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Santa Clara County Soft First Story Multi Unit Building Survey

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Conducting a Soft First-Story Multifamily Dwelling Survey: An Example Using Santa Clara County, California

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The objective of this survey was to provide data to emergency managers in Santa Clara County on the number of soft first-story multifamily dwellings (MFD) located in their communities using a cost-effective town-gown partnership. Target areas of cities were found by identifying areas containing residential units of two or more stories that had four or more living units. The survey found that 2,630, or 36%, of the 7,391 MFD in Santa Clara County are of the soft first-story construction type. It was found that one out of every nine apartment units in Santa Clara County is located in a soft first-story building. It is estimated that approximately 83,000 persons could be affected in the event of a severe earthquake. Emergency managers were given maps indicating areas of high-, medium-, and low-volume clusters of soft first-story MFD in each city. Follow-up interviews found that the communities that contain 67% of the identified soft-story MFD are using the survey information in their post-earthquake planning. [DOI: 10.1193/1.2359004]

INTRODUCTION

Seismic events such as the Loma Prieta, Northridge, and Hanshin-Awaji (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. Woodframe apartment buildings, particularly those with first-story tuck-under parking, have been found to be vulnerable to earthquake damage. City and county officials in Santa Clara County have been concerned about these types of buildings for the following reasons:

- A major earthquake is likely to occur in Santa Clara County, which 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.
- Apartment buildings constructed similarly to those that collapsed in recent earthquakes can be found in Santa Clara County. There were 2,700 multifamily dwellings (30,000 living units) that were vacated or had significant structural damage

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due to the Northridge earthquake (Comerio 1995). Because of similarities in the housing stock, it is reasonable to expect similar damage in Santa Clara County.

- Most residents of these apartment buildings in Northridge had to be provided for in mass care shelters, with some remaining for as long as six months (Comerio 1995).

In order to reduce the risk to human life and property, and also be able to prepare adequate response measures, there is a need to better identify the localities where vulnerable buildings are located and the number of residents involved. To address this need, the Users' Group of the Collaborative for Disaster Mitigation (CDM) at San Jose State University (SJSU) proposed a survey of soft first-story multifamily dwellings in Santa Clara County. The survey was partially funded by the Santa Clara County Emergency Preparedness Council.

UNDERSTANDING EARTHQUAKE BEHAVIOR OF LOW-RISE BUILDINGS

The multi-unit residential buildings in Santa Clara County 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 and some insight into the motivation for performing the survey.

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 transmitted to the foundation by specially designed walls called shear walls. The seismic forces are carried by the floors and roof to the shear walls. Floor and roof framing specially designed to carry seismic loads to the walls is known as a diaphragm to structural engineers. The diaphragms and shear walls act together to carry the seismic load to the foundation. This particular type of system carries lateral loads in the same way a box resists collapse, and so 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 shear walls must be sufficiently strong and stiff 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 shear walls is to sheathe them with structural grade plywood that is securely nailed to the wood framing. One of the primary reasons that older multi-unit buildings have performed poorly in past earthquakes is that shear walls have been sheathed with inadequate materials such as gypsum wallboard or stucco instead of plywood.

Another concept that is important in understanding the behavior of buildings during 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 that separate rooms and individual units, the upper levels of multi-unit construction tend to be rela-

