1. Introduction

Earthquakes are one of the most destructive of natural hazards. Earthquake occurs due to sudden transient motion of the ground as a result of release of elastic energy in a matter of few seconds. The impact of the event is most traumatic because it affects large area, occurs all on a sudden and unpredictable. They can cause large scale loss of life and property and disrupts essential services such as water supply, sewerage systems, communication and power, transport etc. They not only destroy villages, towns and cities but the aftermath leads to destabilize the economic and social structure of the nation.

2. Earthquake Hazards

The primary hazards associated with earthquakes are fault displacement and ground shaking. Secondary hazards include ground failure, liquefaction, landslides and avalanches, and tsunamis and seiches.

2.1 Fault Displacement and ground shaking

Fault displacement, either rapid or gradual, may damage foundations of buildings on or near the fault area, or may displace the land, creating troughs and ridges. Ground shaking causes more widespread damage, particularly to the built environment. The extent of the damage is related to the size of the earthquake, the closeness of the focus to the surface, the buffering power of the location's rocks and soils, and the type of buildings being shaken. Secondary tremors that follow the main shock of an earthquake, called aftershocks, may cause further damage. Such tremors may recur for weeks or even years after the initial event.

2.2 Landslides and avalanches

Slope instability may cause landslides and snow avalanches during an earthquake. Steepness, weak soils and presence of water may contribute to vulnerability from landslides. Liquefaction of soils on slopes may lead to disastrous slides. The most abundant types of earthquake-induced landslides are rock falls and rock slides usually originating on steep slopes.

2.3 Ground failure

Seismic vibrations may cause settlement beneath buildings when soils consolidate or compact. Certain types of soils, such as alluvial or sandy silts are more likely to fail during an earthquake.

2.4 Liquefaction

Liquefaction is a type of ground failure which occurs when saturated soil loses its strength and collapses or becomes liquefied. During the 1964 earthquake in Niigata, Japan, ground beneath buildings that were earthquake resistant became liquefied, causing the buildings to lean or topple down sideways. Another type of ground failure that may result from earthquakes is *subsidence* or vertically downward earth movement caused by reduction in soil water pressure

2.5 Tsunami

Tsunami is a Japanese word meaning "harbor wave". Tsunamis are popularly called tidal waves but they actually have nothing to do with the tides. These waves, which often affect distant shores, originate from undersea or coastal seismic activity, landslides, and volcanic eruptions. Whatever the cause, sea water is displaced with a violent motion and swells up, ultimately surging over land with great destructive power. In 1883, the violent explosion of the famous volcano, Krakatoa in Indonesia, produced tsunamis measuring 40 meters which crashed upon Java and Sumatra. over 36,000 people lost their lives as a result of tsunami waves from Krakatoa.

3. <u>Typical Effects</u>

3.1 Physical Damage – Damage occurs to human settlements, buildings, structures and infrastructure, especially bridges, elevated roads, railways, water towers, water treatment facilities, utility lines, pipelines, electrical generating facilities and transformer stations. Aftershocks can do much damage to already weakened structures. Significant secondary effects include fires, dam failures, and landslides, which may block waterways and also cause flooding. Damage may occur to facilities using or manufacturing dangerous materials resulting in possible chemical spills. There may be a breakdown of communications facilities.

Destruction of property may have a serious impact on shelter needs, economic production and living standards of local populations. Depending on the vulnerability of the affected community, large numbers of people may be homeless in the aftermath of an earthquake.

3.2 Casualties – The casualty rate is often high, especially when earthquakes occur in areas:

a) Of high population density, particularly when streets between buildings are narrow and buildings themselves are not earthquake resistant, and/ the ground is sloping and unstable;

b) Where adobe or dry-stone construction is common with heavy upper floors and roofs.
Casualty rates may be high when quakes occur at night because the preliminary tremors are not felt in sleep and people are not tuned in to media to receive warnings. In daytime, people are particularly vulnerable if in unsafe structures such as schools and offices and casualties may be very high. Casualties generally decrease with distance from the epicenter. As a very rough rule of thumb, there are three times as many injured survivors

as persons killed. The proportion of dead may, however, be higher if there major landslides and other hazards, such as tsunamis. In areas where houses are of light-weight construction, especially with wood frames, casualties generally very much lower although fires may spread rapidly causing injuries and deaths.

