



PERSPECTIVES

Major Earthquakes: What to Expect During & After Seismic Events

Our perspectives feature the viewpoints of our subject matter experts on current topics and emerging trends.

INTRODUCTION

Consider the things you rely on during a normal day that support your routines and well-being—lifelines such as electricity, water, gas, roadways, public transportation, bridges, and others commonly thought of as essentials such as the internet, your phone, your home, your vehicle, and much more. You use them so frequently that you may not give them a second thought. However, any of these can be lost in less than a minute during a major earthquake.

Major earthquakes have potential to cause serious harm to life, property, and infrastructure. What makes them particularly dangerous is the fact they commonly strike with little or no warning. Therefore, it is important to understand what to expect during and after this type of catastrophe and to be prepared to ensure your own safety and that of others.

Damaging earthquakes are generally considered to be those with moment magnitudes of 5.0 or higher. These are the events that one should prepare for. The Moment Magnitude Scale (MMS) is a measurement of the release of energy at the epicenter of the seismic event. The MMS is also a logarithmic scale, meaning each whole number on the scale is ten times stronger than the preceding whole number. For example, a magnitude (M)7.0 earthquake is 1,000 times stronger than an M5.0 event.

The magnitude of an event is, however, often not a good gauge as to what effect it can have on one's location. Factors such as distance from the fault, soil type, topography, and other conditions can affect the intensity of shaking that may occur at any given location within proximity of the epicenter. It is also important to note that the original shock from an event may be only the beginning of a series of seismic events and other hazards that prolong the period of potential danger and damage.

The purpose of this paper is to provide general information regarding:

- How to safely respond to the immediate effects of a major earthquake.
- What to expect and do in the days and weeks following a major earthquake.

- How to prepare and plan for major earthquakes and their long-term impacts from both a physical and economic standpoint.
- How building code seismic design requirements help to ensure that structures are prepared for seismic events.

WHAT TO EXPECT AND DO DURING A MAJOR EARTHQUAKE

During an earthquake, the most immediate and noticeable effect will be powerful shaking that, depending on its intensity, will cause minor to severe damage to buildings and infrastructure. For this reason, countries around the world have seismic codes to help engineers design seismically resilient structures.

Still, the main objective for modern seismic design is the preservation of life and public safety. With this in mind, we expect structures to suffer damage while safeguarding the occupants within and people nearby. Walls will groan and crack. Windows will rattle and possibly shatter. Water and gas lines may break. Non-structural items that are improperly attached to the building might fall or tip over. Before these things occur, you should know what to do to avoid being injured.

Avoiding Injury & Harm During an Earthquake

Many earthquake-related injuries and deaths happen because of falling objects. Be aware of your surroundings, taking note of particularly heavy or tall furniture (see Photo 1), chandeliers and ceiling fans, and/or any fixture or appliance that can fall or fly during the shaking. Stay where you are, whether inside or outside. Follow the “Drop, Cover, and Hold On” protocol: drop to the floor or ground, seek cover under a table, desk, or other sturdy piece of furniture, and hold on to the item, which may move during the quake. If you cannot find appropriate cover, move away from windows, get next to an interior wall (if inside), and drop to the ground, covering your head and neck.¹

¹ <https://www.shakeout.org/dropcoverholdon/>

If you are in your bed or in your car and under any structure (e.g., a bridge or a parking garage), you should either lie down next to your bed or exit the vehicle and lie down next to the vehicle (not under the bed or under the vehicle) and cover your head. Doing this allows the bed or vehicle to bear the impact of falling debris and creates a triangular, protective pocket around your body. This “triangulation” helps prevent debris from falling directly on you (see Photo 1 for an example of a situation where triangulation may come into play). In the event of a major collapse, it can also create an air cavity, allowing you to breathe prior to rescue.



Photo 1 - Heavy bookcases, boxes, and shelving toppled during an earthquake (Credit: [USGS Denver Library Photographic Collection](#))

Hold on for as long as the shaking lasts. Generally, an earthquake lasts only a couple of seconds, but the shaking from major quakes can last 45 to 90 seconds. In the moment, it might feel like a lifetime is passing, but remember that the shaking will end soon and that avoiding injury is much easier when you remain calm.

