EARTHQUAKE

INTRODUCTION

Earthquakes are one of nature's most severe natural hazards. According to the United States Geological Society (USGS) between 2000 and 2012 there were over 332,700 recordable earthquakes worldwide. However this number low since the USGS stopped locating earthquake below a magnitude 4.5 outside the US in January 2009. The USGS estimates that several million earthquakes occur in the world each year, but many go undetected because they have very small magnitudes. There were a reported 34,743 earthquakes measuring magnitude 5.0 to 9.9 between 2000 and 2018. The top 10 costliest earthquakes that have taken place is shown in Table 1

TABLE 1
Costliest Earthquakes

Year and Location	Magnitude	Cost
2011 Tōhoku earthquake, Japan	9	$235 billion
1995 Great Hanshin earthquake, Japan	6.9	$200 billion
2008 Sichuan earthquake, China	8	$86 billion
2011 Christchurch earthquake, New Zealand	6.3	$40 billion
2010 Chile earthquake, Chile	8.8	$15–30 billion
1994 Northridge earthquake, United States	6.7	$20 billion
2012 Emilia earthquakes, Italy	6.1	$13.2 billion
1989 Loma Prieta earthquake, United States	7	$11 billion
1999 921 earthquake, Taiwan	7.6	$10 billion
1906 San Francisco earthquake, United States	7.9	$9.5 billion

Earthquakes tend to reoccur along faults or long breaks in the earth's bedrock. While sites of greatest hazard are identifiable, individual earthquakes usually occur without warning. They can affect wide areas of the land surface and cause almost total destruction of some structures. They can cause bodies of water to overflow and rivers to change courses. Earthquakes can set in motion the mechanisms for forming new bodies of water or for totally changing shorelines. They can permanently alter the land surface with consequent landslide, subsidence, uplift and dislocation of landmass in a matter of minutes. If earthquakes occur beneath the ocean, they can generate tsunamis.

Property damages will result depending upon the integrity and stability of the building, structures and contents; the distance from the focus of the quake; the magnitude of the quake; and the ground conditions of the building site.

“Earthquake resistant” or “earthquake proof” construction does not afford full protection against earthquake damage. These designs will prevent total collapse of the building based on a certain magnitude earthquake at a certain return period. There may still be significant damage.

New structures can be designed and built to withstand collapse; existing structures can be reinforced. Pre-emergency training programs can assist employees to prepare for such a disaster.

This section provides sufficient information to acquaint personnel with the hazard.

POSITION

Prepare loss-mitigating designs for new buildings and for reinforcement of existing buildings in accordance with local building design standards.[1] See PRC.2.0.9 for more details.

When evaluating a building for earthquake protection, physically inspect and estimate the potential for damage to building, stock, equipment and production techniques. A structural engineer familiar with earthquake motions should examine and analyze the building structural components.

To estimate the loss potential for non-structural features, inspect stock, equipment and production techniques. Consider indirect and consequential damage resulting from the earthquake shaking. Establish priorities and programs for loss prevention and control. Where hazardous materials are involved, take special precautions.

Loss Mitigation

Restrain objects that could be toppled by anchoring and fastening them at their bases and tops. Strap together shelving and file cabinets at top corners to form more uniform and stable shapes. Anchor floor mounted transformers and switchgear at their bases and brace at the top to the building structural elements. Sway brace and securely support ceiling tiles, light fixtures, diffusers and other hanging objects. Provide sway bracing for piping. Brace parapets, signs and other attached structures.

Restrain desktop equipment by hook and loop form fasteners or adhesive material. Provide secure bolting if necessary. Bolt desks, tables and workbenches to the floor. Anchor fragile, delicate and precision equipment subject to damage from vibration, bumping and falling. Stabilize stacks, piles, racks and shelving subject to toppling or falling. Label stock in open bins subject to spill and mixing.

Provide flexible connections for piping and wiring conduits. For example, anchor a suction tank to its foundation and anchor the pump and driver as a unit assembly to a base on the floor of the adjoining pump house. The tank will oscillate at a different frequency in an earthquake than at the pump house or the pump assembly. Provide flexible connectors in the piping between the pump and tank. Piping at building entrances, across faults and at ground type changes (soil vs. rock) should be flexible. Also provide emergency equipment, such as power generators, with this protection.

Provide isolation valving, excess flow devices and disconnects for water, gas and fuel, electrical supply and communication conduits. Loss prevention for public service utility connections and on-site service connections may be more complex. Provide adequate on-site control to retain these resources.

For additional details on how to mitigate the loss see PRC.2.0.9.1.

Pre-emergency planning helps to avoid property losses after an earthquake. Refer to *OVERVIEW* or PRC.1.7.0.1 for a discussion of good earthquake emergency planning and preparedness.

Earthquake simulation and training scenarios should involve general panic, partial building collapse, disruption of essential services such as electrical and water utilities, lack of public fire protection or police assistance, loss of outside communications, transportation disruption, and perhaps loss of key personnel.

After the initial earthquake shaking, shut off all power and isolate hazardous liquids and gases and extinguish open flames. Have the emergency coordinator assess damage to utilities and implement contingency plans. Begin salvage operations as soon as possible.

Because aftershocks can be as dangerous as the initial quake, keep nonessential personnel out of buildings and structures until the damage has been thoroughly evaluated. Document task requirements and assign responsibilities for nonoperating hours as well as for normal production periods.

Integrate earthquake emergency training with other existing programs. Make it an integral part of the overall emergency procedures program.