3.3 Public health – multiple fracture injuries and number of severely and moderately injured is the most widespread problem, breakdown in sanitary conditions pose a threat and fear of epidemic due to large deaths .The most widespread medical problems are fracture injuries. Other health threats may occur if:

a) There is secondary flooding
b) Water supplies are disrupted and contaminated water is used (although to date no documented significant outbreaks of water-borne diseases have followed an earthquake) or
c) People are concentrated into high-density relief camps.

Although an earthquake is unlikely to cause any new outbreaks, endemic diseases may become virulent if control measures break down and unsanitary conditions develop. The psychological consequences of experiencing an earthquake, including trauma and depression, often last for several months.

3.4 Water supply – Severe problems due to failure of the water supply and distribution network and storage reservoirs. Severe problems are likely because:

- Piped (municipal) water systems may be seriously damaged or become
- Contaminated, especially if sewage systems have also been damaged.
- Reservoir dams may be broken.
- Open wells may be blocked by debris.
- Earthquakes can change levels in the water table with the possible effect of drying up wells and surface springs.

3.5 Transport network – is severely affected due to failure of roads and bridges, turns in railway track alignment, failure of runway etc

3.6 Electricity and Communication – All links are affected. Tower collapse, transponders collapse, transformers collapse etc.

3.7 Food Supplies- Food distribution and marketing systems may be disrupted. Irrigation works may be damaged. In areas where earthquakes give rise to flooding or a tsunami strikes, food stocks and standing crops may be lost. Typically, however, earthquakes do not reduce the local food supply.

4. <u>Predictability</u>

Although some scientists claim ability to predict earthquakes, the methods are controversial. For example, the 1995 earthquake in Kobe, Japan was not predicted. Accurate and exact predictions of sudden fault displacements and the resultant

earthquakes are still not possible, however mechanical observation systems make it possible to issue warnings to nearby populations immediately after detection of an earthquake.

Reasonable risk assessments of potential earthquake activity can be made with confidence based upon:

1. Knowledge of seismic zones or areas most at risk, gained through study of historical incidence and plate tectonics.
2. Monitoring of seismic activity by use of seismographs and other instruments.
3. Use of community-based scientifically sound observations such as elevation and turbidity of water in wells and recording radon gas escape into well water. (Use of animal behavior as an indicator is subject to controversy as it is often difficult to interpret.)

5. Indian Earthquakes

The Indian sub-continent is highly prone to multiple natural disasters including earthquakes, which is one of the most destructive natural hazards with the potentiality of inflicting huge loss to lives and property.

Earthquakes pose a real threat to India with 59% of its geographical area vulnerable to seismic disturbance of varying intensities including the capital city of the country. Almost the entire Northeast region, Northern Bihar, Himachal Pradesh, Jammu & Kashmir and some parts of Kutch are in seismic zone V, while the entire Gangetic plain and some parts of Rajasthan are in seismic zone IV.

India has experienced some of the most intense earthquakes in the world and is also one of the most earthquake prone countries in the world. Data from 1897-1991 shows that an average of three earthquakes of magnitude 6.0 or more, occur in India every year and the high degree of seismic vulnerability of the country poses a real threat to the millions of its people.

In the span of last 15 years, India has experienced six earthquakes of moderate intensity. Although moderate in intensity, these earthquakes caused considerably high degree of losses to human life and property, which highlights the vulnerability of the population and infrastructure to earthquakes and the inadequacy of preparedness measures in the country.

