



# **EARTHQUAKE FIELD GUIDE**

**Spotting Common Problems in  
Bay Area Housing**



**Association of Bay Area Governments**

**August 2018**

# EARTHQUAKE FIELD GUIDE

## Spotting Common Problems in Bay Area Housing

The Association of Bay Area Governments and the Metropolitan Transportation Commission are the regional land use and transportation planning agencies for the nine counties and 101 cities and towns of the San Francisco Bay region.

ABAG's Resilience Program assists Bay Area local governments, and provides resources for residents in planning for earthquakes, the effects of climate change and other hazards.

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ASSOCIATION OF BAY AREA GOVERNMENTS  
METROPOLITAN TRANSPORTATION COMMISSION

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# Introduction

Living in Earthquake Country means that Bay Area residents need to be prepared for an earthquake and possible damage to their homes, ranging from cracks and leaning to complete collapse. When housing is damaged, people and communities are impacted in many ways. People in or near their homes may be harmed. Many people will have to move out of their homes, depending on shelters or temporary housing, for weeks, months, or even years as their homes are repaired or rebuilt. Homeowners may no longer be able to afford their mortgages, or find repairs too expensive, and may move away for good. Renters may not be able to find another place to live in a hyper-competitive market. Even homeowners and renters with an earthquake insurance policy will struggle to rebuild their lives if their homes are seriously damaged.

## Use this Field Guide with the Online Home Quiz to Identify Risks in Your Home or Rental.

The *Earthquake Field Guide: Spotting Common Problems in Bay Area Housing* (Field Guide) is designed to help Bay Area residents identify possible earthquake-related problems in common home types in the region. The Field Guide only identifies potential problems with a home's structure. The Field Guide should be used in conjunction with the online *Earthquake Home Quiz* (Home Quiz) to identify additional potential problems, including geologic hazards, non-structural items like furniture, chimneys and water heaters. The Home Quiz ([homequakequiz.org](http://homequakequiz.org)) provides residents with next steps to improve earthquake performance.

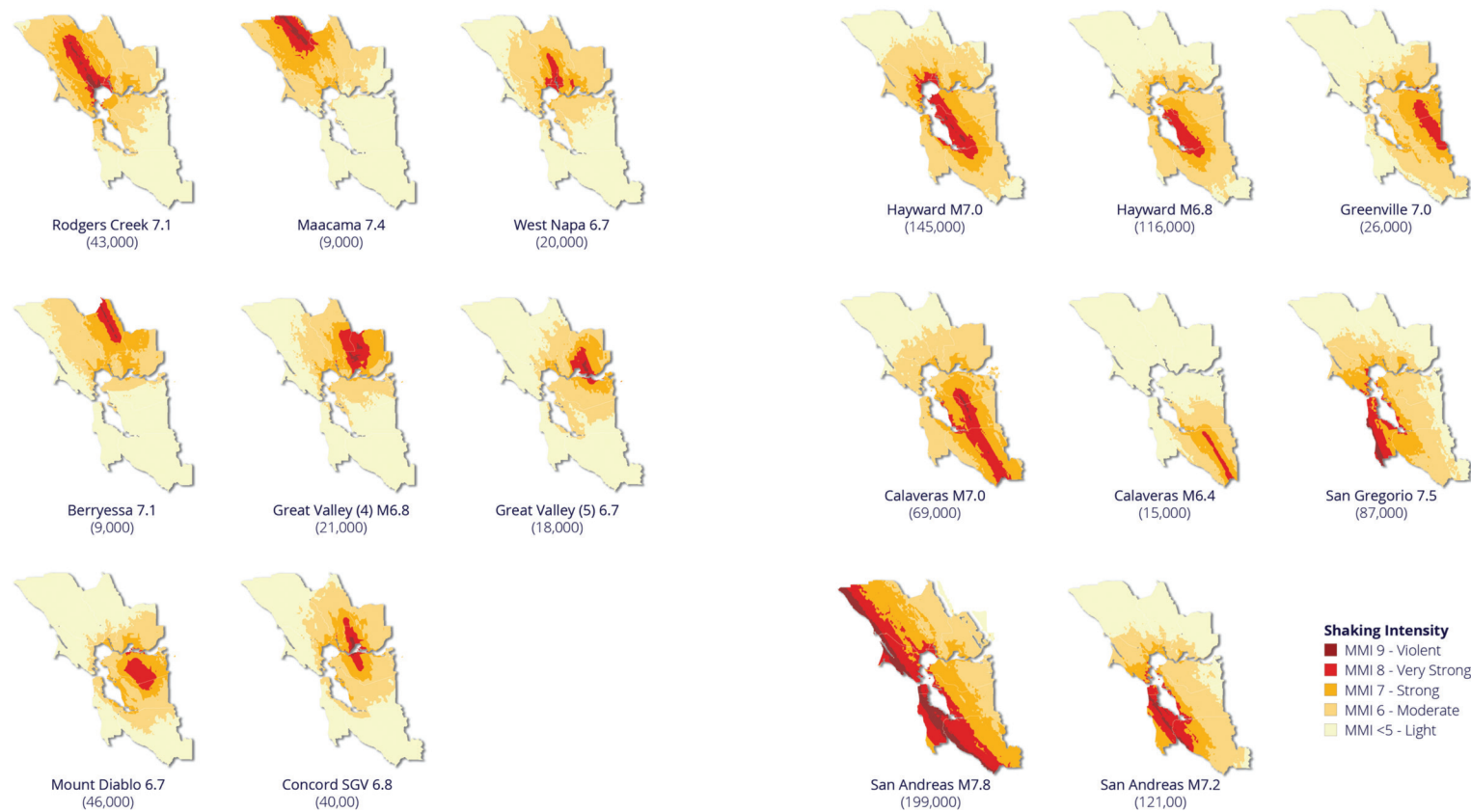
Only an engineer can tell you for sure if a home is vulnerable. The Field Guide and Home Quiz are a starting point.