DISCUSSION

Water, gas and fuel, electrical supply and communication conduits (piping or wiring) may rupture. The potential for rupture is greater in installations involving brittle materials. Fire after an earthquake can lead to conflagration because of reduced firefighting capabilities. Damage to communication systems and roads will impede fire and other emergency traffic. Ruptured gas, water and electrical conduits will create other loss situations. Business interruption may become considerable.

Property damage from an earthquake will depend upon the magnitude of the event, the integrity and stability of structures, buildings and contents, the distance of a site from the focus of the quake, and the site's ground conditions.

Near the epicenter, low buildings are more likely to be damaged. Farther from the epicenter, tall buildings are more likely to be damaged because low frequency vibrations tend to retain their energy over longer ground distances.

Direct damage to buildings may include floor and wall cracks and fractures, and foundation-to-wall or roof-to-wall connection failures. The extent of damage may range from hairline cracks to major fractures and total wall collapse, possibly with toppling of entire structures. Loss of wall support can result in "pancaking" of building floors. Closely adjoining buildings, if rocking out of sync, may pound against each other. Wing structures may separate at the joining or suffer severe stress damage because of differential oscillation. Nonsupporting structures such as office partitions or nonbearing walls are susceptible to damage.

Older masonry buildings (pre-1940) may have unreinforced walls of brick or block which are easily cracked or broken and floors and roofs that are loosely connected. Tilt-up structures have reinforced concrete walls tilted in place. Wall-to-roof connection is typically weak.

During the fifties to mid seventies non-ductile reinforced concrete frame buildings were constructed. A brittle rather than ductile concrete frame was produced. The columns and beams of these structures formed the building frame and were designed to support the structures and resist horizontal forces as well. Load bearing walls were not provided. When these structures are overstressed in an earthquake, the frames can come apart and collapse, rather than simply bend with controlled cracking. Plain or unreinforced concrete is now considered too weak for structural members in earthquake prone regions.

Structures other than buildings subjected to the same seismic force are affected in a similar manner, depending upon size of the structures their shape, weight, height and construction. Stacks, towers, tanks, and reservoirs, whether elevated, on grade, or embedded in foundations, are subject to the oscillating motion of the seismic wave energy. The oscillation also causes liquid in storage to slosh. Reservoirs, treatment ponds and impoundments, settling ponds and clarifiers may have walls cracked, and embankments breached or overflowed. Brick and masonry stacks, silos and tanks can be damaged. Masonry can crack or fracture, and steel can be stressed.

Liquid in a vertical tank can slosh and produce stress beyond design load. Sloshing can topple tanks, buckle plates, pull anchor bolts, rupture base plates, and depress foundations differentially. Plate welds can fracture, cast flanges can crack, and tanks can slide sideways. Tank connections and risers can crack or break, and horizontal tanks can slide off saddles.

Contents of buildings, if not adequately supported or anchored, can be damaged. Fixtures, furniture and equipment will topple, fall, slide or tip. Shelving may sway, rock, tip, spill stock and collapse.

Equipment on desks or benches may slide, ceiling tiles fall, partitions crack and break, and glass windows break. Piled stock may topple. Equipment not properly anchored to the floor may slide or tip and pull wires and pipe connections. Inline units may misalign. Control equipment in particular may be susceptible to shaking. Container leakage can be a serious matter.

Building utilities such as boilers, pumps, piping, transformers, substations, emergency generators, wiring, water, air and gas lines will be exposed to oscillating motions. Underground piping is subject to rupture, offset, compression buckling, and joint rupture. Brittle pipe types (cast, PVC, asbestos cement) that lack flexibility may crack and fracture.

Structural damage to dams may result in flooding. Damage to some types of manufacturing plants can lead to hazardous substance spills or releases.

BACKGROUND

Plate tectonics is the mechanism of earthquake activity. The earth’s crust consists of 70 different plates, 15 major plates, 41 minor plates, 11 Ancient and 3 orogens plates. These plates move with individual characteristics (rates of movement, force and directions). The interaction at plate boundaries is seen as the cause of tectonic earthquakes. An earthquake is a sudden release of stresses causing a sudden movement of the earth. It is felt because of the vibrations generated by dislocation of work segments past each other. Areas of the earth’s surface subject to volcanism can also receive stresses on the crust, which are due to the movement of molten rock material and can generate an earthquake of volcanic origin.

As rock masses scrape against each other, they generate vibrations called seismic waves. These energy waves are radiated outwardly from the origin or focus of an earthquake through overlying rock strata and soil layers to the earth’s surface. The area effected by these seismic wave will depend on the soil conditions, bedrock and locations of faults. Seismic waves have a hard time passing through rock strata with faults, but the waves will be magnified by poor soil conditions such filled in land.

There are two types of seismic waves, body waves and surface waves. Body waves travel through the interior of the earth. There are two types of body waves, P-wave and S-wave. The P-wave or primary wave is a compressional wave (forward and backward motion) that is a fast moving shock wave. These are the tremors first felt during an earthquake. The P-waves can move over 1080 ft/s (330 m/s) in air, 3770 ft/s (1450 m/s) in water and 16,395 ft/s (5000 m/s) in granite. The S wave or secondary wave is a surface shear wave (side-to-side motion). Surface waves travel more slowly than body waves, about 60% slower that P-waves through solid objects. S-waves can not travel through liquids or gases. During an earthquake, the S-waves are the first set of strong violent waves felt because of their amplitude. Because of their low frequency, long duration, and large amplitude, they can be the most destructive type of seismic wave. There are two types of surface waves: Rayleigh waves and Love waves. Rayleigh waves, are surface waves that travel as ripples, while Love waves are surface waves that cause horizontal shearing of the ground.