The Latur earthquake of 1993 and the Bhuj earthquake of 2001 which caused extensive damage to lives and properties further highlighted the need to focus upon long-term seismic mitigation and preparedness in order to reduce the human and economic losses due to earthquakes. However, the September 1993 earthquake that struck Maharashtra State in Central West India that claimed nearly 12,000 lives, was not a particularly strong event, but caused such devastation because of other factors. Another earthquake also struck Central India in May 1997, but fortunately not on such a devastating scale. The

26th January Bhuj Earthquake was the most devastating one which scaled very high in terms of loss of life and property. 13,805 human lives were lost, and over 1,67,000 persons were injured in the earthquake. This earthquake is the first major earthquake to hit an urban area of India in the last 50 yrs.

5.1 Great Earthquakes in India

Strong and damaging earthquakes have been felt in all parts of the Indian Sub-continent. The most seismically active areas are those in the northern regions of the sub-continent and in the Andaman and Nicobar Islands. This is where the Indian plate is thrusting (diving below) under the Eurasian plate. In the Andaman & Nicobar Islands, the Indian plate subducts (dives) beneath the Burmese Micro-plate.

The deadliest earthquake in Indian history so far has been the M7.8 Kangra earthquake in Himachal Pradesh in 1905, which left 19,700 people dead.

The *largest earthquake* recorded was an earthquake in Arunachal Pradesh in 1950. It had a magnitude of 8.6 (Mw) and was the 6th largest earthquake in the world, in the 20th century.

The most widely felt earthquake in India to date, has been the M7.6 Bhuj earthquake in 2001. Shaking was experienced as far away as Chennai in the south, Shillong in the east, Quetta in the west and Kashmir in the north. After the Kangra earthquake, this is the next earthquake to have caused heavy casualties. More than 13,000 people were killed in Gujarat.

The peninsula area was generally thought to be "seismically safe". But recent large earthquakes in this area, have proven this statement wrong. Apart from the M 6.2 Khilari (1993) and M6.6 Koyna (1967) earthquakes, several damaging shocks have hit this region, in historical and ancient times.

5.2 Earthquake Risk in the Himalayas

Earthquakes are a great threat to environmental stability and life in the Himalayan region as almost the entire region is prone to high seismic activity. The region has been hit by earthquakes of varying intensities in the past and similar threats remain imminent.

The Himalayas were formed by a head on collision of the Indian and Eurasian plates, and the Indian plate continues to push the Asian plate northward at the rate of about 2 cm per year. This means that in every 100 years India moves 200 cm north against the Asian plate, and this colliding force builds up pressure continually for several years and is released in the form of earthquakes.

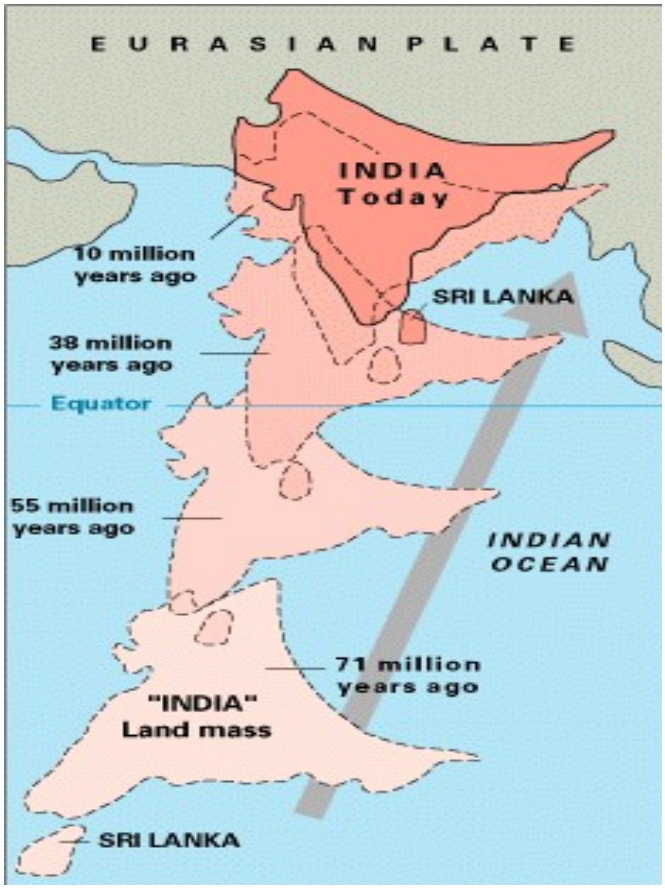
Four great earthquakes of Himalaya i.e., Assam earthquake of 1897, Kangra earthquake of 1905, Nepal-Bihar earthquake of 1934 and Assam earthquake of 1950 rocked the Himalayan Kingdom of Nepal whose magnitude exceeds 8.0 Richter scale. The

