Earthquake Vulnerability of Buildings in Santa Barbara County

The State of California and Santa Barbara County have significant areas of land with high seismic activity that are capable of producing significant earthquakes. The purpose of this report is to describe earthquake hazards and to review building types that are at risk during an earthquake in Santa Barbara County. It will also identify courses of action that can be taken to lessen impacts to structures and injuries to inhabitants.

There are other significant earthquake hazards that are not addressed in the report. These include: slope stability, tsunamis, liquefaction, post earthquake fires, etc.

Buildings Codes are adopted by the State of California every three years. The structural aspects of the building codes in most part are developed by input from civil/structural engineer associations and industry groups. These groups include the American Institute of Steel Construction, American Concrete Institute, American Wood Council, research institutes, academia and other subject matter experts. The changes to earthquake design and construction of buildings are based on new experiments, testing and research, as well as lessons learned from the behavior of buildings following an earthquake. Building Codes evolve over time to modify design and construction standards to eliminate identified weaknesses.

Building Codes also are updated to more accurately estimate earthquake ground shaking at a particular building site. Recent code updates have dramatically affected properties in the southern part of Santa Barbara County requiring greater structural strength to account for newly mapped earthquake hazard zones. It is important to note that pre-2010 construction standards were not designed to withstand the level of earth shaking that may occur in southern Santa Barbara County. This understanding is important in making earthquake related policy decisions.

THE MOST VULNERABLE BUILDING TYPES AND THEIR CORRESPONDING HAZARDS

Soft-Story Buildings


Soft-Story Apartment Building Failure in Northridge earthquake

Soft-story buildings typically have drastically reduced stiffness at certain floors (called soft or weak floors). Usually, the soft story is caused because the walls that resist earthquakes are eliminated at the soft or weak floor to provide for open floor plans. A common type of soft-story building is an apartment building with tuck under parking. The soft floor sustains most of the building deflection and damages. Many early apartment buildings were built without any earthquake design consideration and even some mid-20th century buildings with earthquake design consideration failed to recognize this weakness and are subject to major damage and collapse of the entire floor.

In 2005 the State Legislature passed AB 304, which encourages cities and counties to address the seismic safety of soft story residential buildings. Local governments were encouraged to initiate efforts to reduce the seismic risk in vulnerable soft story residential buildings. The cities of Alameda, Berkeley, Fremont, San Francisco, San Leandro, San Jose, Santa Rosa, Los Angeles, Concord, Rohnert Park, Burbank, Pasadena, Santa Monica, and Santa Barbara all have either undertaken or are in the process of beginning a soft story building inventory.

The Cities of Fremont, Berkeley, and San Francisco have enacted a mandatory soft-story retrofit programs. The average cost of retrofits can vary greatly depending on the method of retrofit. Costs range from $2,500 per open parking space to over $10,000 per unit when the retrofit has to be done completely within the existing footprint of the building. Considerable research is underway to identify the most effective method of retrofitting these buildings.

In Santa Barbara County we are fortunate that most apartments were provided with carports or open air parking and do not have soft stories. A windshield survey of Isla Vista apartments did not reveal any buildings that would readily fall into this category. A more rigorous and countywide survey is recommended to identify buildings that may have soft or weak story levels.

Pre-1973 Concrete and Concrete Masonry Buildings with flexible floor or roof


Tilt-up Building Collapse

Concrete and concrete masonry buildings constructed prior to the standards that became effective with 1973 edition of the Building Code, typically had vulnerability to earthquake forces at the connections of walls to roofs and floors. Plywood of roofs and floors of these buildings were typically connected to walls with nails to a wood ledgers and wood ledgers where connected to wall with steel anchor bolts. This connection caused the ledgers to be stressed in the weak axis during earthquake, causing failure of the ledger and separation of the roof and floor from the walls. In an earthquake, these buildings often experience partial or total collapse of walls and collapse of roofs that were supported by the wall.

The County has not conducted a survey of these types of buildings; however, we anticipate the number to be low since most of them are found in industrial zones. There may be some commercial buildings, wineries or production buildings in the County that will fall within this category. Average retrofit costs are approximately $5 per square foot using 2007 dollars.

The State of California Multi-Hazard Mitigation Plan, Chapter 5, shows the following jurisdictions have enacted a retrofit program for tilt-up and similar buildings.

Jurisdiction	Number of Buildings	Program
Burbank	Unknown	Mandatory
Los Angeles	2,618	Mandatory
Los Angeles County & Contract	Unknown	Mandatory
Fullerton	220	Mandatory
Hayward	130	Voluntary
La Palma	Unknown	Mandatory
Brisbane	Unknown	Voluntary
Santa Monica	Unknown	Mandatory
Berkeley	75	Inventory
Fremont	Unknown	Mandatory

Source: California Seismic Safety Commission

Single family homes without bracing in the crawl space and proper anchoring to the foundation.