The comparatively high rate of seismicity in the U.S. is in California. However, many parts of the U.S. are susceptible to earthquakes. Seismic activity maps are helpful in determining whether or not a risk is in a seismic area. Figure 1 shows locations where damaging earthquakes have occurred in the United States. Figure 2 locates notable historic U.S. earthquakes in the moderate or higher magnitude ranges. Figure 3 locates areas of high seismicity throughout the world. It also shows the boundaries of the tectonic plates.

The amount and extent of damage resulting from an earthquake bears a complex relationship to the energy release, or strength of the event. This feature of an earthquake is stated in various ways. Magnitude, seismic energy and intensity are well known references.

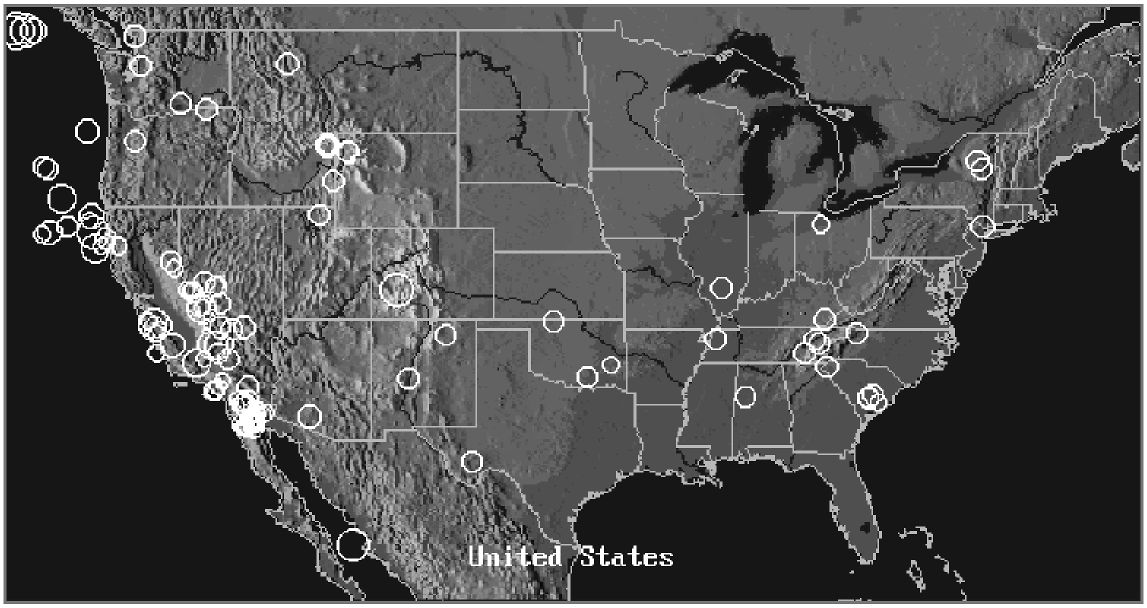

Figure 1. Locations Of Selected U.S. Historic Earthquakes.

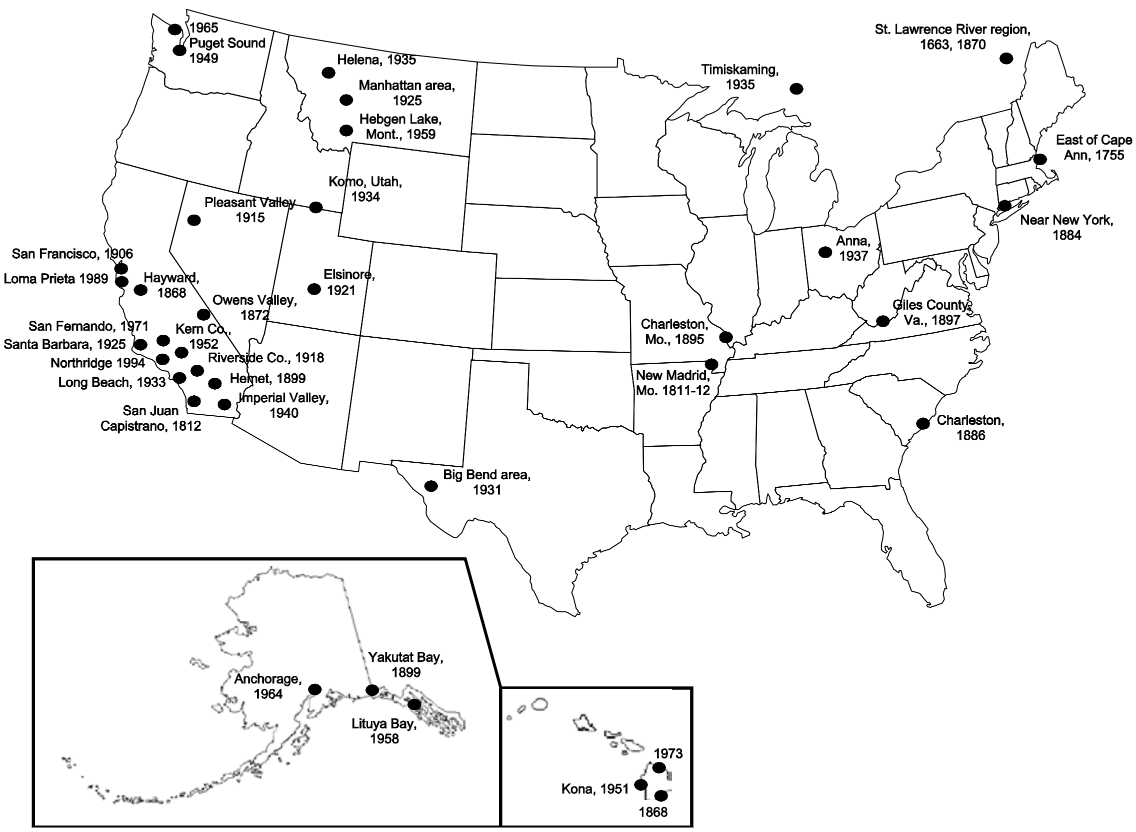

Figure 2. Notable Damaging U.S. Historic Earthquakes.