earthquake of 1833 with magnitude 7.8 occurring at a distance of 50kms NE of Kathmandu also affected the Kathmandu Valley. In the last few decades, the major amongst them are the Kinnaur earthquake of 1975, Dharchula earthquake of 1980 and the Uttarkashi earthquake of 1991, which resulted in tremendous loss of life and property.

5.3 Himalayan Seismicity

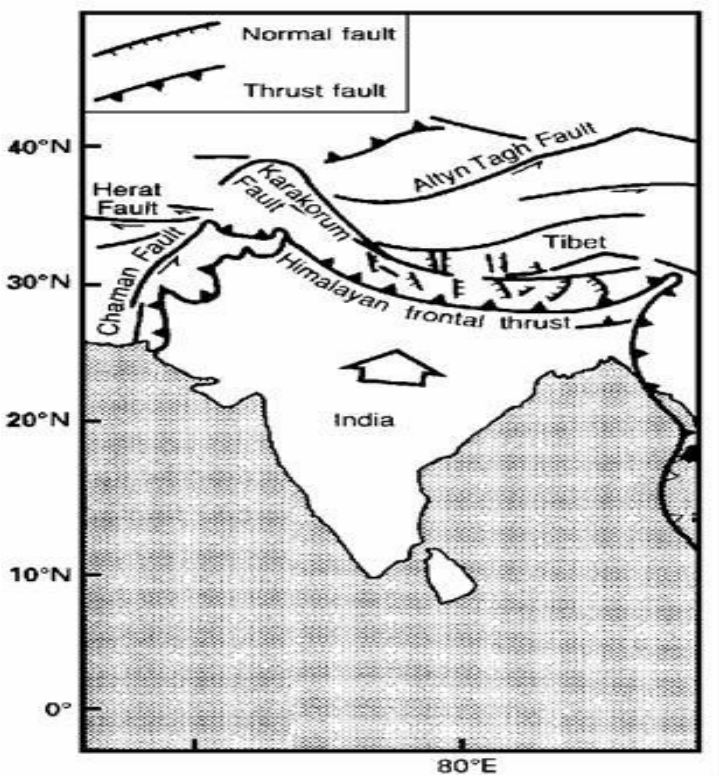
Plate tectonics studies reveal that the Himalayan mountain ranges were formed when Indo-Australian plate collided with the Eurasian plate. The Indian subcontinent, once part of the supercontinent called Gondwanaland, which consisted also of present-day Africa and Antartica, broke away about 100 million years ago and crawled northwards across the Tethys Sea before ramming into Asia. Figure 10 shows the plate tectonics of the Himalayas.

Figure 10: The Himalayan Plate Tectonics



Around 45ma, during the Eocene, India collided with Eurasia; this was the end result of India's northward migration caused by the subduction of the Tethyan Ocean beneath the Eurasian Plate. The Indian plate slid under the Asian landmass. Its upper layers peeled and thrust upward, forming the Himalayan ranges. Giant cracks (fault zones) formed along its northern perimeter. Since then India has penetrated some 2000km into Asia leading to the creation of the Himalayan mountain range. Recent GPS measurements put the present convergence rate between India and Asia at 58 ± 4mm.yr-1 [Bilham et al., 1997], roughly a third of this motion (17.52 ± 2mm.yr-1) is accommodated by the Himalayan thrust system meaning that the Kingdom of Nepal is shortening by about 2cm.yr-1.