# Bay Area Earthquake Risk

The Bay Area is riddled with earthquake faults capable of producing both small and large earthquakes. In the next 30 years, scientists predict there is a 72 percent chance of a magnitude 6.7 or greater earthquake on at least one of these faults. Quakes of this magnitude

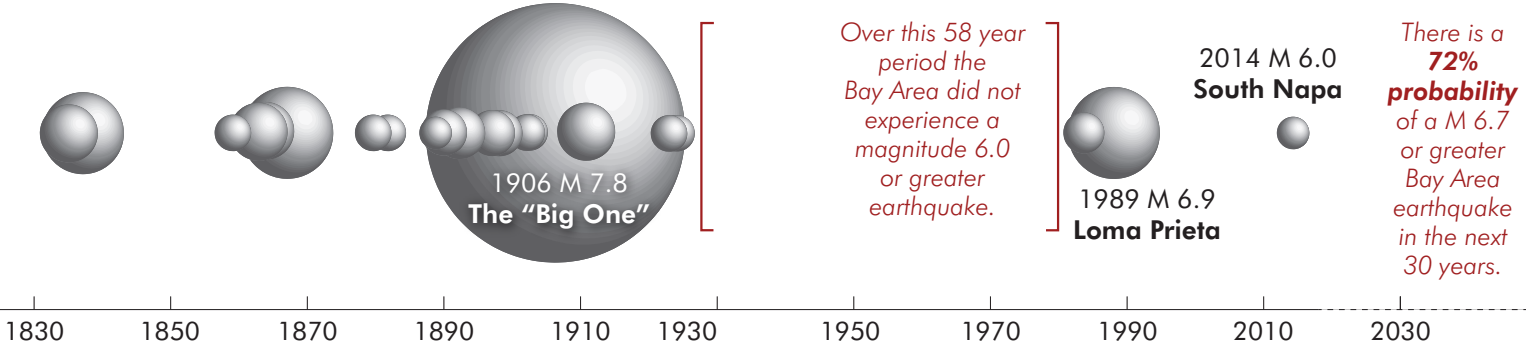
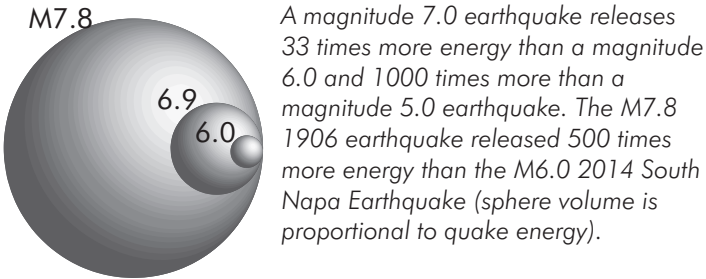
could cause violent shaking anywhere in the Bay Area. Figure 1 below shows how an earthquake on any number of active faults in the region could distribute shaking, which helps to predict how many housing units may be damaged in that particular earthquake scenario.

**Figure 1: 16 Potential Earthquake Shaking Maps and Estimated Households Displaced by Damage**  
(Estimated households displaced shown in parentheses.)



Earthquakes are common in the Bay Area, and the region has a history of damaging quakes. In 1868, an earthquake estimated at a magnitude of about 7.0 occurred on the Hayward Fault. Perhaps most famously, the magnitude 7.8 1906 earthquake on the San Andreas fault devastated San Francisco and caused extensive damage all the way from San Jose up to Santa Rosa. Twenty-two magnitude 6.0 or greater events have rocked the Bay Area since 1840, and smaller earthquakes occur every day. The 2014 South Napa earthquake was a wake-up call, reminding residents that even moderate earthquakes can damage homes and disrupt lives.

**Figure 2: Earthquake Magnitudes and History of Magnitude 6+ Bay Area Earthquakes**

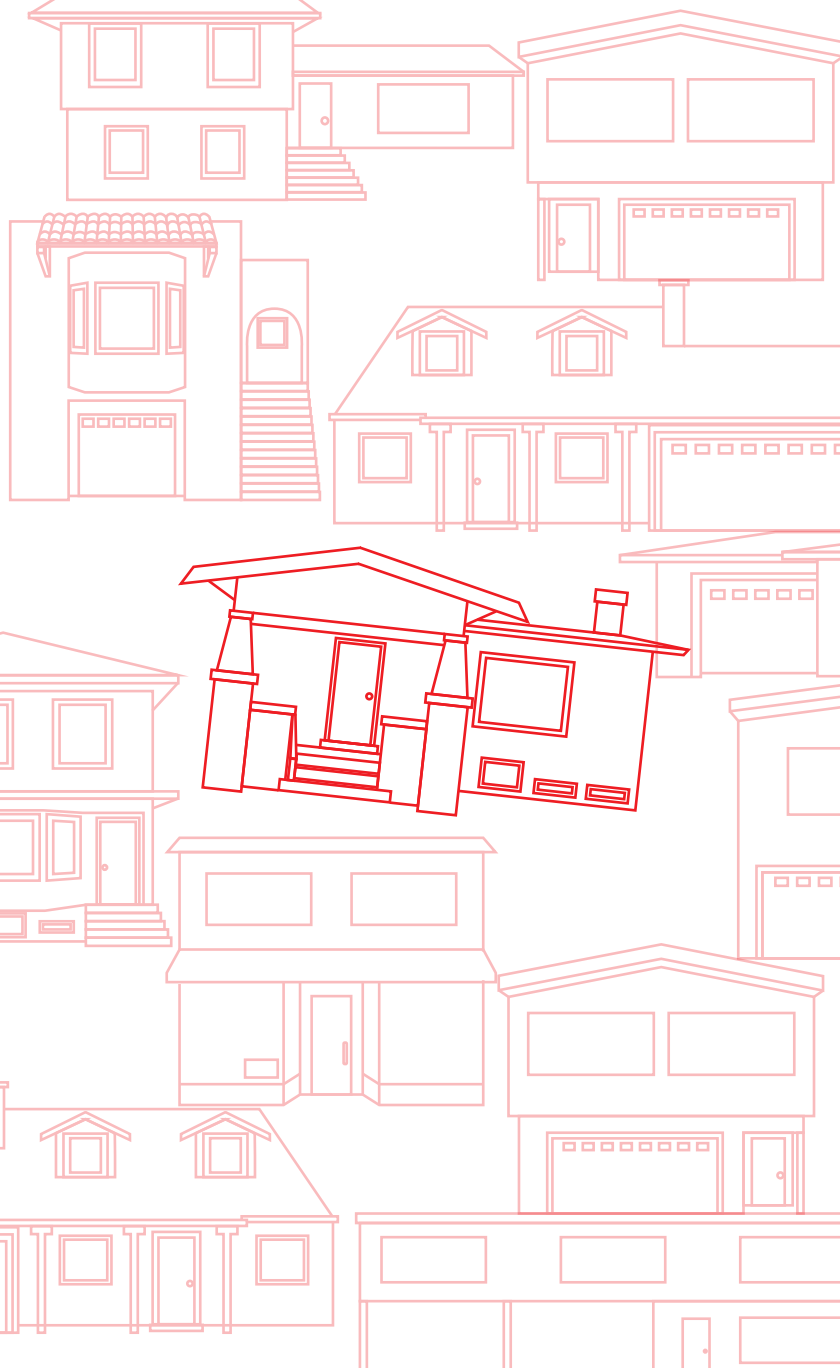


# Building Types

The Bay Area is home to a wide range of housing types, from different eras, and in different styles, ranging from the ornate Victorians of San Francisco, to East Bay craftmans, colorful hillside homes, mid-century ranches, high-rise apartments, and everything in between. Every type of home in the region may be vulnerable to earthquakes in different ways, depending on how it was built and how long ago. While many variations on these homes exist, some common types are widely identified throughout the region.