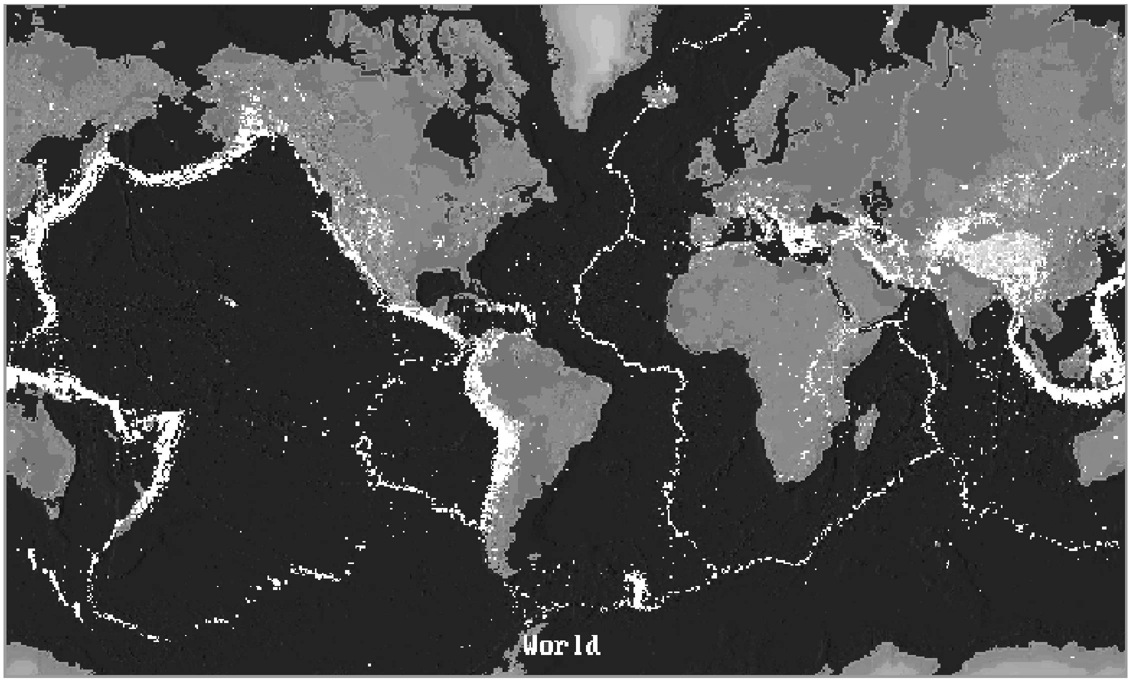

Figure 3. Global Earthquakes 1960 to 2005.

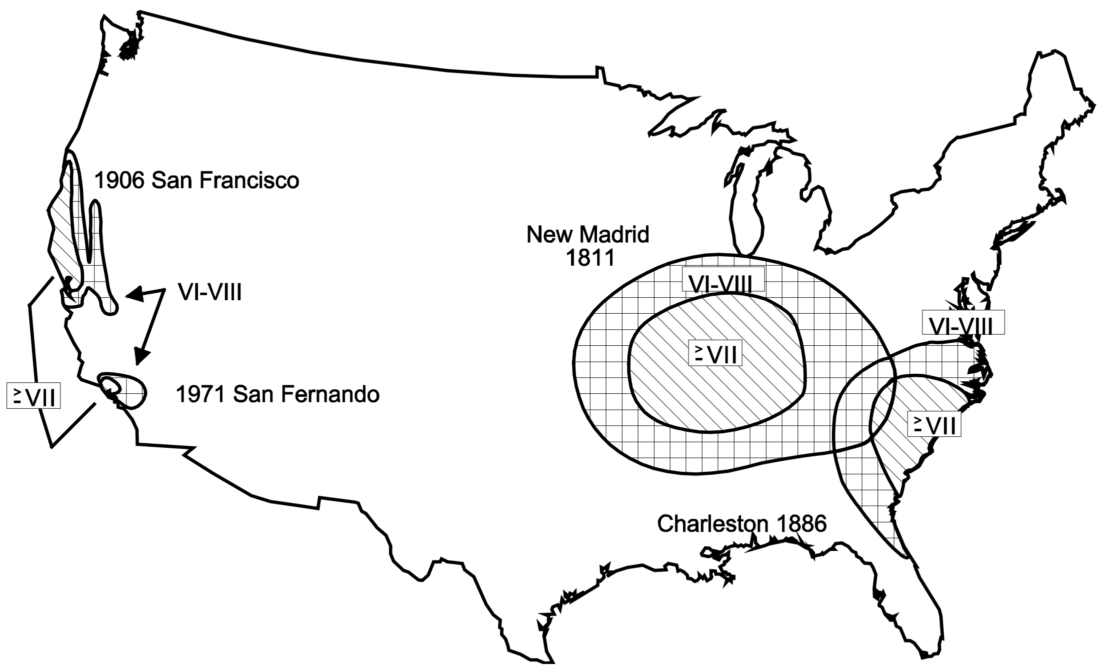

Figure 4. Ground Shaking Effects - Compare Eastern U.S. with Western U.S.