The seismic zoning map of India shows that the entire Himalayan region lies in Zone IV and V, which correspond to MMI of VIII and >IX respectively. Seismic studies show that great earthquakes (M>8) tend to recur in cycles of 200 – 300 years along the length of the Himalayas.



5.4 Earthquake Zones in India

The varying geology at different locations in the country implies that the likelihood of damaging earthquakes taking place at different locations is different. Thus, a seismic zone map is required so that buildings and other structures located in different regions can be designed to withstand different level of ground shaking. The current zone map divides India into four zones – II, III, IV and V. Parts of Himalayan boundary in the north

and northeast, and the Kachchh area in the west are classified as zone V (See figure 13 and Table 4) .

Figure 12: History of Seismic Zone Map of India: 1962, 1966, 1970

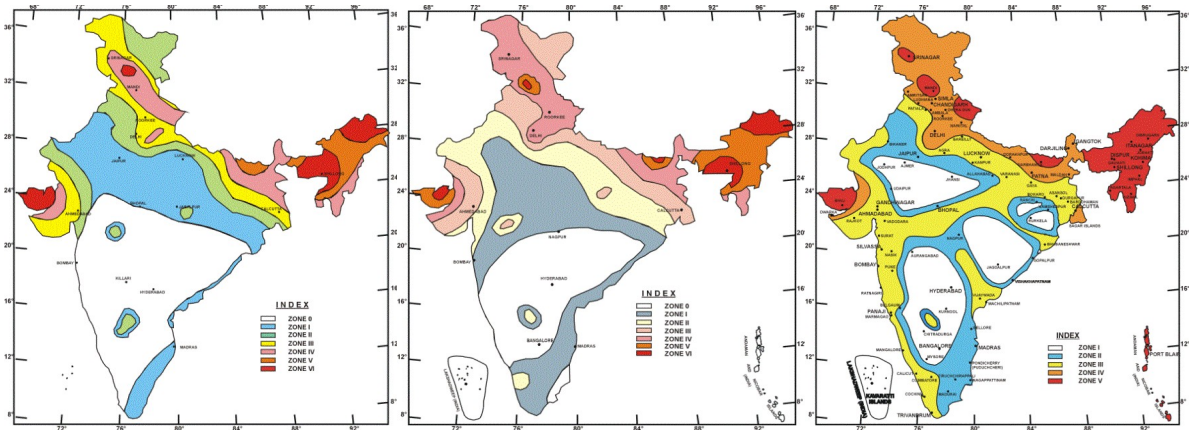
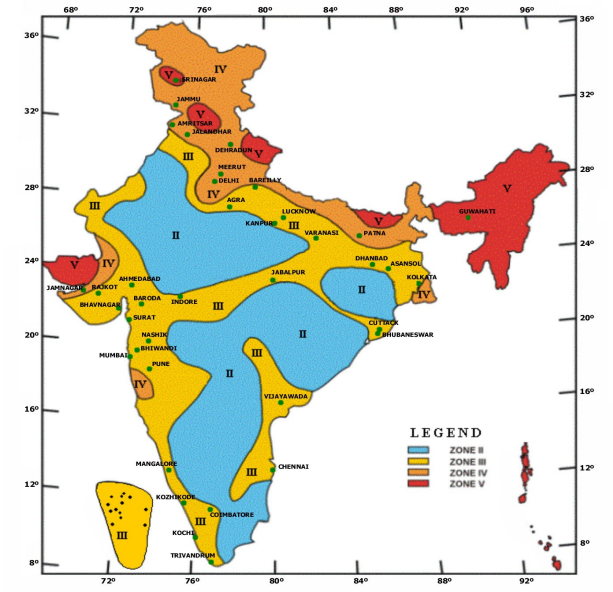