Many pre-1950 houses do not have proper bracing walls in the crawl space and/or walls are not secured to the foundation causing them to deflect excessively and fall off the foundation during a medium to strong earthquake. These weaknesses are exacerbated on hillside houses with taller cripple walls. Cripple walls are that portion of the exterior wall between foundation and the first floor. In pre-1950 houses, cripple walls typically have no sheathing on their interior face and are commonly weaker than the portion above the first floor.

House separated from foundation

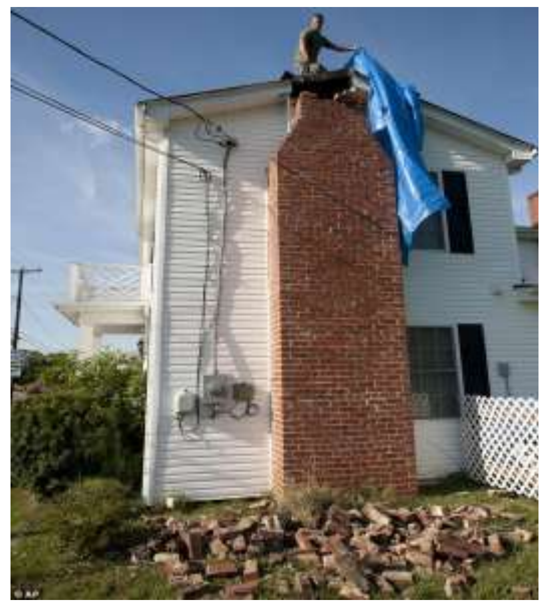
These types of buildings constitute the majority of earthquake vulnerable buildings in the County. Retrofitting is relatively simple and consists of applying plywood to the walls of crawl spaces and bolting the sill plate of these walls to their foundation. The performance of these types of buildings can improve significantly once retrofitted. Although most owners opt to retrofit their house during major additions or alterations, there is rarely any proactive seismic retrofit.

According to the State of California Multi-Hazard Mitigation Plan, Chapter 5, the following cities have voluntary dwelling retrofit programs:

- Los Angeles – 6,000 dwellings retrofitted as of February 2006 (also adopted a voluntary hillside dwelling retrofit ordinance)
- Berkeley
- San Leandro
- Oakland
- Santa Barbara
- Santa Monica

Brick and Stone Chimneys

Many pre-1960 chimneys were built of unreinforced brick or stone that can separate from the building during an earthquake. They may fall outward toward neighboring structures or fall inward, causing serious injury or death to the occupants or neighbors. According to the Bay Area Government Association, approximately 60,000 masonry chimneys were destroyed or damaged beyond repair during the 1994 Northridge earthquake. Replacing the brick chimney with a wood framed chimney is the best option in mitigating this hazard. Properly bracing and connecting the chimney to the roof and floors can also considerably reduce the hazard. Evaluation of brick chimneys and stone chimneys at the time of alteration can be an effective method of reducing this type of hazard over time.



Chimney failure under earthquake forces

Wood frame building on steep slopes

City of Los Angeles has enacted special provisions for construction of wood frame buildings on slopes greater than 33% following the Northridge earthquake. Typical design and construction for homes constructed on a steep hillside used a stepped foundation to accommodate the change in elevation of the building site. The damage observed after the Northridge earthquake to houses built on steep hillsides indicates that stepping of the footing to negotiate the sloped site creates discontinuities at the foundation which weakens lateral resistance of the buildings. While not common, this type of construction is present in the County and adopting code provisions that will mitigate this weakness for new buildings and retrofit of existing buildings can considerably reduce their vulnerability in the event of an earthquake.

Mobile Homes


Mobile Home fire after earthquake

Mobile home construction and manufacturing are regulated by the State of California, Housing and Development Department. Santa Barbara County issues permits for site installation of these pre-manufactured houses. When installed in Mobile Home Parks these structures are often installed on a pedestal. These pedestals are small stands often made of metal and placed on the ground. Prior to 1994, pedestals were not designed to resist lateral forces and those mobile homes are susceptible to fall off the pedestal causing damages to the home and/or rupturing gas lines. Gas line failures have led to post-earthquake fires. This hazard can be mitigated by securing the mobile home to the ground. Any seismic retrofit program will require State Department of Housing and Community Development approval.

Non-ductile Concrete Frames

Olive View Hospital, 1971 San Fernando Valley earthquake

Concrete buildings constructed prior to the 1976 Building Code typically lack proper reinforcement resulting in brittle mode of failure during an earthquake. Brittle failure is sudden and accompanied with total loss of strength resulting in catastrophic failure in buildings. Although non-ductile concrete buildings are rare in the County of Santa Barbara, a complete survey of the County is necessary to identify all suspect structures. These types of buildings are typically used for multi-story offices, apartment buildings, schools, hospitals, etc.