Magnitude, Seismic Energy and Intensity

Magnitude is the calibrated measure of the strength of an event at its source. The force is expressed as a fixed value. The U.S. currently uses the scale devised by seismologist Charles F. Richter, who defined magnitude as the logarithm, to the base 10, of the amplitude in millimeters of the maximum amplitude of seismic waves that would be observed on a standard torsion seismograph at a distance of 100 km (about 60 mi) from the epicenter. Magnitude characterizes an earthquake event at its source and is a fixed value.

Seismic energy is a measure of the strength of an earthquake in ergs. The energy release associated with an increase of one magnitude is not tenfold, as in the Richter scale, but about thirty times. In the 1964 Alaskan earthquake of magnitude 9.2, about 4.5×10^{25} ergs of seismic energy were released. The seismic energy of an earthquake is not usually given in media reports.

Another scale used by seismologists to measure the magnitude of the earthquake is the Moment Magnitude scale or "MMS." MMS is also logarithmic to express the terms of the energy released from the earthquake. The scale was developed in the 1979 as a successor to earlier Richter magnitude scale. The MMS was developed to handle larger magnitude, over 7.0 earthquakes and on those where the measurements were taken more than 350 mi (600 km) from the epicenter. The Richer scale was developed for medium-sized earthquakes, 3.0 to 7.0. The MMS is the scale used in press releases for all modern large earthquakes by the USGS.

The intensity is a non-instrumental measure of the “effects” felt at a location. During an earthquake event, seismic waves passing through varying types of rock, stratifications and soils have different effects in different locations. Descriptions by witnesses of the visual, audible and physical effects of the earthquake and damage at various locations are collected and categorized.

Intensity levels at different locations and distances from the epicenter are mapped. Intensity maps subjectively describe the effect at a location of interest. An event will have a single calibrated magnitude but will have intensity levels that generally diminish away from the epicenter. Figure 4 illustrates the incongruous nature of attenuation (decay rate) of seismic energy and the intensity of comparable magnitude events. Note that the intensity effects in California cover only a small area. In the New Madrid region fault zone, the same intensity effects cover a much larger area.

The Modified Mercalli (MM) Intensity Scale of 1931 is currently in use in the U.S. (Refer to Table 1 and the Modified Mercalli scale in PRC.15.2.A.) Intensity VI relates to Magnitude 5 and Intensity VII relates to Magnitude 6, moderate to strong earthquakes. Other countries use different scales and descriptions of intensity and there should not be an attempt to relate these to U.S. scales.

The Medvedev-Sponheuer-Karnik scale (MSK-64), was developed by Sergei Medvedev of the USSR, Wilhelm Sponheuer of East Germany, and Vít Kárník of Czechoslovakia in 1964. MSK-64 is an intensity scale based on the MM scale and was first used in Europe before the European Seismological Commission (ESC) modified it to produce the European Macroseismic Scale (EMS-98). MSK-64 is being used in India, Israel, Russia, and the Commonwealth if Independent States (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Turkmenistan, Tajikistan, Ukraine, and Uzbekistan).

The EMS-98 started development in 1988 by the ESC after they decided to review and update the MSK-64 scale. EMS-98 is now used in Europe and on most other continents. Issued in 1998 as update of the test version from 1992, the scale is referred to as EMS-98. The EMS-98 is designed for engineers as well as seismologists.

The Japan Meteorological Agency (JMA) seismic intensity scale is a scale used in Japan and Taiwan to indicate the strength of earthquakes. JMA was first developed in 1884 and is measured in units of shindo or "degree of shaking" at a point on the surface. The original scale had four stages: faint, weak, strong, and violent. In 1898 this scale was changed to a numerical system, assigning earthquakes levels from 0 to 7.

Earthquake Effects

Surface faulting is the fracture of the earth’s surface with movement of ground on either side of a fracture. Offsetting of ground on either side of the fault will damage any structure, road, bridge, pipeline, canal or dam that straddles the fault. Building foundations are particularly susceptible to damage.

Figure 5 illustrates types of fault movements. The movement of fault displacement deforms the land surface and can bring about uplift, subsidence and offsetting of adjoining ground. Subsidence along a shoreline or city waterfront can cause flooding. Uplift can reduce harbor and waterway depths, making them and their facilities useless.

