

What are Magnitude and Intensity?

Terminology

The point on the fault where slip starts is the *Focus* or *Hypocenter*, and the point vertically above this on the surface of the Earth is the *Epicenter* (Figure 1). The depth of focus from the epicenter, called as *Focal Depth*, is an important parameter in determining the damaging potential of an earthquake. Most of the damaging earthquakes have shallow focus with focal depths less than about 70km. Distance from epicenter to any point of interest is called *epicentral distance*.

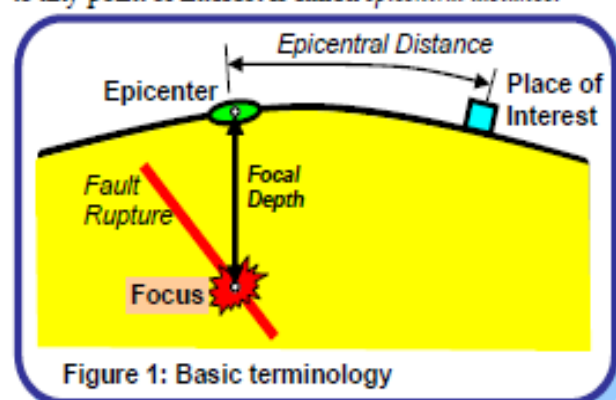


Figure 1: Basic terminology

A number of smaller size earthquakes take place before and after a big earthquake (i.e., the *Main Shock*). Those occurring before the big one are called *Foreshocks*, and the ones after are called *Aftershocks*.

Magnitude

Magnitude is a *quantitative* measure of the actual size of the earthquake. Professor Charles Richter noticed that (a) at the same distance, seismograms (records of earthquake ground vibration) of larger earthquakes have bigger wave amplitude than those of smaller earthquakes; and (b) for a given earthquake, seismograms at farther distances have smaller wave amplitude than those at close distances. These prompted him to propose the now commonly used magnitude scale, the *Richter Scale*. It is obtained from the seismograms and accounts for the dependence of waveform amplitude on epicentral distance. This scale is also called *Local Magnitude* scale. There are other magnitude scales, like the *Body Wave Magnitude*, *Surface Wave Magnitude* and *Wave Energy Magnitude*. These *numerical* magnitude scales have no upper and lower limits; the magnitude of a very small earthquake can be zero or even negative.

An increase in magnitude (*M*) by 1.0 implies 10 times higher waveform amplitude and about 31 times higher energy released. For instance, energy released in a *M*7.7 earthquake is about 31 times that released in a *M*6.7 earthquake, and is about 1000 ($\approx 31 \times 31$) times that released in a *M*5.7 earthquake. Most of the energy

released goes into heat and fracturing the rocks, and only a small fraction of it (fortunately) goes into the seismic waves that travel to large distances causing shaking of the ground en-route and hence damage to structures. (Did you know? The energy released by a *M*6.3 earthquake is equivalent to that released by the 1945 Atom Bomb dropped on Hiroshima!!)

Earthquakes are often classified into different groups based on their size (Table 1). Annual average number of earthquakes across the Earth in each of these groups is also shown in the table; it indicates that on an average one *Great Earthquake* occurs each year.

Table 1: Global occurrence of earthquakes

Group	Magnitude	Annual Average Number
Great	8 and higher	1
Major	7 - 7.9	18
Strong	6 - 6.9	120
Moderate	5 - 5.9	800
Light	4 - 4.9	6,200 (estimated)
Minor	3 - 3.9	49,000 (estimated)
Very Minor	< 3.0	M2-3: ~1,000/day; M1-2: ~6,000/day

Source: <http://neic.usgs.gov/neis/eqlists/eqstats.html>

Intensity

Intensity is a *qualitative* measure of the actual shaking at a location during an earthquake, and is assigned as *Roman Capital Numerals*. There are many intensity scales. Two commonly used ones are the *Modified Mercalli Intensity (MMI) Scale* and the *MSK Scale*. Both scales are quite similar and range from I (least perceptible) to XII (most severe). The intensity scales are based on three features of shaking - perception by people and animals, performance of buildings, and changes to natural surroundings. Table 2 gives the description of Intensity VIII on MSK Scale.

The distribution of intensity at different places during an earthquake is shown graphically using *isoseismals*, lines joining places with equal seismic intensity (Figure 2).