This Field Guide distinguishes eleven common Bay Area housing types. It is intended to help you identify your home's type through easy visual cues, and understand possible earthquake problems unique to that type. From there, you can take our online Earthquake Home Quiz to dig deeper into specific vulnerabilities and find out what you can do to improve your home's performance in an earthquake.

Lastly, only an engineer can tell you for sure if your home is vulnerable. This Field Guide, and the Earthquake Home Quiz, are a starting point. If you are unsure if your home may be vulnerable, call a contractor or engineer to get a professional opinion.



## Single Family Homes

Bay Area single family homes come in a variety of types and styles. Many neighborhoods were built around the same time, so the houses have similar materials and designs. The overwhelming majority of single family homes are wood frame construction. In small quakes, wood frame houses tend to do well, because wood can bend and twist a little without breaking. However, in stronger shaking, the damage may be severe and is described for each home type in the following pages.

Many identifying features are relatively distinctive and will make identification easy, while others may be more difficult. Additionally, your home may be a blend of multiple types. If your home has characteristics of more than one type, explore the sections for each type.

Use this Field Guide to identify what possible problems your home may have, and take the Home Quiz for more detailed information about potential problems and a list of things you can do to avoid damage and make your property safer.

# Home With a Crawl Space

## Also Called: Cripple Wall

One of the most common types of single family homes in the Bay area is wood frame with a crawl space. The term crawl space refers to unoccupied space between the foundation and the first floor, which is usually only a few feet tall, and is framed by a “cripple wall.” Most single family homes on flat sites built before 1940 have a crawl space, as well as both older and newer homes built on slight slopes.

### Identifying Features

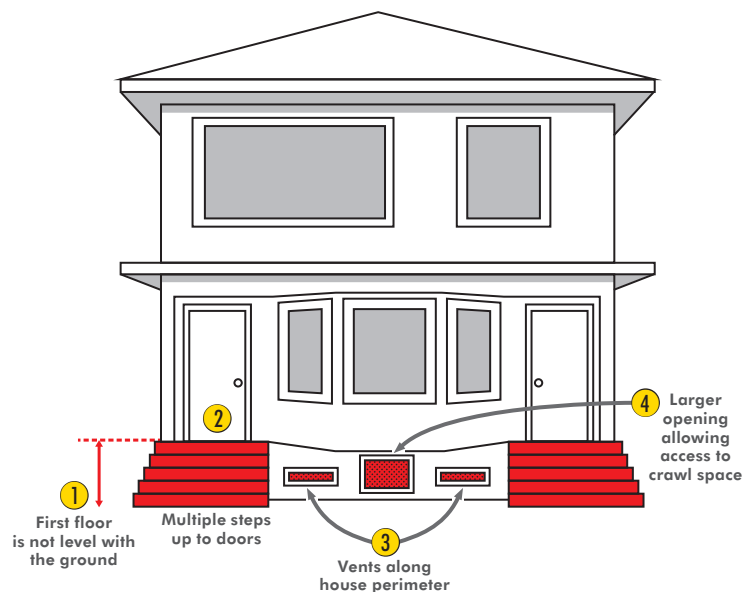
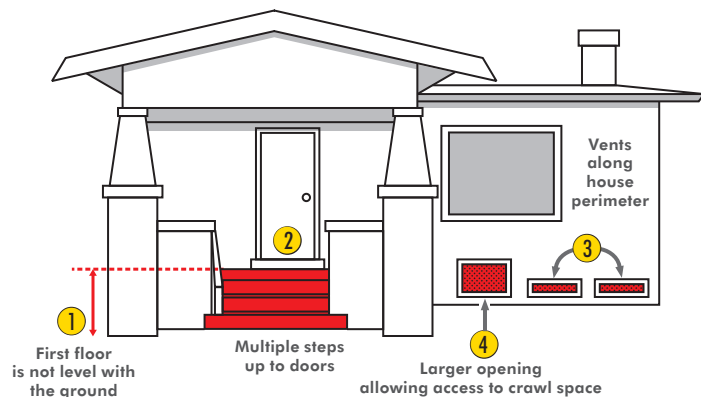
- ① The first floor is not level with the ground.
- ② There are typically multiple steps up to the doors.
- ③ There are typically vents/screens along the perimeter of the house between the foundation and the first floor.
- ④ There is often a larger opening that allows for someone to access the crawl space.

### Common Problems in an Earthquake

If the cripple wall frame is not bolted to the foundation, the home may slide off the foundation. If the cripple walls are not strong enough, some or all of the crawl space can collapse under the weight of the home above. If either of these occur, the home can sustain considerable damage, and may be uninhabitable. In addition, the home’s gas, water or sewer lines may also break. The cost to repair, or demolish and rebuild, can be very high.

### What to do Next

Go to [homequakequiz.org](http://homequakequiz.org) and answer a few more questions about your home. After that, you’ll be given specific next steps and resources to help you address potential problems.



### This home may also have

- Living Space Over Garage – p. 12
- Built Into a Steep Hillside – p. 16
- Split Level – p. 18



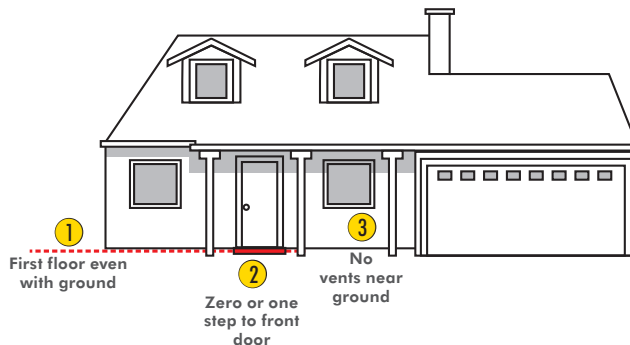
# Home With a Slab Foundation

## Also Called: Slab on Grade

Many homes built after the 1940s on flat sites are built with a slab foundation. A slab foundation is made of a solid slab of concrete and extends to all sides of the home. The home typically sits directly on top of the slab.

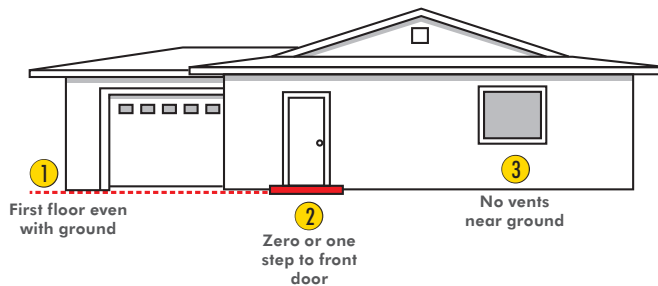
### Identifying Features

- 1 The first floor is level or near-level with the ground.
- 2 There is typically zero to one step to the front door.
- 3 There are typically not vents present, however, there may be a single appliance vent near the ground on the first floor.