Some additional advice to remember includes:

- Do not go under a door frame. Door frames, like the walls they are within, are relatively thin and would not provide suitable protection from flying or falling objects.
- Get away from windows or furnishings with glass. Glass may shatter during an earthquake, and the shaking can throw shards several feet from a window.

- Resist the urge to run. Ground motion during an earthquake can be violent, and it is not uncommon for people to trip, fall, or sustain injury while trying to “outrun” an earthquake. Do not run outside as you can be hit by falling debris.
- Stay out of elevators. Modern elevator cars are designed to stay put during an earthquake, but they will shut down to do so, even if the power remains functional.
- If you are outside, avoid areas near or below building facades, power lines, gas lines, streetlights, and utility poles. Be aware of downed power lines in water as they may create risk of electrocution.
- Do not stand near an exterior building wall. Items projecting out of buildings, such as chimneys, glass from curtain walls, and facade cladding are all considered non-structural items and can be minimally attached to the structure. If the connections fail, these non-structural elements can cause personal injuries and deaths.
- If you are in your car, move your vehicle to the curb or side of the road and away from utility poles. Do not leave your vehicle except in the case that you are under a suspect structure such as a bridge or parking garage. Wait for the shaking to stop.



Photo 2 - Soft story collapse resulting in crushed vehicles, (Credit: [USGS archive](#))

WHAT TO EXPECT AND DO IMMEDIATELY AFTER A MAJOR EARTHQUAKE

Following a significant earthquake, first make sure you are not injured. Assess your health status before attempting to support those around you. If you are trapped, with no way of communicating with anyone nearby, try to make noise, as this may aid rescuers in locating you.

Staying Safe Following an Earthquake

Stay away from ocean shorelines, lakes, reservoirs, and other bodies of water. A tsunami (wave in the ocean) or seiche (wave in a lake) event can follow a major earthquake. An early sign of a tsunami is the sudden recession of water from the shoreline of the ocean. If you see water receding, do not stay on or near the shoreline, and seek higher ground immediately. A seiche is an oscillation of water within a lake or pond. Seiches can produce unexpected waves that can injure people on shorelines or drag them into the body of water.

Avoid driving immediately after an earthquake, as there could be significant damage to infrastructure and streets need to be clear for emergency responders (See Photo 3).



Photo 3 - A destroyed segment of the I-5 Freeway in Northridge, California; 1994 (Credit: [FEMA/Wikimedia Commons](#))

Monitoring the news and official disaster management agencies' broadcasts will help you stay informed and help you make appropriate decisions for you and your family. Only after ensuring you are safe and unharmed should you attempt to check on those near you. This is a good reason to have a battery-powered radio on hand.

Inspect your home for gas, electric, and water line damage. If you suspect any damage, shut off the valves. If you smell gas, open the windows and doors, leave the house, and contact the authorities immediately. Do not ignite any flames or operate wall switches if you detect the smell of gas (or propane) as any spark could ignite an explosion. Again, be particularly wary of power lines in water.

If your home or building is damaged during the earthquake, do not seek re-entry. Stay out until the property is assessed by a qualified authority. When exiting a building, be mindful of overhead objects that might be detached from the facade, such as chimneys, awnings, or parapets. Remember that aftershocks are a distinct possibility, and in some instances, they can be more damaging than the initial shock, particularly in a structure that was damaged by the initial quake.

After a major earthquake event, you should generally expect and be aware of:

- Emergency responders and hospitals being overwhelmed.
- Communications being overloaded or disabled, including:
 - » Phone lines overloaded or downed (8-12 hours initially, and limited or unreliable after).
 - » Broadcasts interrupted, including loss of internet connectivity (TV, mobile, internet).
 - » Cellular networks may be out of commission.
- Transportation infrastructure damaged and/or overloaded, including:
 - » Roadways that are damaged or overloaded with traffic.

- » Bridges and overpasses that have failed or traffic that has been rerouted to already-crowded streets.
- » Airports, bus and train stations, and other forms of transportation may be shut down.
- Utilities interrupted:
 - » No power or utilities at homes or businesses (8-12 hours initially, and limited or unreliable for days to months after the event).
 - » No supplies purchasable with electronic or digital payment.
 - » Gas station pumps and ATM machines may be inoperable.
- Secondary hazards, such as:
 - » Fires from damaged gas and electrical utilities.
 - » Compromised utility lines (gas leaks, bare electrical wires, gushing pipes, etc.).
 - » Chemical spills.
 - » Contaminants in the air.
 - » Public panic, confusion, and disorganization.
 - » Exposure to weather (hot, cold, rain, etc.).
 - » Crevices that have opened in the ground, sink holes, or surface offsets.
 - » Tsunami waves and seiches.