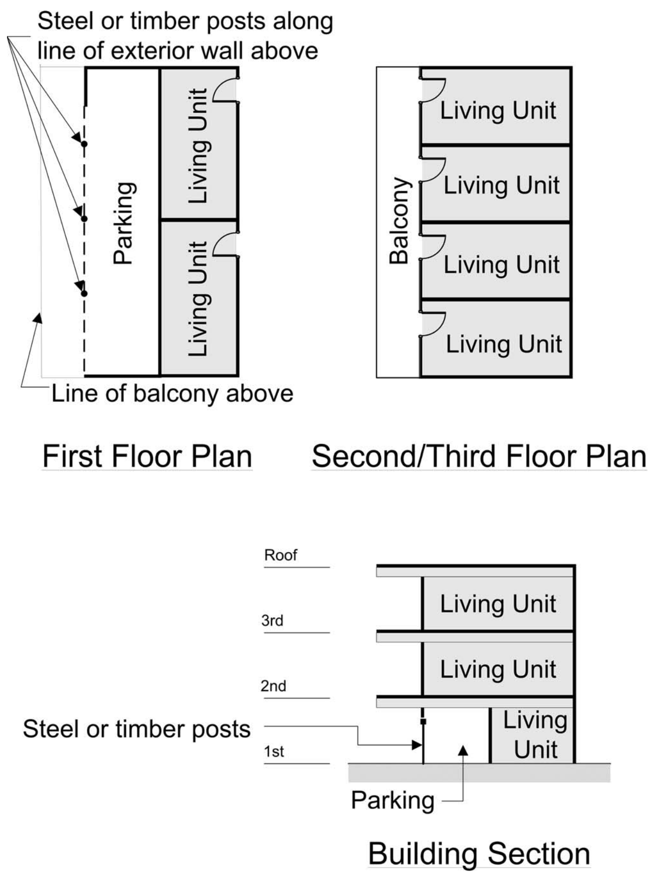


Figure 1. Example of soft-story multifamily dwelling construction with tuck-under parking.

tively rigid. A first-floor parking area, commonly called tuck-under parking, creates a first floor that has fewer walls and thus is much softer (less rigid) than the levels above. The floor plans and elevation of a typical soft-story multifamily dwelling, illustrating the differences in rigidity between the first level that contains parking and the upper levels, is shown in Figure 1. An analogy would be to compare the strength and rigidity of a cardboard box that has a grid of cardboard partitions inserted to carry bottles, which would represent the construction of the upper stories containing living units and partition walls, to the rigidity of the same box that has no internal partitions and has one of its four sides removed, which would represent the open construction of the lower level with tuck-under parking. Figure 2 is a photo of a typical soft-story multifamily dwelling with tuck-under parking. It should be noted that although this work is concerned with vulnerability due to soft-story irregularity, buildings may be vulnerable due to other irregularities such as "weak" stories and "plan" irregularities. These irregularities are described in detail in many building codes and references, e.g., the SEAOC Blue Book (SEAOC 1999).

Figure 2. Photo of a typical soft-story multifamily dwelling (MFD) showing the open parking level and upper levels that are more rigid due to the partition walls in the living units. (Photo by I. Syed)

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. However, performance of similar structures in past earthquakes is a very good indication of future performance. Nearly all of the residential buildings in California have been designed according to guidelines based on those set forth by the *Uniform Building Code* (*UBC*), which is revised every three years. As an example of expected performance, according to the 1999 SEAOC Blue Book, a residential building designed to the 1994 *UBC* standards should be able to resist the following:

- a minor-level earthquake without damage;
- a moderate-level earthquake with architectural damage and potentially light structural damage; and
- a major earthquake without collapse or endangerment of life safety but with potentially severe structural damage. It is expected that most structures would be repairable.

The performance objectives for residential buildings have not changed dramatically over the last half century, but the ability of buildings of different construction types to achieve these objectives has evolved and improved with the evolution of building codes and the practice of earthquake engineering. Due to the evolution of building codes, there will always be older structures that will not be able to achieve the expected seismic performance of structures more recently constructed. Wood buildings with tuck-under parking and buildings with short first-story walls (often called cripple walls), or other shear walls that are not adequately sheathed with plywood, have 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 MULTI-UNIT 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, four types of wood building construction have proven to be vulnerable to earthquakes:

1. buildings with unbraced cripple walls;
2. buildings that contain shear walls constructed from timber studs sheathed with stucco or gypsum board;
3. buildings with "soft" first stories (usually due to tuck-under parking areas); and
4. hillside homes inadequately supported on steep foundations.

Stucco and gypsum board shear walls coupled with tuck-under parking are present in many woodframe 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 shear walls and to increase the seismic load by 40 percent. The direct result was the increased use of plywood shear walls in wood construction, and while tuck-under parking was not eliminated, it was discouraged (EERI 1996). All of the damaged multi-unit buildings inspected after the Northridge earthquake had failed stucco or gypsum board shear walls. The performance of these weak shear walls was often made worse by sloppy construction and poor quality control (SEAOSC 1994).