### Common Problems in an Earthquake

In an earthquake, structures with this foundation type generally perform well. In some cases, pre-1960 homes on a slab foundation may not be sufficiently anchored to the foundation and can shift in an earthquake. Some walls of the home may lean and crack in an earthquake if this happens.



### What to do Next

Go to [homequakequiz.org](https://homequakequiz.org) and answer a few more questions about your home. After that, you'll be given specific next steps and resources to help you address potential problems.

### This home may also have

- Living Space Over Garage – p. 12

# Living Space Over Garage Homes

## Also Called: House or Room Over a Garage

There are two versions of homes with living space above a garage.

**House Over Garage**, where the first story of the home primarily consists of a garage and unfinished space (i.e. not livable space) and the majority of the living space is above this,

**Room Over Garage**, where only a portion of the house is above the garage and the rest of the house has a different foundation type (i.e. crawl space or slab foundation).

## Identifying Features

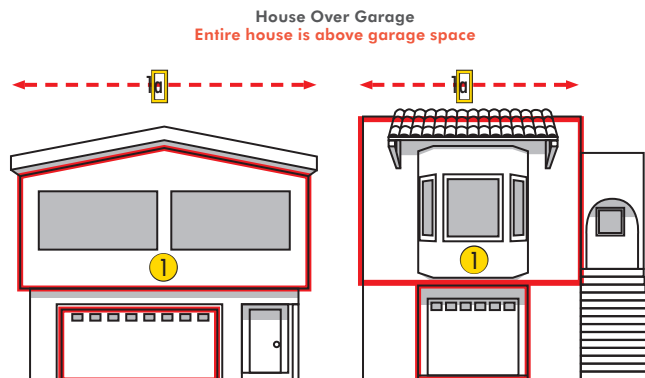
- 1** The garage is integrated into the structure of the house, with living space above.
- 1a** **House Over Garage**, all living space is on the second floor above the garage.
- 1b** **Room Over Garage**, some living space is on the first floor, some is above a garage.

## Common Problems in an Earthquake

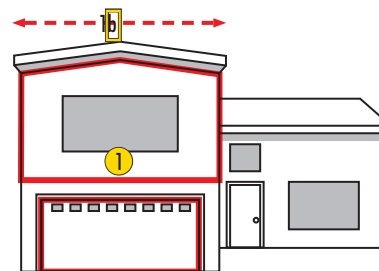
In an earthquake, the garage or unfinished space on the first floor may not be strong enough to resist the side-to-side shaking of an earthquake, leading to collapse of the garage area, or causing a permanent lean. If the garage collapses, the second floor area above it is also likely to be a greater risk for serious harm to occupants in this portion of the home. The home can become uninhabitable if the garage wing or first story leans significantly or collapses.

## What to do Next

Go to [homequakequiz.org](http://homequakequiz.org) and answer a few more questions about your home. After that, you'll be given specific next steps and resources to help you address potential problems.



**Room Over Garage**  
Portion of home is above garage



## This home may also have

- **Crawl Space** – p. 8
- **Split Level** – p. 18

# Home Built Above Steep Hillside

## Also Called: Down-Slope Hillside Home

Homes built above a steep hillside have increased potential for earthquake damage. In these homes, the main living level is built at or near street level, with piers or posts embedded in the ground that support the rear of the house. Homes built into steep hillsides are discussed on the next page.

### Identifying Features

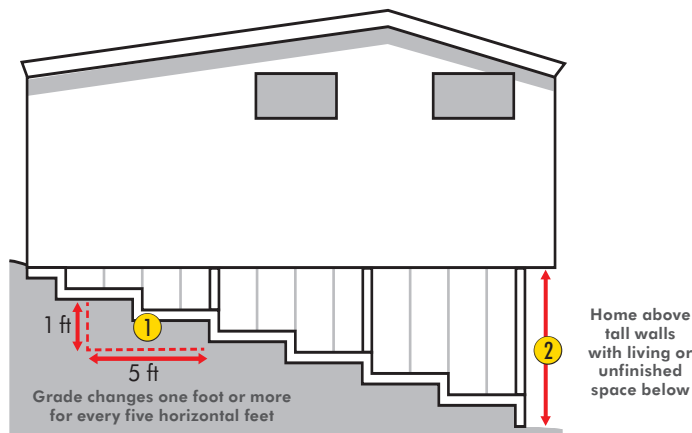
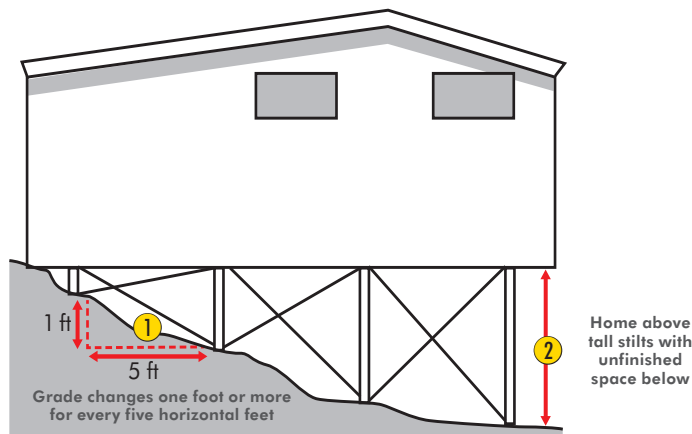
- 1 If slope drops one or more feet for every five horizontal feet on the perimeter of the building it is a “steep” hillside.
- 2 The home extends out over the hillside with living or unfinished space below, either supported by tall stilts (may be braced, see image), or tall walls.

### Common Problems in an Earthquake

In an earthquake, the home can shift, collapse downhill or tilt sideways on the hill. The anchorage connection to the uphill footing is a common weak point and the bracing or tall walls are also often not strong or stiff enough to resist the shaking. If the building collapses, residents can be injured or killed.

### What to do Next

Go to [homequakequiz.org](http://homequakequiz.org) and answer a few more questions about your home. After that, you’ll be given specific next steps and resources to help you address potential problems.



# Home Built Into a Steep Hillside

## Also Called: Up-Slope Hillside Home

These homes typically perform better than their Home Built Above a Steep Hillside counterparts (described on the previous page), but often have at least one of three other potential problems: crawl space, living space over garage and/or split level.