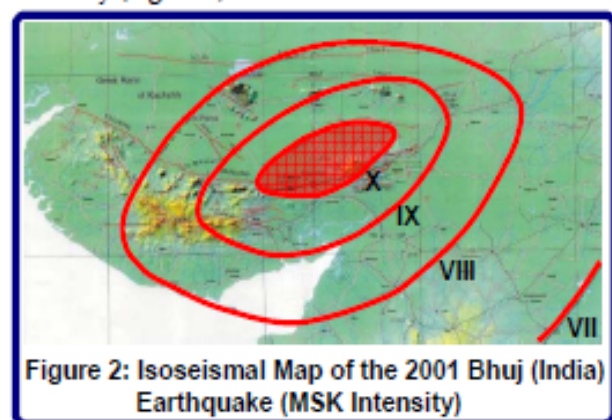


Figure 2: Isoseismal Map of the 2001 Bhuj (India) Earthquake (MSK Intensity)

Source: <http://www.nicee.org/nicee/EQReports/Bhuj/isoseismal.html>

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Table 2: Description of shaking intensity VIII as per MSK scale

Intensity VIII - Destruction of Buildings

- (a) Fright and panic. Also, persons driving motorcars are disturbed. Here and there branches of trees break off. Even heavy furniture moves and partly overturns. Hanging lamps are damaged in part.
- (b) Most buildings of Type C suffer damage of Grade 2, and few of Grade 3. Most buildings of Type B suffer damage of Grade 3, and most buildings of Type A suffer damage of Grade 4. Occasional breaking of pipe seams occurs. Memorials and monuments move and twist. Tombstones overturn. Stonewalls collapse.
- (c) Small landslips occur in hollows and on banked roads on steep slopes; cracks develop in ground up to widths of several centimeters. Water in lakes becomes turbid. New reservoirs come into existence. Dry wells refill and existing wells become dry. In many cases, changes in flow and level of water are observed.

Note:

- Type A structures - rural constructions; Type B - ordinary masonry constructions; Type C - Well-built structures
- Single, Few - about 5%; Many - about 50%; Most - about 75%
- Grade 1 Damage - Slight damage; Grade 2 - Moderate damage; Grade 3 - Heavy damage; Grade 4 - Destruction; Grade 5 - Total damage

enclosed by the isoseismal VIII (Figure 2) may have experienced a PGA of about 0.25-0.30g. However, now strong ground motion records from seismic instruments are relied upon to quantify destructive ground shaking. These are critical for cost-effective earthquake-resistant design.

Table 3: PGAs during shaking of different intensities

MMI PGA (g)	V	VI	VII	VIII	IX	X
	0.03-0.04	0.06-0.07	0.10-0.15	0.25-0.30	0.50-0.55	>0.60

Source: B.A. Bolt, *Earthquakes*, W.H. Freeman and Co., New York, 1993

Based on data from past earthquakes, scientists Gutenberg and Richter in 1956 provided an approximate correlation between the Local Magnitude M_L of an earthquake with the intensity I_0 sustained in the epicentral area as: $M_L \approx \frac{2}{3} I_0 + 1$. (For using this equation, the Roman numbers of intensity are replaced with the corresponding Arabic numerals, e.g., intensity IX with 9.0). There are several different relations proposed by other scientists.

Basic Difference: Magnitude versus Intensity

Magnitude of an earthquake is a measure of its size. For instance, one can measure the size of an earthquake by the amount of strain energy released by the fault rupture. This means that the magnitude of the earthquake is a single value for a given earthquake. On the other hand, intensity is an indicator of the severity of shaking generated at a given location. Clearly, the severity of shaking is much higher near the epicenter than farther away. Thus, during the same earthquake of a certain magnitude, different locations experience different levels of intensity.

To elaborate this distinction, consider the analogy of an electric bulb (Figure 3). The illumination at a location near a 100-Watt bulb is higher than that farther away from it. While the bulb releases 100 Watts of energy, the intensity of light (or illumination, measured in lumens) at a location depends on the wattage of the bulb and its distance from the bulb. Here, the size of the bulb (100-Watt) is like the magnitude of an earthquake, and the illumination at a location like the intensity of shaking at that location.

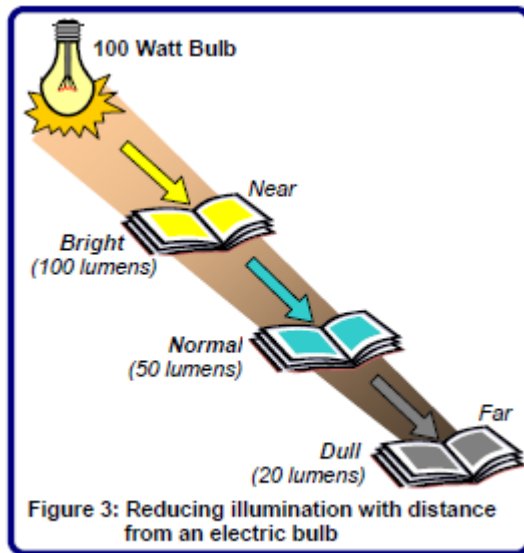


Figure 3: Reducing illumination with distance from an electric bulb

Magnitude and Intensity in Seismic Design

One often asks: Can my building withstand a magnitude 7.0 earthquake? But, the M7.0 earthquake causes different shaking intensities at different locations, and the damage induced in buildings at these locations is different. Thus, indeed it is particular levels of intensity of shaking that buildings and structures are designed to resist, and not so much the magnitude. The peak ground acceleration (PGA), i.e., maximum acceleration experienced by the ground during shaking, is one way of quantifying the severity of the ground shaking. Approximate empirical correlations are available between the MMI intensities and the PGA that may be experienced (e.g., Table 3). For instance, during the 2001 Bhuj earthquake, the area