As previously mentioned, multistory wood apartment or condominium buildings with open first-story parking and upper stories containing many partition 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 (EERI 1996). The mode of collapse generally followed the pattern of the open first-story parking level collapsing with the more rigid upper stories riding down remaining almost completely intact. The soft first story is often comprised of exterior shear walls on three sides with flimsy steel or timber posts on the fourth side, as was previously described and illustrated in Figures 1 and 2. These posts are inadequate to resist seismic forces or provide adequate stiffness to prevent the large deformation due to transverse displacement and rotation of the "soft" story that is likely to occur during a major earthquake. Figure 3 shows a tuck-under parking building that collapsed during the Northridge earthquake and illustrates the previously mentioned mode of collapse. The soft tuck-under parking area of the building pictured on the left of Figure 3 has collapsed while the tuck-under parking area of the building on the right is severely damaged due to the large relative deformation. Both of the buildings shown in Figure 3 were of nearly identical construction prior to the earthquake. Note that the upper stories of the collapsed building have remained almost completely intact and, at first glance, appear to resemble an undamaged two-story building. Figure 3 illustrates the inherent weakness of the tuck-under parking configuration and the dangers to human life and property. In addition, this type of collapse can be difficult

Figure 3. Damage to two tuck-under parking buildings in the 1994 Northridge earthquake. (Photo by G. S. Selvaduray)

to identify in post-earthquake reconnaissance surveys due to the upper levels exhibiting very little exterior damage after collapse. There are several accounts from the Northridge earthquake in which immediate post-earthquake reconnaissance surveys failed to identify collapsed tuck-under parking buildings, like the one shown in Figure 3, as damaged (Garrat 2002).

OVERVIEW OF THE SURVEY

The survey focused on developing an inventory of multifamily dwellings so that areas of cities that have potential soft-story buildings could be identified, as could the number of such buildings in those areas. The CDM Users' Group and the Santa Clara County Emergence Managers Association wanted the survey to contain data that was compatible with, and suitable for input into, currently available risk assessment software programs like HAZUS (NIBS 1997).

There was considerable discussion regarding the format of the output. It was agreed at the outset that each city would be provided with the information pertaining to that particular city. Due to the legal concerns involved in identifying individual properties, it was decided that maps identifying areas where there were clusters of soft first-story buildings would be produced for each city in Santa Clara County. Maps were produced for San Jose, Mountain View, Palo Alto, Los Gatos, Santa Clara, Morgan Hill, Gilroy, Milpitas, Monte Sereno, Cupertino, Saratoga, Campbell, Los Altos, and Sunnyvale. It was decided that the clusters would be identified as high, medium, and low. "High" represented a cluster of more than 30 buildings, "medium" represented a cluster of 10–29 buildings, and "low" a cluster of 1–10 buildings. Street addresses and GPS readings were recorded for each building surveyed, but this information was not released.

The main priority of the survey was to identify all multi-unit residential buildings in Santa Clara County that were thought to be vulnerable by virtue of being a soft first-story building. All multifamily dwellings were inspected and those with soft first stories identified. Visual details of each building were recorded, including photographs of the buildings and their key features. It should be noted that differences in the "extent of vulnerability" among the soft first-story buildings were not addressed. Such an effort requires more detailed engineering analysis and was beyond the scope of this project.

The survey was initiated by using the MetroScan® database (developed by Transamerica Intellitech for real estate professionals) to identify buildings with four or more living units that were two or more stories in height and built before 1990, in each city. Target areas of each city were identified by the MetroScan® search, then HomeProfile®, another software program used by the real estate industry, was used to find exact street addresses for the buildings. Trained student surveyors were then sent to the targeted areas to collect data which included Global Positioning System (GPS) data. The decision to consider multifamily dwellings as buildings with four or more living units was based on the definition of a "home," from the Homeowner's Guide to Earthquake Safety, as being single family residences, duplexes, triplexes, and fourplexes (Calif. Seismic Safety Comm. 2005).

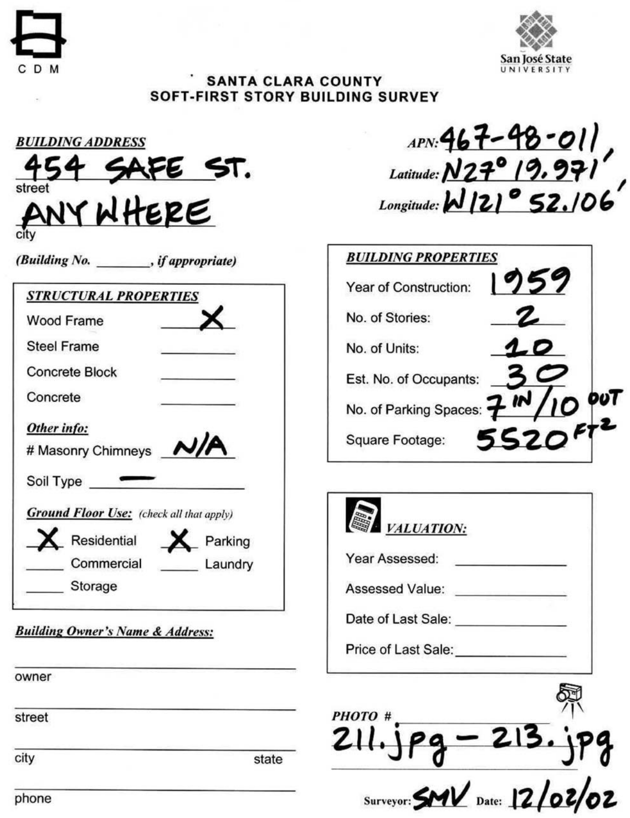
Six student surveyors were recruited from San Jose State University's College of Engineering and trained by Steven Arnold, a licensed civil engineer, before being sent to the target areas for data collection. Data were collected only for buildings that were found to have soft first stories. Survey work began in January 2002 and was completed in December 2002. Survey results were distributed to the emergency managers of each city and to the Santa Clara County Emergency Preparedness Council in June 2003. The following sections describe the details of how the survey was implemented.