### Identifying Features

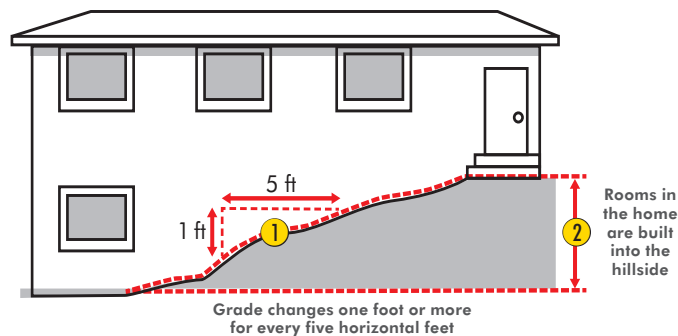
- 1 If slope drops one or more feet for every five horizontal feet on the perimeter of the building it is a “steep” hillside.
- 2 Portions of rooms in the home are built into the hillside. The home was built into excavations cut in the slope.

### Common Problems in an Earthquake

In an earthquake, damage is typically related to the other problems: crawl space, living space over garage or split level. If your home has any of these problems visit these sections for common issues in an earthquake.

### What to do Next

Go to [homequakequiz.org](http://homequakequiz.org) and answer a few more questions about your home. After that, you’ll be given specific next steps and resources to help you address potential problems.



### This home may also have

- Crawl Space – p. 8
- Living Space Over Garage – p. 12
- Split Level – p. 18

# Split Level Home

Split level homes come in a variety of shapes and sizes. The split level can be an architectural feature or be a result of sloping ground, or a garage with a living space above. Sometimes a split level home can be identified from the outside, but often verifying features are needed on the inside – mainly steps between rooms that don't go up or down a full story.

## Identifying Features

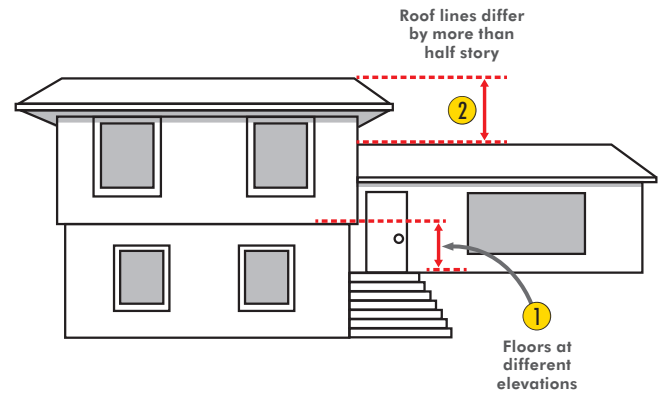
- 1 Floors that are at different levels, but less than one full story difference.
- 2 Roof lines that are at different levels, but less than one full story difference.

## Common Problems in an Earthquake

In an earthquake, the home may respond as two separate sections, one on each side of the shared wall. Separation between the sections can occur at the shared wall, with the possibility of severe damage or partial collapse. If the split level home also has a living space over garage or a crawl space, these elements can also fail as described in other sections.

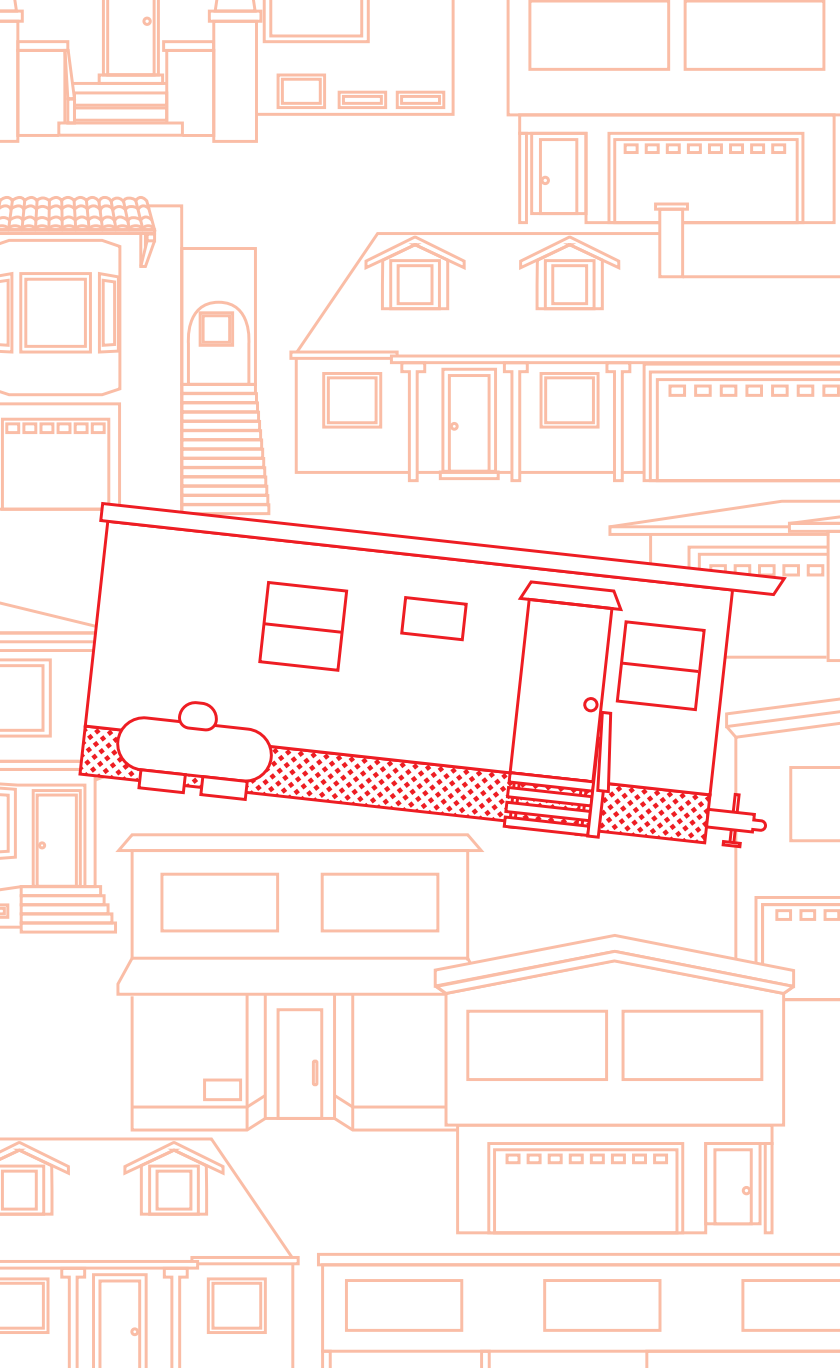
## What to do Next

Go to [homequakequiz.org](http://homequakequiz.org) and answer a few more questions about your home. After that, you'll be given specific next steps and resources to help you address potential problems.