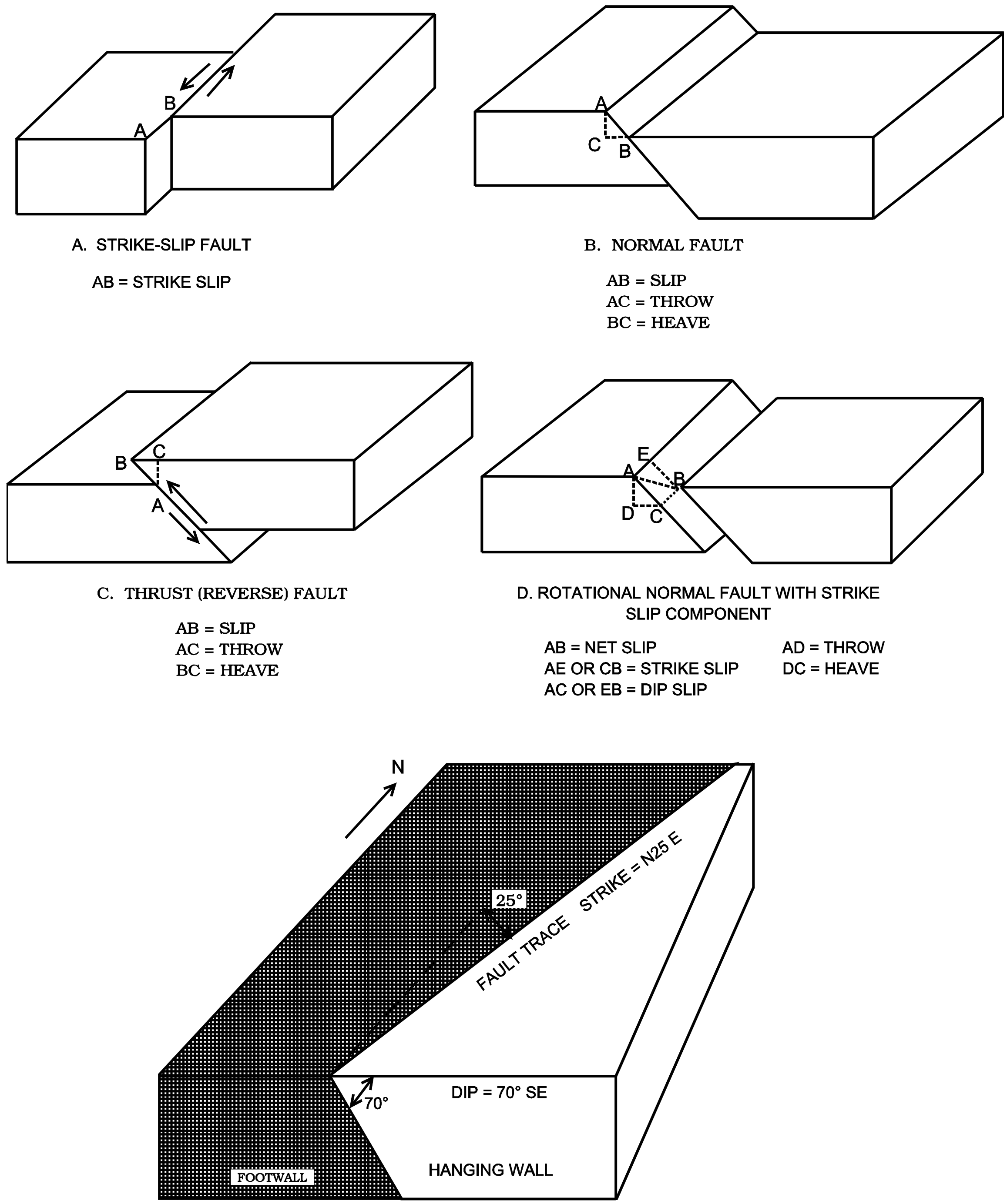

Figure 5. Fault Movement Descriptive Terms.

Ground shaking causes the most earthquake related damage. Seismic waves cause buildings to rock or shake from side to side. Since the usual building construction practice requires less strength in the horizontal plane, buildings are particularly susceptible to damage from horizontal movement. Major damage in the January 1994 Northridge, CA earthquake was due to ground shaking.

The initial shaking can trigger other natural hazard events such as ground failure. Unstable soils are an important factor in earthquake induced ground failure.

One form of ground failure is liquefaction. Liquefaction results when the internal water pressure of saturated soil increases during shaking, forcing apart the grains of the soil. The solid particles literally float in suspension, and the mass behaves as a fluid. Earthquake vibrations trigger the soil-water interaction and subsequently the ground fails. Soft compressible soils are subject to differential settlement and loss of strength. During shaking, there is uneven loss of support because of variable soil conditions. These poor ground conditions are particularly damaging where facility foundation soil substructures have not been thoroughly stabilized. Examples of susceptible soils are marshes, reclaimed land, construction fill, river flood plain soils, coastal plain deposits, glacial sands, gravels, clays and windblown deposits. Liquefaction caused severe damage in the January 1995 earthquake in Japan.

Landslides are a unique form of ground failure and can cause considerable damage if susceptible soil or ground conditions exist. A landslide triggered by an earthquake may occur on a moderate to steep slope and involves earth movement such as rockfall or earth slide. The landslide may be spectacular, as in 1959 where shaking fractured supporting bedrock strata near the base of Madison Canyon in Montana. The loss of ground support resulted in a massive landslide that filled the canyon to a depth of 200 to 300 ft (60.9 to 91.4 m), completely burying roads, campgrounds and the Madison River with 37,000,000 yds^3 (28,288,720 m^3) of rock and debris. This formed a natural dam and subsequently a new lake, “Earthquake Lake,” 200 ft (60.9 m) deep and 6 mi (9.65 km) long.

Vibratory or shaking effects are less obvious on loose soils and rock lying at a relatively shallow or flat angle (slope angle about 1° or 2°) off horizontal. Movement depends upon the type of material, e.g., silt, sand, gravel or larger particle unit size, packing of material (contact of particle and void space), wetness of mass (saturation with fluids and pore pressure), contact surfaces between material types (soil layers, formations, etc.), and superficial loading of the slope. A tsunami can occur when the ocean water responds to sudden vertical displacement of a large area of the sea floor. A strong or great magnitude earthquake or significant volcanic eruption near or under the sea is necessary to generate a tsunami.