IMPLEMENTATION OF THE SURVEY

DEVELOPMENT OF THE SURVEY FORM

The survey form was developed based on a similar survey form that was prepared for use in the city of San Jose's Apartment Owner's Guide to Earthquake Safety (Vukazich 1998) that was based on the Applied Technology Council guidelines for rapid visual screening of buildings for potential seismic hazards (FEMA 1988). The survey form was modified to concentrate on identifying multifamily residential buildings with soft first stories and to gather information that could be used in the future by local governments to evaluate seismic vulnerability (e.g., information that can be input into programs like HAZUS). Steven Arnold P.E., a practicing civil engineer in San Jose, and Dr. Vukazich developed the survey form knowing that the surveyors would be engineering students with only rudimentary knowledge of structural engineering. An example of a completed survey form is shown in Figure 4. Buildings were identified by address, Assessor's Parcel Number (APN), an internal control number, and latitude and longitude from GPS readings.

The basic structural building material was recorded along with other potential seismic hazards such as the presence of masonry chimneys. A space for soil type information was included for possible future use. The ground floor use, which can be useful in identifying soft-story structures and also possible increased vulnerability, was also re-


CDM

San José State University

SANTA CLARA COUNTY
SOFT-FIRST STORY BUILDING SURVEY

BUILDING ADDRESS
454 SAFE ST.
street
ANYWHERE
city
(Building No. _______, if appropriate)

APN: 467-48-011
Latitude: N27° 19.971'
Longitude: W121° 52.106'

STRUCTURAL PROPERTIES
Wood Frame X
Steel Frame
Concrete Block
Concrete
Other info:
Masonry Chimneys N/A
Soil Type —
Ground Floor Use: *(check all that apply)*
X Residential X Parking
___ Commercial ___ Laundry
___ Storage

BUILDING PROPERTIES
Year of Construction: 1959
No. of Stories: 2
No. of Units: 10
Est. No. of Occupants: 30
No. of Parking Spaces: 7 IN / 10 OUT
Square Footage: 5520 FT2

VALUATION:
Year Assessed:
Assessed Value:
Date of Last Sale:
Price of Last Sale:

Building Owner's Name & Address:
owner
street
city state
phone

PHOTO # 211.jpg – 213.jpg
Surveyor: SMV *Date:* 12/02/02

Figure 4. Example of the survey form.

corded. For example, a soft-story structure with first-floor residential units may be thought to be potentially more hazardous in terms of life safety than a soft-story structure with no living units on the first floor.

Building properties recorded included the year of construction, the estimated number of occupants, number of stories, and the number of units. The year the building was constructed was obtained from Santa Clara County records. When possible, the building owner's name and address were also recorded. A space for value assessment of the building was included on the form for possible future economic analysis, and a space for information like soil type was included for further engineering analysis. As previously mentioned, the survey form was developed to include information that can be entered into a HAZUS model.

In addition to the survey form shown in Figure 4, each survey contained a sketch of the building plan and elevation, the appropriate assessor's map, and several digital photos of the building. An example of a typical building sketch is shown in Figure 5. Figure 2 is an example of a typical building photo from the survey.