### This home may also have

- Crawl Space – p. 8
- Living Space Over Garage – p. 12
- Built Into a Steep Hillside – p. 16



## Mobile or Manufactured Homes

Mobile and manufactured home communities have experienced higher concentrations of damage in past California earthquakes. After earthquakes, many mobile homes required lifting and setting the mobile homes into their original positions, while others were unreparable. In the 1994 Northridge earthquake in Southern California, half of the mobile homes in areas of strong shaking fell off of their supports, and an additional 10% had other forms of damage. In the 2014 South Napa earthquake, in certain mobile home communities, 25% of homes shifted off of their supports.

Use this Field Guide to identify what possible problems your home may have, and take the Home Quiz for more detailed information about potential problems and a list of things you can do to avoid damage and make your property safer.

# Mobile or Manufactured Home

Mobile and manufactured housing is found in pockets across the Bay Area. The walls of mobile homes are fairly seismically resilient because they are designed to resist high wind loads during transportation, but the homes are often highly vulnerable because many do not have a proper bracing system below the floor or a proper foundation.

## Identifying Features

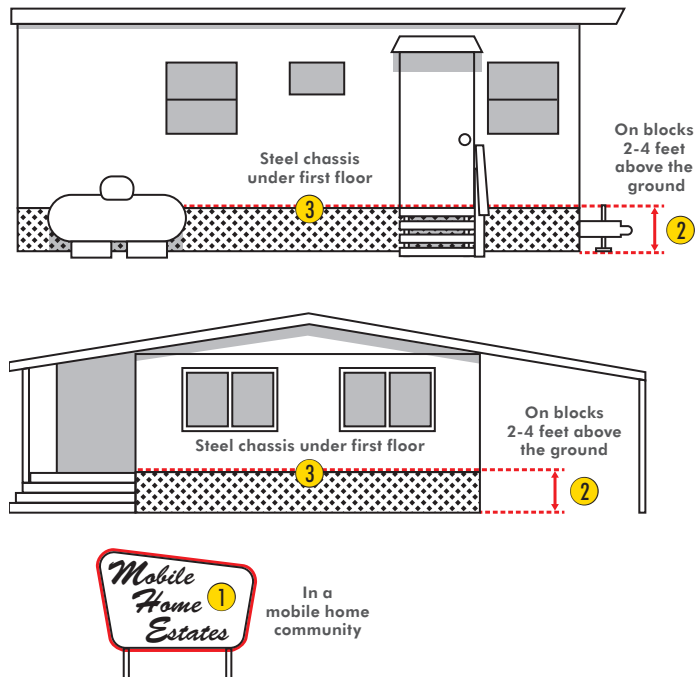
- 1 The homes are often in a neighborhood specifically designated for mobile or manufactured housing.
- 2 The homes are often placed on concrete blocks or steel piers 2-4 feet above the ground.
- 3 Most manufactured and mobile homes have a steel chassis under the first floor, enclosed by covering panels of aluminum or plywood.

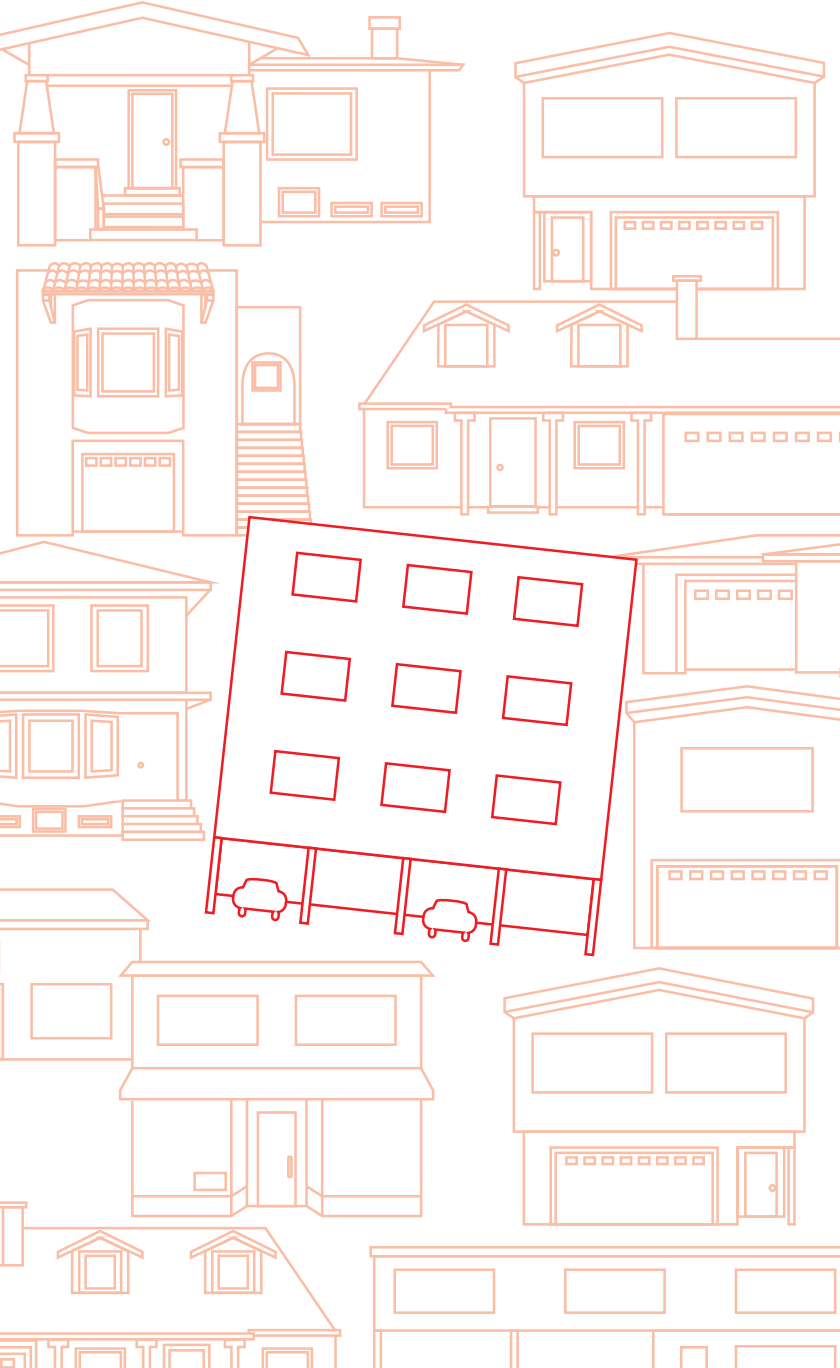
## Common Problems in an Earthquake

In an earthquake, these homes can fall off their supports, damaging the home and rupturing utility connections (gas, water, sewer) which can cause fires.