Figure 13: Recent Map indicating Earthquakes Zones in India (IS 1893 – 2002)



Zone	Magnitude
Zone V	**Very High Risk** Quakes of magnitude 8 and greater
Zone IV	High Risk Quakes upto Magnitude ***7.9***
Zone III	**Moderate Risk** Quakes upto Magnitude **6.9**
Zone II	**Seismic Disturbances upto Magnitude 4.9**

The seismic zone maps 1967 are revised from time to time as more understanding is gained on the geology, the seismotectonics and the seismic activity in the country (see Figure 12). For instance, the Koyna earthquake of occurred in an area classified in zone I as per map of 1966. The 1970 version of code upgraded the area around Koyna to zone IV. The Killari (Latur) earthquake of 1993 occurred in zone I (now in Zone III). The new

zone map places this area in zone III. The new zone map will now have only four seismic zones – II, III, IV and V. The areas falling in seismic zone I in the current map are merged with those of seismic zone II. Also, the seismic zone map in the peninsular region is being modified. Madras will come under seismic zone III as against zone II currently. The national Seismic Zone Map presents a large scale view of the seismic zones in the country. Local variations in soil type and geology cannot be represented at that scale. Therefore, for important projects, such as a major dam or a nuclear power plant, the seismic hazard is evaluated specifically for that site. Also, for the purposes of urban planning, metropolitan areas are microzoned. Seismic microzonation accounts for local variations in geology, local soil profile, *etc.*

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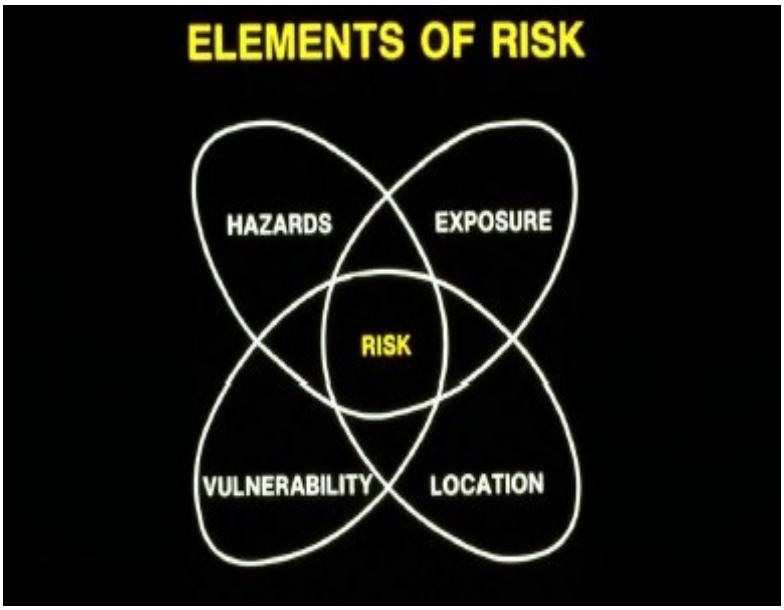
Table 4: Region falling in various zones of the country

Zone	**Damage risk and Intensity**	**Region**
Zone V	(**Earthquake Very high damage risk zone** - areas may expect intensity maximum of ***MSK IX or more***)	The entire North-east, including all the seven sister states, the Kutch district, parts of Himachal and Jammu & Kashmir, and the Andaman and Nicobar islands.
Zone IV	(**Earthquake High damage risk zone** - areas may expect intensity maximum of ***MSK VIII***)	Parts of the Northern belt starting from Jammu and Kashmir to Himachal Pradesh. Also including Delhi and parts of Haryana. The Koyna region of Maharashtra is also in this zone.
Zone III	(**Earthquake Moderate damage risk zone** - areas may expect intensity maximum of ***MSK VII***)	A large part of the country stretching from the North including some parts of Rajasthan to the South through the Konkan coast, and also the Eastern parts of the country.
Zone II	(**Earthquake Low damage risk zone** - areas may experience intensity ***MSK VI***)	These two zones are contiguous, covering parts of Karnataka, Andhra Pradesh, Orissa, Madhya Pradesh, and Rajasthan, known as low risk earthquake zones.