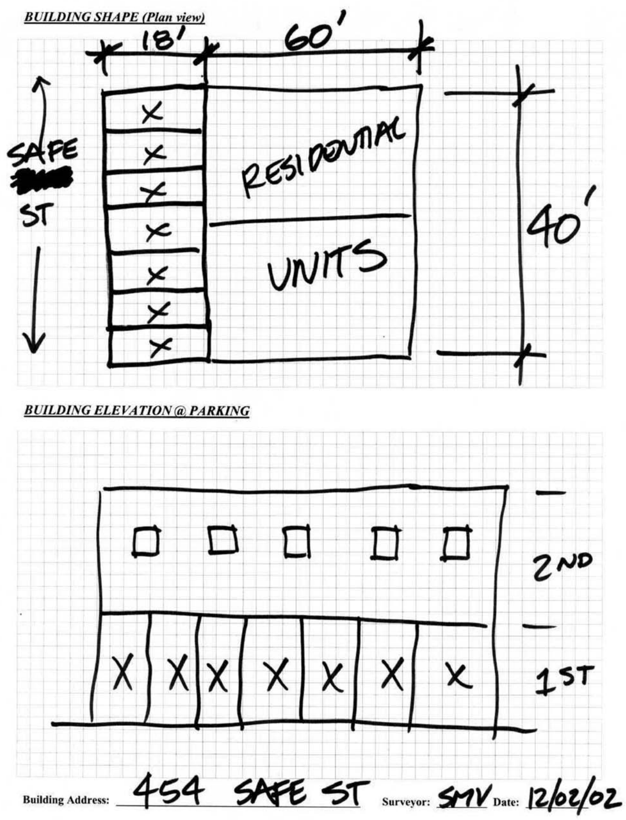


Figure 5. Example of a building sketch from a survey.

TRAINING OF STUDENT SURVEYORS

Steven Arnold trained six students by means of an eight-hour workshop, held at San Jose State University (SJSU), consisting of a classroom session on background information including the following:

- identifying basic structural building types,
- characteristics of soft-story structures and how to identify them,
- how best to photograph each building,
- how to use the GPS system,
- list of multifamily dwellings for the area that they would be surveying, and
- a field trip to soft first-story structures near the SJSU campus.

During the field trip, example surveys were performed on buildings around the SJSU campus. There are many good examples of soft-story buildings within walking distance of the campus. At the conclusion of the workshop the students were required to perform a building survey independently. These surveys were then evaluated by Steven Arnold for accuracy and completeness. The students were not permitted to do surveys on their own until they could demonstrate competency on the test survey. During the project, after the student surveyors completed their work, Steven Arnold did spot quality control checks of about 25 buildings in Sunnyvale, San Jose, and Santa Clara. He found that the surveys were accurate in all of the spot checks he performed.

CONDUCT OF THE SURVEY

Before the student surveyors were sent out, CDM worked with each city's emergency services officer, who alerted the appropriate local authorities in order to minimize public concern. This was particularly important since all of the surveys were performed after September 11, 2001. Each student surveyor carried an official ID card and a letter from Professor Selvaduray explaining the project. The student surveyors asked permission to access each building owner's property in order to perform the survey. If the building owner could not be contacted, a curbside survey was performed. Student surveyors carried the following items: survey forms, digital camera, GPS system, assessor's and zoning maps, and an official ID card and authorization letter.

Student surveyors were paid an hourly wage plus mileage. Although six surveyors were trained, most of the surveys were performed by three surveyors.

SURVEY RESULTS

The results of the survey showed that Santa Clara County has a significant number of soft first-story multifamily dwellings (MFD). The results are summarized in Table 1, sorted by city, in descending order based on the total number of soft first-story MFD.

A total of 7,391 multifamily dwellings were identified in Santa Clara County. Of these, 2,630 were found to be of the soft first-story construction type. This represents 36% of the total number of multifamily dwellings.

San Jose, Santa Clara County's largest city, with a population of 945,000, has both the largest number of multifamily dwellings and the largest number of soft first-story buildings (1,093), which is more than twice the number of soft-story MFD found in Sunnyvale, the city with the secondmost soft-story MFD. Note that the soft-story MFD found in San Jose make up 42% of all of the soft-story MFD in Santa Clara County.

Four small, relatively affluent cities (Monte Sereno, Los Altos Hills, San Martin, and Stanford) were found to have no soft-story multifamily dwellings.

Approximately 90% of the soft-story buildings were two-story buildings; the others were three and four story buildings. The age of the soft-story buildings varied anywhere from 15 to 45 years old. It was found that an average size building contained between 4 and 10 living units. The largest complexes had up to 50 living units.

Table 2 contains data related to the number of apartment units that are found in soft first-story buildings compared to the total number of apartment buildings as presented in Table 1. The data in Table 2 are sorted by city, in descending order based on the total number of soft first-story MFD apartment units.