## What to do Next

Go to [homequakequiz.org](http://homequakequiz.org) and answer a few more questions about your home. After that, you'll be given specific next steps and resources to help you address potential problems.





## Multi-Family Homes

Multi-family homes in the Bay Area are built in a wide variety of types. They can be apartments or condominiums, sometimes with small businesses or parking on the first story. Similar to single family homes, there are potential seismic problems in many types of multi-family buildings.

The focus of this guide is on wood frame multi-family housing, typically fewer than 5 stories. Multi-family homes of all heights can also be built of concrete or steel. Older concrete and steel buildings can be vulnerable to damage in earthquakes but are not addressed here; see page 32.

Some smaller (duplex, triplex and quadplex) buildings might not match a building type in this section but may be more similar to a type described in the Single Family Homes section.

Use this Field Guide to identify what possible problems your home may have, and take the Home Quiz for more detailed information about potential problems and a list of things you can do to avoid damage and make your property safer.



# Wood Frame With Soft, Weak Story or Open Front

## Also Called: Soft Story

Many wood frame apartment and condominium buildings have openings on the ground floor to allow for parking or storefronts. Buildings of this type built before 1978 may be unable to resist earthquake shaking in the bottom level, and even some built before 1995 may have potential problems. Some Bay Area cities have created lists of potential soft story buildings that residents can use to look up addresses, with some cities even requiring retrofit.

## Identifying Features

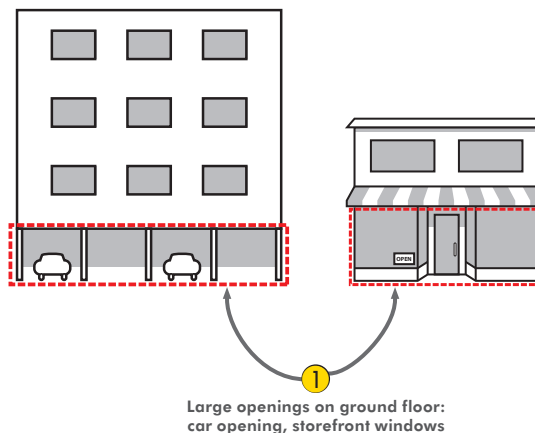
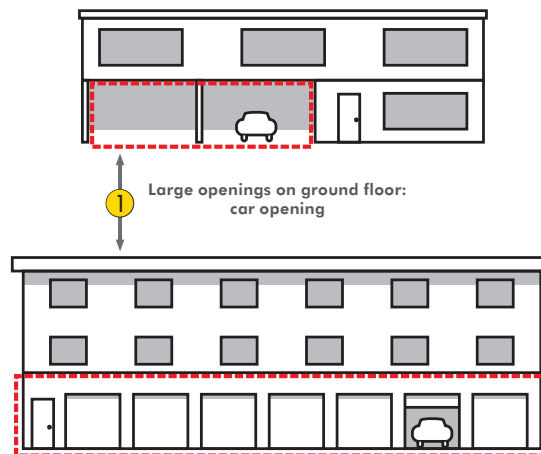
- 1 First story consists primarily of large openings (garage doors, garage spaces, large storefront windows) with mostly residential units above.
- 2 The ground floor is constructed with wood frame.
- \* If your building is constructed with concrete, or cinder blocks on the first story it is not a wood frame soft story building. It is likely a “podium building” (not shown in this guide).

## Common Problems in an Earthquake

The ground floor has more large openings, and fewer walls than the floors above it, so it is less able than upper stories to resist shaking. In an earthquake, the lower story can tilt sideways or collapse, resulting in total loss of the building and a significant risk to life for occupants. If the building does not collapse it may tilt permanently, which would displace tenants.

## What to do Next

Go to [homequakequiz.org](http://homequakequiz.org) and answer a few more questions about your home. After that, you'll be given specific next steps and resources to help you address potential problems.



## Wood Frame Without Soft, Weak Story or Open Front

There are many wood frame multi-family buildings that do not have any large openings on the first story. Many are two stories, but they could be as high as five stories. The walls may be covered by wood siding, stucco or brick veneer. In earthquakes, these buildings tend to perform well – problems occur if the building also has a crawl space below the first story.

### Identifying Features

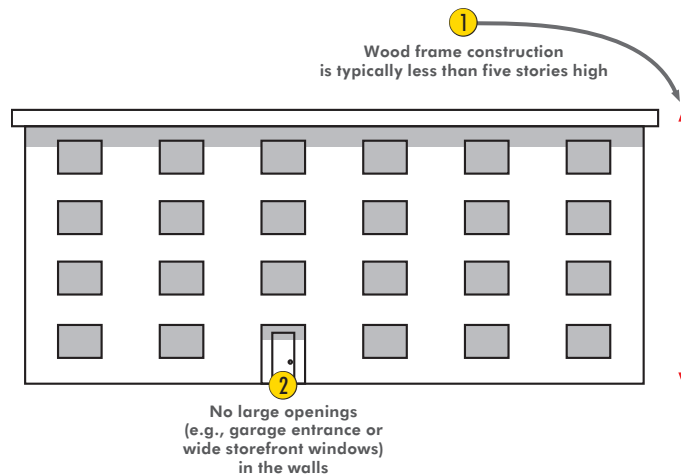
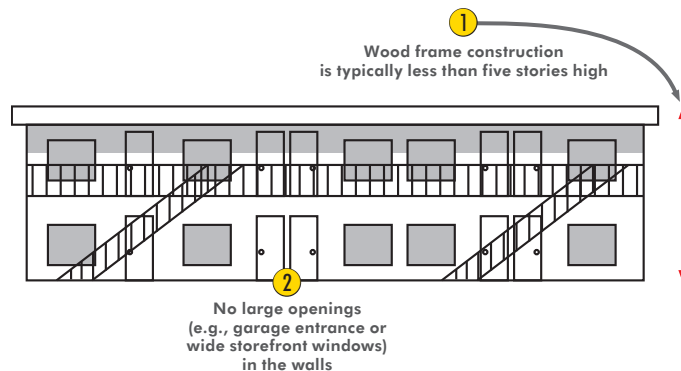
- 1 Wood frame construction is typically less than five stories high.
- 2 There are no large openings (garage entrance, wide storefront windows) in the walls.

### Common Problems in an Earthquake

In an earthquake problems may occur if the foundation is a crawl space or slab foundation. If the base is a crawl space, the building can fall off the foundation. If the building is on a slab foundation it may shift and lean in an earthquake. For more detail on problems in an earthquake look at Crawl Space or Slab Foundation in the Single Family Home Section.

### What to do Next

Go to [homequakequiz.org](http://homequakequiz.org) and answer a few more questions about your home. After that, you'll be given specific next steps and resources to help you address potential problems.