A similar effect caused by an earthquake upon a confined body of water is called a seiche. During the 1959 Montana earthquake, the preexisting Hebgen Lake experienced a seiche that sloshed water over the top of Hebgen Dam several times as it oscillated. After the earthquake the lakebed was left tilted and with a new shoreline.

When a tsunami is formed, the seismic sea wave generated in the ocean can be 5 min to an hour or more between the passing of crests and is of low amplitude (a few feet or less in height) when traveling in the deep open ocean. The forward motion of the wave can be 500 mph (804.5 km/h) with crest-to-crest distance of 50 to 250 mi (80.5 to 402.3 km) or more. Upon approaching coastal areas the wave shape changes because of shoaling and bottom shallowing. Wave refraction and resonance pile up the water as the forward speed slows, resulting in significantly increased amplitude (high wave height) which can be 50 to 100 ft (15.2 to 30.5 m) depending on the original wave energy. The advancing wave front overruns low lying coastal areas and sweeps inland.

Since tsunamis are associated with earthquakes, it follows that susceptible coastlines are associated with areas of seismic activity.

Approximately 80% of recorded tsunamis occur in the Pacific Ocean and 10% in Atlantic Ocean areas. Pacific shores experiencing tsunamis include the coasts of California, Oregon, Washington, British Columbia, Canada, Alaska, the Aleutian chain, Chile, Hawaii, the Pacific Islands and Japan. While the East Coast of North America has had tsunami events, more potential exists in the Caribbean, Puerto Rico, Virgin Islands and West Indies areas. On the eastern Atlantic side, Portugal and Morocco have been most frequently damaged.

On April 1, 1946 a tsunami hit Hilo in Hawaii with a 45 ft (14 m) high wave surge when a magnitude 7.8 earthquake occurred near the Aleutian Islands, Alaska. On June 26, 2004 a 100 ft (30 m) high wave surge hit Indonesia, Sri Lanka, India, and Thailand killing more than 225,000 people after magnitude 9.1 and 9.3 earthquakes occurred in the Indian Ocean just north of Simeulue island, off the western coast of northern Sumatra. On July 17, 1998 a 30 ft (10 m) high tsunami struck Papua New Guinea after a 7.1 earthquake occurred in northern New Guinea near the coast. On March 11, 2011 a magnitude 9.0 earthquake occurred in the ocean off the northeast coast of Japan. The earthquake caused a reported 23 ft (7 m) high tsunami wave. The tsunami killed a reported 15,839 people, injured 5,950 people, and 3,642 people are missing. According to the World Bank the estimates of the damages are placed around $235 billion and the Japanese banks estimate the damage could reach $309 million.

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EARTHQUAKE MM INTENSITY SCALES

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows and doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken. Noticed by persons driving motorcars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed.

IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upwards into the air.

TABLE 1

Earthquake Scale Comparison

Intensity (MM)	Magnitude (Richter Scale)
I - II	to 2
III	2 - 3
IV - V	3 - 4
VI - VII	4 - 5
VII - VIII	5 - 6
IX - X	6 - 7
XI	7 - 8
XII	8 - 8.5

Generalized approximate Mercalli (MM) to Richter Relationships

TABLE 2

Comparison of MM with Selected Other Intensity Scales

Modified Mercalli	Rossi-Forel	Japanese	European
I	I	0	I
II	I-II	I	II
III	III	II	III
IV	IV-V	II-III	IV
V	V-VI	III	V
VI	VI-VII	IV	VI
VII	VIII	IV-V	VII
VIII	VIII+ to IX	V	VIII
IX	IX+	V-VI	IX
X	X	VI	X
XI	----	VII	XI
XII	---	---	XII

EARTHQUAKE GLOSSARY

Active Fault - A fault that, on the basis of historical, seismological, or geological evidence, has a high probability of producing an earthquake. (Alternate: a fault that may produce an earthquake within a specified exposure time, given the assumptions adopted for a specific seismic-risk analysis.)

Alluvium, Alluvial Soils - In the context of earthquake, the term is loosely used to indicate soils of silts, sands and gravels of geologically “recent” deposition which are not consolidated and offer general susceptibility to liquefaction.

Attenuation - Seismic strength decreases as distance from the epicenter increases. This weakening depends on geometrical spreading and the physical characteristics of the transmitting medium that cause absorption and scattering.

Design Acceleration - A specification of the ground acceleration at a site, in terms of a single value such as the peak; used for the earthquake resistant design of a structure (or as a base for deriving a design spectrum).

Design Documents - The drawings, specifications, computations, reports, certifications and other substantiation required to verify compliance with provisions.

Design Earthquake - A specification of the seismic ground motion at a site; used for the earthquake-resistant design of a structure.

Designated Seismic Systems - The Seismic Resisting System and those architectural, electrical and mechanical systems and their components that require special performance characteristics.

Diaphragm - A horizontal, or nearly horizontal, system (usually applied to roof or floors) designed to transmit seismic forces to the vertical elements of the seismic resisting system, thus capable of resisting earthquake forces in the horizontal plane.

Displacement - The change in relative position of ground (usually measured across or along a fault) caused by the movement of opposing fault walls during a seismic event.

Duration - A description of the length of time during which ground motion at a site exhibits certain characteristics such as being equal to or exceeding a specified level of acceleration such as 0.05g.

Earthquake - A sudden motion vibration in the earth caused by the abrupt release of energy. The wave motion may range from violent at some locations to imperceptible at others.

Earthquake Hazards - Natural events accompanying an earthquake, such as ground shaking, ground failure, surface faulting, tectonic deformation and inundation, which may cause damage and loss of life during a specified exposure time.