Table 1. Soft first-story multifamily dwellings in Santa Clara County (Vukazich et al. 2005)

City	Total number of MFD	Number of soft first-story MFD	Ratio
San Jose	2,823	1,093	39%
Sunnyvale	993	415	42%
Santa Clara	1,021	320	31%
Campbell	506	221	44%
Palo Alto	458	130	28%
Mountain View	584	111	19%
Los Gatos	235	96	41%
Gilroy	207	71	34%
Milpitas	194	55	28%
Cupertino	166	53	32%
Morgan Hill	138	37	27%
Los Altos	43	19	44%
Saratoga	17	9	53%
Los Altos Hills	0	0	0
Monte Sereno	0	0	0
San Martin	2	0	0
Stanford	4	0	0
Total	7,391	2,630	36%

The data from Table 2 can give one an approximate idea of how many people are living in soft first-story MFD in Santa Clara County. The occupants listed in Table 2 were calculated at an average of 2.5 occupants per unit. This average is based on discussions with the CDM User's Group and Executive Board and is considered to be a conservative estimate of the occupancy density in the area.

There are a total of 33,119 apartment units located in soft first-story apartment buildings in Santa Clara County. This projects the total occupant population housed in soft first-story MFD in Santa Clara County to be about 83,000. It should be noted that the total population of Santa Clara County, based on 2004 Census findings, is about 1,800,000. Thus about 5% of the total Santa Clara County population is housed in soft first-story MFD. As would be expected, San Jose has the largest number of units in soft first-story MFD and thus the largest population at risk. San Jose has 33% of the total number of apartment units in soft first-story MFD in Santa Clara County. Table 2 shows the ratio of soft first-story MFD apartment units to total MFD apartment units in San Jose to be only 6%. This is a reflection of the explosive growth that San Jose experienced starting in the late 1980s and early 1990s when soft first-story MFD construction was being discouraged. From Table 2 one can also see that Sunnyvale, Santa Clara, Los Gatos, Cupertino, Campbell, Palo Alto, and Mountain View each have over 1,000 apartment units in soft first-story MFD and thus a significant number of occupants at risk.

Table 2. Soft first-story apartment units in Santa Clara County (Vukazich et al. 2005)

City	Total number of MFD apartment units	Number of soft first-story MFD apartment units	Ratio	Occupants
San Jose	187,229	10,923	6%	27,308
Sunnyvale	27,109	7,439	27%	18,598
Santa Clara	25,424	3,297	13%	8,243
Los Gatos	8,404	2,967	35%	7,418
Cupertino	7,670	2,597	34%	6,493
Campbell	8,922	1,971	22%	4,928
Palo Alto	9,937	1,263	13%	3,158
Mountain View	16,900	1,129	7%	2,823
Gilroy	2,601	422	16%	1,055
Morgan Hill	4,368	371	8%	928
Saratoga	600	262	44%	655
Milpitas	9,504	256	3%	640
Los Altos	837	222	27%	555
Los Altos Hills	0	0	0	0
Monte Sereno	0	0	0	0
San Martin	26	0	0	0
Stanford	185	0	0	0
Total	309,716	33,119	11%	82,798

The overall average of the ratio of soft first-story apartment units to the total number of apartment units was found to be 11% for all of Santa Clara County. Therefore, about one in every nine apartment units in Santa Clara County is located in a soft-story MFD.

The total amount of time spent on this survey was close to 2,600 hours. Of this total, about 2,200 hours were spent on the actual data collection, including travel time. Approximately 200 hours were spent on data entry and plotting the distribution maps, and another 160 hours were spent on project management and project coordination. The surveyors traveled a total of approximately 13,500 miles during the course of the survey.

REDUCTION OF DATA AND MAPS

All of the survey forms were submitted to the CDM office, where they were recorded and the data analyzed so that they could be organized and presented in the form of city maps indicating regions where soft first-story multifamily dwellings are clustered. The GIS software program ArcView® was used to construct each map using the survey data and a reference database containing all of the streets in Santa Clara County. The number of soft-story buildings are indicated on each map by three types of groups:

1. high-volume cluster (more than 30 soft-story units are present in the region indicated),
2. medium-volume cluster (10–29 soft-story units are present in the region indicated), and