The collapse of two concrete structures in the 2011 Christchurch, New Zealand magnitude 6.3 earthquake caused 135 out of the 182 total fatalities (Kam, 2011). The failure of these buildings have been observed in almost every major earthquake in the United States and abroad including the 1971 San Fernando, 1981 Northridge, and1995 Kobe Earthquakes.

Although seismic retrofit of these types of buildings can be costly, the high cost of retrofit can be justified considering the major hazard these buildings pose to the life of their occupants. Further, if these types of structures are damaged in an earthquake repair may not be cost effective.

There is currently no program for retroactive mandatory retrofit of non-ductile privately owned buildings in California. Many hospitals and educational buildings with these deficiencies have been retrofitted. The cost of retrofit varies considerably depending on a building's original layout and construction, building occupancy type and, method and level of retrofit.

Modern Steel Frame Buildings

The Northridge Earthquake revealed a serious weakness in connection of steel frames. Following the Northridge earthquake the building code has been changed to disallow these type of connections. Multi-story buildings with this type of connection can collapse in a large earthquake. Shorter buildings with this type of connection can also sustain damage in a major earthquake, but their collapse is less likely.

Steel Moment Fracture Due to Earthquake

This type of framing may have been used extensively in single family homes when floor layout did not allow for constructing walls to resist lateral loads. In wood frame single family homes, the force level is typically low and we do not anticipate major damage to these frames. However, in the case of mid-rise to high-rise buildings with this type of connection, significant failures may occur in an earthquake.
The cities of Los Angeles and Santa Monica have post-earthquake repair ordinances. Los Angeles required owners to remove the finishes from joints in 242 buildings and repair the ones that were cracked. Staff does not expect to find many of these buildings in the County

Unreinforced Masonry Buildings, URM

Unreinforced Masonry Buildings (URMs) are early 19th and 20th century buildings made of brick bearing walls with wood floors and roofs. A great number of these types of buildings were damaged and subsequently demolished in the 1925 Santa Barbara earthquake. The biggest hazard posed by these buildings is the separation and collapse of parapet walls (wall extending above a roof) and walls from the roof and floor.

Failure of URM Building

In 1991, Santa Barbara County enacted Ordinance 4602 mandating earthquake retrofitting of Unreinforced Masonry Buildings (URM). All the privately owned URM buildings identified in the County were either retrofitted or demolished. The intent of the seismic retrofit program was to reduce the earthquake damage to these types of buildings. However, retrofitted buildings still may sustain damages during an strong earthquake.

Summary and Options:

Given our general knowledge of the building stock in Santa Barbara County, staff expects to find that the lack of crawl space bracing and masonry chimneys in the single family homes as the most common deficiencies in building construction for resistance to earthquakes. While not common, concrete and masonry buildings without proper connection of roof/floor to walls, steel building with pre-northridge steel connections and soft-story buildings should also be regarded as a high priority for retrofit due to the potential for catastrophic failure.

The following recommendations address known issues that relate to buildings located within unincorporated boundaries of the County of Santa Barbara. It is important to note that damage from an earthquake would include cities. Therefore a more effective program would include cities within the County and, if possible, adjoining counties as well.

The following are recommended options to address potential earthquake building hazards:

Single family homes:

a. Prepare options for both voluntary and mandatory retrofit programs.
b. Voluntary program will likely consist of an educational program that will inform building owners of the potential hazards of certain types of design and construction practices, and the advantages of proactively seismically retrofitting buildings. This would include masonry chimneys, unreinforced cripple walls, hillside construction, etc.

c. Mandatory retrofit should be triggered when substantial structural modifications or additions are being proposed, and the building does not meet the structural standards set forth in the Uniform Code For the Abatement Of Dangerous Buildings. That code requires a building to meet 66% of the current building code standard for a similar building. Require seismic retrofit of all brick, stone, and masonry chimneys when major modifications or additions are being proposed.
d. Enhance Santa Barbara County building requirements for construction on steep hillsides.

Multi-family residential and Non-residential buildings

2. Conduct a survey of the unincorporated areas of the County to identify buildings at considerable risk of major damage in the event of an earthquake. Use survey results to perform a cost-benefit analysis that can be used to formulate mandatory or voluntary programs for all other hazardous buildings indentified in this report.

References:

Reference 1: Final Report, July, 2000, Earthquake Hazard of the Santa Barbara Fold Belt, California. ,NEHRP Award #99HQGR0081, CEC Award #572726,E. A. Keller (PI), L. D. Gurrola Institute for Crustal Studies, UC Santa Barbara. Reference 2: HAZUS MH Estimated Annualized Earthquake Losses for the United States FEMA 366 / April 2008

Authored by:

Massoud Abolhoda, Building Official