WHAT TO EXPECT IN THE DAYS AND WEEKS FOLLOWING A MAJOR EARTHQUAKE

As with other disasters, the days and weeks following a major earthquake can produce stress, anxiety, and other challenges. Major earthquakes will generally be accompanied by numerous aftershocks that often have magnitudes and intensities near that of the initial event and, in some cases, equal to or greater than the first shock.

Aftershock Events and Impacts

Aftershocks are smaller earthquakes that occur after a larger seismic event and within the same fault system. The magnitude of aftershocks varies, with the largest being generally one magnitude level less than that of the main quake. It is not unusual for aftershocks to number in the hundreds and occur over a period of several weeks, or even months or years after the main quake. However, over time, the magnitude and frequency of aftershocks will continue to decrease. Aftershocks occurring soon after the main quake will typically be large and felt by most people in the vicinity of the earthquake, but later aftershocks (often only hours or days later) will not be noticed by most people.

Although not as strong as initial quakes, aftershocks present a hazard to structures that were damaged by the main quake. If a building experienced moderate damage during the initial event, a strong aftershock may have sufficient energy to cause further damage to the already-compromised structure. For this reason, it is important for first responders and others who are accessing earthquake-damaged buildings soon after an event to follow recognized safety protocols to minimize the potential for injury in the event a building or portion thereof collapses or becomes otherwise dangerous during an aftershock. In some instances, the initial shock is what is known as a foreshock, and the larger main shock can occur after the initial shock, similar to aftershocks. The designation of these types of events will only happen after all events have occurred.



Photo 4 - Structural collapse of a five-year-old parking garage in Northridge, California; 1994. (Credit: [USGS archive](#))

Damages and Impacts to Infrastructure

Major earthquakes can have immediate and lasting effects upon public infrastructure. Buried utilities, such as water distribution systems, wastewater systems, and electrical or gas utilities can be significantly damaged by ground ruptures and liquefaction that often accompany large earthquakes. If a water supply becomes contaminated during a seismic event, the needed repairs can take weeks or months to complete. Roadways, bridges, and train rails can also be displaced and severely damaged by earthquakes. Such disruptions in the transportation networks can isolate neighborhoods and communities for days to weeks after a significant earthquake.

In the event of extensive damage to residential structures, hotels and other lodging options can be overwhelmed as displaced residents seek other accommodations, often on a long-term basis. This also presents a challenge to first responders that may be called in from outlying areas or from other states.

Economic Impacts

Major earthquakes also have the potential to disrupt local, regional, and global economies. Businesses may close due to damaged facilities or the loss of customers and

employees who had to relocate for suitable lodging. There may be a lack of reliable power or utilities for business to operate. Additionally, roads, railroads, airports, and ports may experience logistical problems causing a delay in receiving goods, and, as a result, businesses may be unable to provide goods and services as before. Many employees may be furloughed for several weeks to months while their businesses are repaired and restored to normal or modified operations. Supply chains are disrupted by failures in the transportation network, manufacturing, and possible material shortages.

The impact to businesses can generate a significant worldwide event due to related global supply chain issues. For example, the 2011 Great Tohoku Earthquake in Japan affected global automobile production, both because of shortages of cars produced in Japan and supply of critical parts such as semiconductors, gearboxes, and other components which also affected assembly plants across Europe and North America.

A recent earthquake demonstrated the possibility of compounded problems with multiple, coincident disasters. The March 18, 2020 M5.7 earthquake in Magna, Utah (within the greater Salt Lake City area) occurred soon after widespread shutdowns were enacted due to the COVID-19 pandemic. The pandemic had already substantially decreased availability of various commodities, most notably certain food staples (meats, flour, sugar, etc.), bottled water, and toilet paper. Hundreds of thousands of workers were also working at home, furloughed, or otherwise economically affected by the pandemic. Fortunately, that seismic event was not long in duration and did not result in widespread, catastrophic damage to buildings or infrastructure. Thanks to decades of awareness of a major earthquake event in the Salt Lake City area, prior rehabilitation of older buildings and emergency preparedness of the general public helped minimize the combined effects of the pandemic, the earthquake, and its aftershocks.