Epicenter - The point on the earth’s surface vertically above the point where the first fault rupture and the first earthquake motion occur.

Exceedence Probability - The probability (for example, 10%) over some exposure time that an earthquake will generate a level of ground shaking greater than some specified level.

Fault - A fracture or fracture zone in the earth along which displacement of the two sides relative to one another has occurred parallel to the fracture.

Focal Depth - The vertical distance between the earthquake hypocenter (focus) and the earth’s surface.

Focus - The point of origin of the earthquake. The location on the causative fault where the fracture is initiated. Point of first rupture.

Frame -

Braced Frame - A vertical truss, or its equivalent, provided to resist seismic forces where truss members are subjected to axial stress.

Building Frame System - A structural system providing support for vertical loads. Seismic force resistance is provided by shear walls or braced frames.

Dual System - A structural system with a space frame providing support for vertical loads. A special moment frame is capable of resisting at least 25% of seismic forces. Total seismic resistance is by combination of the special moment frame and shear walls or braced frames.

Moment Resisting Frame System - A structural system with a complete space frame supporting vertical loads. Seismic resistance is by moment frames capable of resisting the total forces.

Moment Frame - Members and joints are capable of resisting forces by flexure as well as along the axis of members.

Space Frame - A structural system composed of interconnected members, other than bearing walls, capable of supporting vertical loads; it may also provide seismic resistance.

Geologic Hazard - A geologic process, e.g., landsliding, liquefaction, surface rupture, etc., which, during an earthquake or other natural event, may produce adverse effects in structures.

Intensity - A non-instrumental numerical index describing the effects of an earthquake as reported by observers in the affected areas. The scale in common use in the United States is the Modified Mercalli scale with intensity values indicated by Roman Numerals from I to XII depending upon the “felt” effects and damage resulting from the earthquake.

Liquefaction - The transformation of unconsolidated materials into a fluid mass. Grain size, soil density, soil structure, age of soil deposit, and depth to ground water are characteristics determining the susceptibility of any particular soil. Fine sands tend to be more susceptible to liquefaction then silts and gravel. Liquefaction can occur when seismic shear waves having high acceleration and long duration pass through a saturated sandy soil, distorting its granular structure and causing some of the void spaces to collapse. The liquefied soil then behaves like a fluid for a short time.

Magnitude - A quantity of energy released by an earthquake, as contrasted to intensity. Professor C.F. Richter devised the logarithmic scale for local magnitude (M_L) in 1935. Magnitude is expressed in terms of the motion that would be measured by a standard type of seismograph located 100 km from the epicenter of an earthquake. Several other magnitude scales in addition to M_L are in use; for example, body-wave magnitude (M_B) and surface-wave magnitude (M_S) utilize body waves and surface waves. The scale is theoretically open ended, but the largest known earthquakes have had M_S magnitudes near 8.9.

Mean Recurrence Interval, Average Recurrence Interval - The average time between earthquakes or faulting events with specific characteristics, e.g., magnitude $\geq$ 6, in a specified region or in a specified fault zone.

Mean Return Period - See Return Period.

Region - A geographical area, surrounding and including the site, which is sufficiently large to contain all the geologic features related to the evaluation of earthquake hazards at the site.

Restraining Device - A device used to limit the vertical or horizontal movement of the mounting system, which is due to earthquake motions.

Restraining Device, Fixed - A non-yielding or rigid type of restraining device.

Restraining Device, Seismic Activated - An interactive restraining device that is activated by earthquake motion.

Return Period - For ground shaking, return period denotes the average period of time or recurrence interval between events causing ground shaking that exceeds a particular level at a site; the reciprocal of annual probability of exceedence.

Seismic-Design Loading - The prescribed representation of seismic ground motion to be used for the design of a structure.

Seismic-Event - The abrupt release of energy in the earth's lithosphere.

Seismic Hazard - Any physical phenomenon, e.g., ground shaking, ground failure, associated with an earthquake that may produce adverse effects on human activities.

Seismic Waves - Elastic waves, e.g., P, S, Love, Rayleigh, propagating in the earth, set in motion by faulting of a portion of the earth.

Seismic Zone - A generally large area within which seismic design requirements for structures are uniform.

Seismogram - The record made by a seismograph.

Seismograph - The instrument which records seismic energy waves.

Seismometer - The instrument which receives and amplifies seismic energy waves.

Seismotectonic Zone, Seismotectonic Province - A seismogenic zone in which the tectonic processes causing earthquakes have been identified.

Shear Panel - A floor, roof or wall component sheathed to act as a shear wall or diaphragm.

Strong Motion - Ground motion of sufficient amplitude to be of engineering interest in evaluating damage due to earthquakes or in earthquake-resistant design of structures.

Tsunamis - A sea wave generated by an earthquake occurrence under the sea. The water waves are caused by the sudden movement of the sea floor. The wave may be of low height in the deep water but run up in the shallows near land to create high waves which over run the shore and dissipate landward.

Wall - A component, usually placed vertically, used to enclose or divide space.

> **Bearing Wall** - A wall providing support for vertical loads. It may be an exterior or interior wall.
>
> **Bearing Wall System** - A structural system with bearing walls providing support for all, or major portions of, the vertical loads. Shear walls or braced frames provide seismic force resistance.
>
> **Nonbearing Wall** - A wall that does not provide support for vertical loads other than its own weight. It may be an exterior or interior wall.
>
> **Shear Wall** - A wall, bearing or nonbearing, designed to resist seismic forces acting in the plane of the wall.