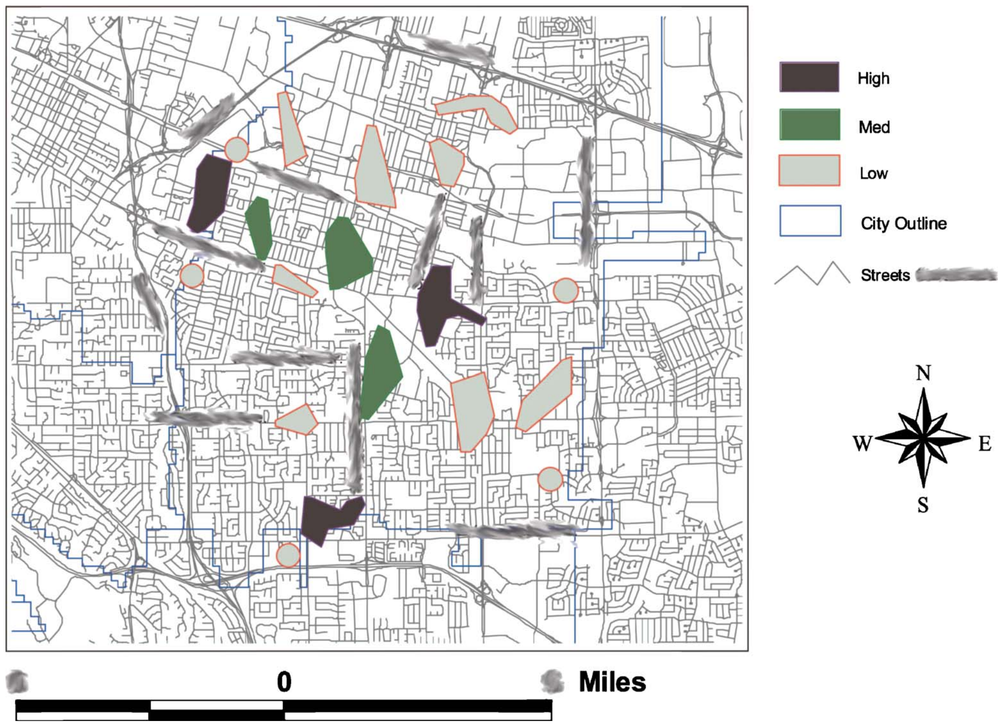


Figure 6. Example of a city map showing high-, medium-, and low-volume clusters of soft-story multifamily dwellings.

3. low-volume cluster (1–10 soft-story units are present in the region indicated).

An example of a city map is shown in Figure 6 (Vukazich et al. 2003). This map is representative of each map that was constructed, showing major streets for orientation, map scale, north arrow, and color-coded areas indicating the location of soft first-story MFD clusters. The map in Figure 6 has the major streets and map scale numbers made illegible. Figure 6 is for illustration purposes only and does not represent an actual city.

FOLLOW-UP INTERVIEWS

In order to determine the impact and usefulness of the project, interviews were performed in April of 2005, almost a full two years after the completion of the project. Persons that were involved for each city were identified an contacted by telephone or e-mail. The interviews were brief and semi-structured, and were conducted with the goal of finding answers to the following basic questions:

- Have the survey results been used? If so, how have they been used?
- If the surveys have not been used, what are the reasons?

- Are there plans to use the survey results in the future?
- Were the survey results useful?

The following is a summary of the information gathered from the follow-up interviews from individual cities in the order of the total number of soft first-story MFD shown in Table 1.

The city of San Jose is distributing the maps to the fire department in order to aid the individual fire captains in making their pre-plans in the event of an earthquake. High-volume areas would be on the target hazard list for individual zones. It was pointed out during the interview that speed is essential in emergency situations since it has been shown that quick response time saves lives. In addition, fire teams have been briefed on what to look for when assessing the damage to a soft first-story MFD, in order to avoid what happened in Northridge, where fire teams actually drove past collapsed tuck-under parking buildings. The San Jose Emergency Operations Center (EOC) also has used the survey in their pre-planning for the allocation of post-disaster resources (e.g., shelters and mass care facilities) (Winslow 2005).

The city of Campbell has incorporated the survey into post-earthquake "windshield" survey plans for the police and fire department. A "windshield" survey is a post-disaster survey in which police and fire units patrol to look for emergency situations and assess damage without responding to calls. The emergency manager mentioned that the survey would have been more helpful if individual addresses were listed. It was also mentioned that the survey has been cited in a proposal by a city councilmember to obtain funding to provide incentives for retrofitting buildings that are potentially susceptible to earthquake damage (Patterson 2005).