HOW TO REDUCE NEGATIVE IMPACTS OF MAJOR EARTHQUAKES

For our own communities, families, and loved ones, preparation for a seismic event can help reduce the negative effects and prolonged impacts. Preparation can be focused in two phases:

- A first phase immediately after the event.
- A second phase that provides tools for the days and weeks after the event.

First Phase Preparation

General safety skills can be learned beforehand to reduce the negative impacts of an earthquake. Learning first aid skills (dressing wounds, CPR, etc.) and knowing how to use a fire extinguisher can help you respond immediately after an earthquake occurs. Additionally, knowing how to shut off natural gas and water supplies will help minimize issues with utilities. Once you learn these skills, encourage family members and friends to do the same so they may be better able to care for themselves regardless of where they (or you) are.

In some regions, government agencies and commercial entities have developed systems to warn the public of imminent seismic activity. For example, a smart phone app utilizes real-time data from an extensive network of ground motion sensors that can provide a few seconds of warning to residents of California, Oregon, and Washington so they have time to take cover before the shaking reaches them.

Second Phase Preparation

Basic preparation supplies recommended by FEMA and the American Red Cross include:

- At least three (3) days of supplies for each person in a group for evacuation and two-weeks of supplies for being at home. This would include one gallon of water per person per day and non-perishable, easy-

to-prepare food items that are familiar to you/your family. Remember that gas or electricity may not be available for this preparation and that you should never ignite and use a charcoal barbecue indoors for cooking or heating.

- Evacuation supplies should be packed and ready to grab and go at a moment's notice (a go-bag). You may not have enough time to safely gather such items from throughout your house or office after an earthquake or other disaster has occurred.
- Other supplies include batteries, a flashlight, a battery-powered or hand-cranked radio, a first aid kit, a whistle, and emergency blankets. Consider including paperback books, card games, or other things to pass the time.
- Be sure and have extra essential medications on hand.
- Cash is helpful to have as ATM machines and other sources for getting cash may not be available and credit card transactions may not be possible.

Discussing a plan for the event is another way to be prepared. Think about the places you could be when the event happens—home, work, in your car, etc.—and the possibility you could be separated from your family. Having a communication plan in place is important; this could include establishing a point of contact outside the affected area with whom everyone can check in as well as written emergency numbers in case mobile phones do not work. Identify safe places to gather after an earthquake, such as a nearby relative or friend. Inquire about emergency plans established by your city or county officials, which will likely include emergency shelters and check-in locations for scattered family members.

Just as important as having a plan for what to do after an event is ensuring your space is as prepared as possible. To reduce danger ahead of time in your home or office, make sure large/heavy objects are secured against falling during ground motion. This would include bookcases, televisions, tall dressers, large paintings, and mirrors that should be properly anchored to the walls. Items that can fall on people while they sleep should be relocated. Water heaters and chimneys should be properly strapped to the structure, and general egress paths should always be clear.

FINANCIAL PREPARATION

Personal

Although most of us think about the physical damages caused by an earthquake, there can also be a financial impact. Being prepared financially may include:

- Storing the contact information of your preferred local repair resources (plumber, electrician, handy man, etc.) on your phone and somewhere in the cloud so you can access the information if your phone is unavailable. Keep a paper copy in your emergency go-bag.
- Storing the contact information of your insurance provider, with policy numbers, if possible. These resources may be inundated following an earthquake.
- Storing copies of important documents, such as passports, marriage licenses, birth certificates, immigration paperwork, etc., which may be damaged or unavailable following an earthquake.
- Taking essential banking documents and internet banking tokens with you in the event you need to evacuate.
- Taking a quick video of your home and its contents.

Business

You should also be prepared for the impact an earthquake can have on your business operations. In addition to the information listed in the previous section, there are additional considerations for a business. For instance, if a location or multiple locations were damaged, can you access the necessary information to continue operations elsewhere? The following might be useful:

- A listing of employees' names and phone numbers.
- Access to suppliers' and vendors' contact information.
- Current inventory, accounts receivable, and accounts payable information. This should be backed up to the cloud so that it can be accessed remotely.

