this handbook, it means that you are concerned with the seismic safety of your building and the well being of your tenants. Hopefully, this handbook has provided information that will aid you in evaluating the seismic performance of your building.

One final thought: earthquakes in California are inevitable, earthquake damage and loss of life is not.

VII. Resources

Sources of Additional Information

Association of Bay Area Governments (ABAG)
P.O. Box 2050
Oakland, CA 94604
(510) 464-7900
http://www.abag.ca.gov

Board of Registration, Professional Engineers and Land Surveyors
2535 Capitol Oaks Drive Suite 300
Sacramento, CA 95833
(916) 263-2222

Structural Engineers Association of Northern California (SEAONC)
74 New Montgomery St., Suite 230
San Francisco, CA 94105-2411
(415) 974-5147
seaonc@ix.netcom.com

Contractors’ State License Board
P.O. Box 26000
Sacramento, CA 95826
(916) 255-3900

Permit Information

For information about obtaining seismic retrofit construction permits in the City of San Jose, contact Ben Yousefi at (408) 277-5651.

Ordering Information

Copies of this handbook are available from the City of San Jose Office of Emergency Services. To order, call (408) 277-4595.

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Photo Credits

Figure 3 and Cover: Karl Steinbrugge. 1971.

Figures 5 and 6: City of Los Angeles Department of Building and Safety. 1994.

Figure 12: James Russell. 1994.