### This home may also have

- Crawl Space – p. 8
- Slab Foundation – p. 10

# Unreinforced Masonry or Stone

## Also Called: URM

While relatively uncommon as a Bay Area housing type, residential buildings built exclusively with brick or stone (unreinforced masonry) are some of the most dangerous buildings in earthquakes.

These types of buildings rely on bricks or stone and mortar for their structure, and do not have a separate wood or steel frame.

In California, a building code change in 1933 eliminated the construction of most new unreinforced masonry buildings. Most Bay Area cities have identified their URM buildings. Many cities have mandated strengthening, but some have not.

## Identifying Features

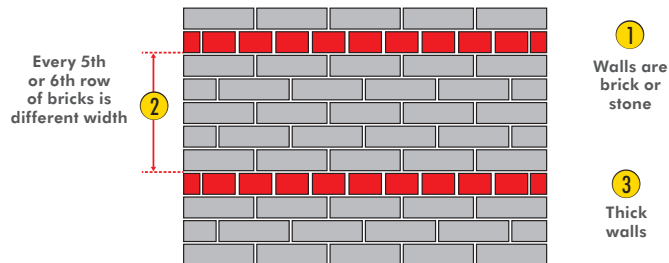
- 1 Have walls made out of brick or stone. Bricks may be visible on both the outside and inside walls.
- 2 If every 5th or 6th row of bricks has a different width (because it has been turned perpendicular), this indicates that the wall is a likely a structural brick wall, not just a decorative siding.
- 3 May have thick window sills due to thicker walls (more common in stone buildings, but may also be seen in brick buildings).

## Common Problems in an Earthquake

In an earthquake, the entire building or individual building components (sections of walls above roof line, portions of walls) can collapse, killing or injuring people inside and around the perimeter of the building. The first component to fail is often the bricks at the top of the building that extend above the roof. Walls can collapse inward or outward onto streets, sidewalks, or neighboring buildings. The roof can collapse inward.

## What to do Next

Go to [homequakequiz.org](http://homequakequiz.org) and answer a few more questions about your home. After that, you'll be given specific next steps and resources to help you address potential problems.



## Other Multi-Family Building Types not Included

There are other multi-family building types in the region that also have potential seismic problems. Concrete and steel buildings are not covered in this document because they can be difficult to identify visually without an engineer. Most structures taller than five stories are concrete or steel frame construction, but these building types may also exist for buildings less than five stories.

## Common Problems in an Earthquake

There are many different construction methods for concrete and steel buildings. Many perform well in earthquakes, while others are known to be a risk for collapse or experience irreparable damage, especially if they are older buildings. At this date, we do not have good simple guidance for non-engineers to identify deficiencies in concrete and steel buildings.

## What to do Next

The best approach for these buildings is to have a licensed engineer perform a preliminary seismic evaluation of likely problems. You can go to [homequakequiz.org](http://homequakequiz.org) and answer questions about mapped geologic site conditions.

## Glossary

**Anchorage** – Hardware used to connect parts of structures together and to the foundation, such as, nails, sill plates or bolts.

**Building Code** – Set of rules that specify the standards for building construction, updated every few years. In California the building code has improved over time as more knowledge of earthquake-resistant design has been developed. Buildings built to older codes are typically less earthquake-resistant.

**Chassis** – Manufactured housing is often built on top of a steel chassis which is a rigid base, allowing for transportation of the manufactured housing.

**Concrete and Steel Frame** – The frame of a building gives a structure support and shape. The structural support elements in concrete or steel frame buildings are made with concrete or steel. Large residential buildings, or buildings designed for commercial, retail or office uses are often built with concrete and steel frame elements. These buildings may be difficult to identify without an engineering background or access to building plans.

**Cripple Wall** – A wood wall that encloses the crawl space (unoccupied space) under the first floor of a wood frame home.

**Footing** – A footing is a concrete or masonry foundation element that sits on the soil and forms the base on which a home is constructed. Footings at a home perimeter are often continuous strips of material.

**Inhabited** – Spaces of a building that are designed to be occupied and used by people. Uses of inhabited spaces include living areas, offices, shops and parking.

**Magnitude (M)** – A number that characterizes the relative energy release of an earthquake. Magnitude is measured on a logarithmic scale, which means a magnitude 7.0 earthquake is 33 times more powerful than a 6.0 earthquake.

**Modified Mercalli Intensity (MMI)** – Estimates the intensity of shaking from an earthquake at a specific location by considering its effects on people, objects and buildings. The scale runs from 1 to 12. Poor performing buildings can be damaged in MMI 7, with some collapsing in MMI 8 and many collapsing in MMI 9. Well-constructed buildings may also be damaged in MMI 9 shaking intensity.

**Partially below grade** – An area of a building that is built below the ground level along the surrounding exterior walls.

**Piers or Posts** – Vertical members between the ground and first floor of a building. They support the home vertically, but are often not designed to support a building that is shaken sideways in an earthquake.

**Podium Building** – In a multi-family residential building, a ground story constructed of concrete or masonry while the stories above are wood frame. The ground story is often used for parking or shops.

**Possible or Potential** – The field guide generalizes common problems found in Bay Area housing. In this guide, the word “possible” or “potential” means something might happen but is not for certain.

**Safety Risk** – In earthquakes, building failures can cause injury or death to inhabitants. Some earthquake damage to buildings doesn’t present a safety risk to humans, but other damage can injure and in some cases be fatal. The online Quiz addresses safety risks from nonstructural elements like furniture and appliances.

**Soft Story** – Describes buildings that lack sufficient bracing to resist earthquake shaking. Soft story buildings are often identifiable by the presence of large openings for windows or parking stalls in the building’s perimeter walls. Also called “wood frame with soft, weak story or open front.”

**Unreinforced Masonry (URM)** – Brick or stone wall construction that does not have embedded steel bars (reinforcing). Newer masonry construction has embedded steel bars that strengthens it for earthquakes. Embedded bars were not included in older masonry construction, making it vulnerable to earthquake damage.

**Unfinished** – In many homes the first floor of a building, the garage, or the portion of a home built into a hillside remains unfinished. Unfinished spaces often have exposed interior walls that lack interior drywall or plywood, and can be less resistant to earthquakes than finished spaces.

**Uninhabited** – A portion of a building that is not designed for people to spend time. Examples of common uninhabited space are crawl spaces and other unfinished areas.

**Veneer** – A finish material applied to the outside of a wall, most often made of brick or stone.

**Wood Frame** – The frame of a building gives a structure support and shape. The interior walls in wood frame buildings are made with wood. Because the wood frame is covered by a range of materials (plywood, wood siding, stucco and drywall) it can be difficult to know that it is wood frame. Most single family homes in the Bay Area are wood frame buildings, and most residential multi-family structures less than 5 stories are also wood frame.

## Credits

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