- Back-up of Financial Statements for the past five years. This could be helpful in filing for an insurance claim following the earthquake, for obtaining state or federal funding, or even applying for a loan.
- A quick video of your business operations, facility, equipment, and inventory.

Additionally, in preparation for an earthquake, it might be prudent to review your insurance coverage. Would you have adequate coverage to return your business back to its previous operations? For businesses, where practical, ensure appropriate policy coverage (covering property and consequential losses) and an appropriate business continuity plan are in place.

It is important that a business continuity plan considers earthquake damage to its own premises in addition to those of key suppliers, utility providers, customers, as well as potential damage within the vicinity which could potentially give rise to denial or hindrance of access or result in a loss of attraction. Some of these scenarios will likely require insurance coverage, and businesses are advised to discuss with their advisors and brokers to identify the relevant risks. Businesses may also wish to consider whether key suppliers have their own business continuity plans and perhaps stipulate certain insurances contractually. Concentrated risk, such as sole supply or even dual sourcing from a similar geographic region, may give rise to an undue level of risk.

Consideration should also be given to outsourcing of IT systems and support, or payroll which will be critical to ongoing business operations as well as ensuring off-site back-ups of critical documents.

BUILDING SEISMIC RETROFIT

Following historic seismic events, lessons learned regarding building performance and expected damage are identified. Modifications to improve the earthquake resistance of structures are incorporated into future editions of the building codes. Events that serve as examples of significant earthquakes—where lessons learned have resulted in a greater knowledge of building

performance and have resulted in significant changes in the design requirements for structures—include:

- The 1933 Long Beach Earthquake (M6.4).
- The 1971 San Fernando Earthquake (M6.6).
- The 1989 Loma Prieta Earthquake (M6.9).
- The 1994 Northridge Earthquake (M6.7).

Although there were other significant earthquakes in the past, these four events provided significant advancements in the United States' building code seismic design requirements.

To reduce the effects of the earthquake ground movements beneath structures, implementation of seismic improvements or retrofits is warranted in older buildings. Examples of seismic retrofits to homes and wood-framed residential structures include:

- Positive anchorage of the structures to their foundations.
- Bracing of cripple walls for crawlspace foundations.
- Reinforcement or securing of brick/masonry chimneys.
- Sheathing the wood framing of buildings with gypsum board or stucco walls with plywood.
- Utilizing wider framing members where forces dictate the tight spacing of nails.
- Improving shear transfer from the structure to the supporting foundation.
- Addressing the soft-story vulnerability in tuck-under parking (see Photo 4) of some multi-level apartment buildings with sheltered parking (not addressed by building codes in some areas of the United States).

Examples for commercial structure retrofit, in addition to the items noted above, would include:

- Anchorage of heavy walls (concrete, masonry) to their roof and floor framing.

- Strengthening or adding welded connections to dated seismic detailing.
- Addressing unreinforced masonry vulnerabilities with new steel elements or changing the lateral force-resisting system.
- Repairing and strengthening of rigid beam-to-column steel moment frame connections.
- Enhancement of concrete or masonry shear walls with high strength composites or shotcrete thickening of the walls.
- Replacement or strengthening of non-ductile concrete elements with better performing lateral force-resisting components.
- The addition of collector elements to ensure an adequate load path for seismic loads to lateral force-resisting elements.
- Improving strength and detailing of braced frame elements.

Ultimately, any type of strengthening in older structures will reduce the risk to life and safety during a seismic event. An engineer experienced in seismic design and retrofitting can provide recommendations on how to strengthen an existing building, improve its seismic response, and correct life safety issues. It should be noted that the building codes are tailored to the protection of life safety. Enhanced performance objectives can be desired by property owners, and essential facilities such as hospitals, police and fire stations, schools, and other public facilities have requirements higher than those for typical structures.

CONCLUSION

Major earthquakes have the potential to threaten life, property, and finances. What makes them especially dangerous and damaging are that they can, and most often do, occur with little or no warning; that they cause extensive and complex damage to buildings, infrastructure, and local economies; and that they can result in aftershock events that continue to complicate

existing damage and impacts. Learning about earthquakes, knowing what to expect during and after a seismic event, and adequate, informed preparation can each contribute to your personal safety and help you avoid making life-threatening decisions. Being aware of your own level of preparedness, at home, work, or elsewhere is critical to ensure that you are better protected from the structural impacts and hazards resulting from major earthquakes and related seismic events.

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