The emergency manager from the city of Palo Alto was familiar with the project and was very positive about the work done by the CDM. The city of Palo Alto has used the data by providing it to their GIS department, which has created hazard plans based on building construction types (Cimino 2005).

The city of Mountain View has given the survey to its Community Development Department, which is in charge of planning for post-earthquake response. The indicated areas on the maps were added to the post-earthquake priority list. It was also mentioned that the survey was cited in a proposal for upgrading the infrared night vision goggles used for nighttime damage assessment (Brown 2005).

The contact person for the city of Los Gatos was not familiar with the survey, probably due to turnover in the position since the time of the original survey. Subsequently, the senior building inspector contacted the author and was interested in receiving the final report in order to use it for post-earthquake planning (Ghiossi 2005).

The emergency manager for the city of Gilroy stated that the data from the survey has been forwarded to the fire and community development departments and they are considering a possible outreach program. The emergency manager also stated interest in receiving additional guidance or products from the CDM (Shackel 2005).

The city of Milpitas director of the Office of Emergency Services (OES) keeps a copy of the map in the Emergency Operations Center (EOC) for use in post-earthquake damage surveys. During the interview it was noted that local politicians were worried about the survey information getting out to the public as the property values in the targeted areas could be negatively affected (Washburn 2005).

The OES director for the city of Cupertino said that they keep a copy of the survey to include in post-earthquake damage survey plans. The survey was presented to the Emergency Preparedness Council (EPC) and one city council representative wanted to contact owners in the areas to start a seismic upgrade incentive program. Due to the legal and political sensitivity, the EPC did not want to take this issue up with individual property owners and so nothing further was done. The head of the OES is interested in making another attempt to start an upgrade program.

Interviews from the cities of Morgan Hill, Los Altos, Saratoga, Los Altos Hills, Monte Sereno, San Martin, and Stanford were not available at the time of writing due to difficulty in finding a contact person. It should be noted that many of these communities are small and, as can be seen in Table 1, had few or no soft first-story residential multifamily dwellings.

All of the communities contacted except one said that the information was useful to some degree. As expected, the survey results seem to be most useful in planning for post-earthquake response. Many of the building officials contacted thought that the survey would be of more use if it contained individual address information.

Seven of the ten communities contacted are using the survey as part of their post-earthquake planning. These seven communities have 67% of all soft-story MFD and 64% of all soft-story MFD apartment units found in Santa Clara County.

It should be noted that three of the ten communities contacted expressed interest in using the survey as a point of reference to pursue a retrofit incentive program for soft first-story MFD in their community.

CONCLUSIONS AND FURTHER WORK

The survey was able to identify the number and location of soft first-story MFD clusters in Santa Clara County cities and give emergency managers an estimate of the number of persons in each community that could be affected in the event of an earthquake. Data were collected and compiled in a cost-effective manner by using the combined resources of the university and local government. The cost-effectiveness of the survey was aided by the fact that soft first-story construction is relatively easy to identify by persons who only have rudimentary knowledge of structural engineering, and so engineering students could be used to perform the surveys.

The results of the survey found that 36% of the MFD in Santa Clara County are of the soft first-story construction type. It was found that one out of every nine apartment units in Santa Clara County is located in a soft first-story building. In a conservative estimate, approximately 83,000 persons could be affected in the event of a severe earthquake. Follow-up interviews found that the survey results were well received by most of the communities and that the cities that contain 67% of the identified soft-story MFD in Santa Clara County are using the maps and survey information in their pre-disaster earthquake planning.

The data that were collected in this survey can be used by officials in individual cities to ascertain vulnerability. Officials may continue to use this data in a number of ways, such as the following:

- incorporating data into risk assessment software such as HAZUS;
- performing more detailed investigations into the vulnerability of areas containing a high number of soft-story buildings; and
- further investigating economic and social impact, considering factors like potential property damage, need for relocation, and the number of people affected.

This survey represents the advantages of a "town-gown" (local jurisdiction–academic institution) partnership. Useful data were collected in a timely and cost-effective manner that benefited both the university and the local community. Engineering students were able to learn engineering concepts and see how engineers can play a role in public safety. In turn, city governments were provided with valuable data that can be used to improve public safety and aid in disaster mitigation. It should be noted that due to legal and political issues the data needed to be presented in a form in which individual properties could not be identified. Perhaps local governments can take steps toward resolving these issues in the interest of public safety.

The Collaborative for Disaster Mitigation is using this survey as a model to pursue further work that might include surveys of soft-story buildings in other Bay Area counties or a similar survey focusing on critical facilities in Santa Clara County.

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