6. Factors contributing to vulnerability and elements of risk

Several key factors contribute to vulnerability of human populations:

- Location of settlements in seismic areas, especially on poorly consolidated soils, on ground prone to landslides or along fault lines.
- Building structures, such as homes, bridges, dams, which are not resistant to ground motion. Unreinforced masonry buildings with heavy roofs are more vulnerable than lightweight wood framed structures. Dense groupings of buildings with high occupancy.
- Lack of access to information about earthquake risks.



The above figure illustrates schematically the four elements contributing to risk (chance of loss). They are -

a) ***hazards*** (physical effects generated in the naturally occurring event),
b) ***location*** of the hazards relative to the community at risk,
c) ***exposure*** (the value and importance of the various types of structures and lifeline systems in the community serving the populace), and
d) ***vulnerability*** of the exposed structures and systems to the hazards expected to affect them during their useful life.

7. Preparedness measures

7.1 Community preparedness–

Community preparedness is vital for mitigating earthquake impact. Most effective programs are formal and initiated at the community level with support by local or national governments.

7.2 Public Education

Preparedness includes educating the public on the causes and characteristics of an earthquake and what they should do if one occurs. Public officials and services must make contingency plans to react to the emergency. Nearly every country has a means of communicating with its most remotely located citizen either through media or informal communication networks. Public awareness programs can be designed to reach every vulnerable person and may significantly reduce the social and material costs of an earthquake. Some examples of information to be provided include:

- causes of earthquakes and warning signs

- awareness of earthquake risks and ways to minimize personal vulnerability
- practical ways to reinforce vulnerable houses
- what to do in the event of an earthquake (with possible participation in a drill)
- how to form teams to assist in search for injured and post-disaster recovery activities.

7.3 Planning

Public officials and services must make contingency plans to react to the emergency. Activities the public sector may undertake include:

- Reviewing the structural soundness of facilities that are essential for disaster response such as hospitals, fire stations, communications installations and upgrading them if needed
- Training teams for search and rescue operations or ensuring the rapid availability of detection equipment
- Training teams for disaster assessment
- Identifying safe sites where vulnerable populations could be relocated.
- Training personnel in trauma care
- Planning for an alternative water supply
- Preparing plans to clear streets for emergency access
- Preparing emergency communication systems and messages to the public regarding their security
- Training teams to determine if buildings are safe for reoccupancy
- Preparing flood plans for susceptible areas
- Coordinating preparations with voluntary organizations

8. Typical Post Disaster Assistance Needs

The immediate impact of an earthquake affects all sectors of the community and local authorities should initially emphasize **search and rescue** of victims.
Secondly, e**mergency medical assistance** must be provided especially during the first 72 hours.
Third, a **damage and needs assessment survey,** should be conducted to inform local and international agencies of needs.
Fourth, the survivors will require **relief assistance** such as food, water and emergency shelter. Attention should be given to reopening roads, re-establishing communications, contacting remote areas and conducting disaster assessments.
At the end of the emergency period, long-term recovery needs to take priority. The post earthquake period presents an opportunity to minimize future risks through enactment or strengthening of land use and building codes as rebuilding takes place. The focus should be on:

- repair and reconstruction of water, sewer, electrical services and roads
- technical, material and financial assistance for repair and reconstruction of houses and public buildings

- programs to rejuvenate the economy
- financial assistance for loans to individuals and businesses for economic recovery.

9. Mitigation

The golden rule is that there is no standard solution to mitigate a disaster risk. The goal is to minimize the impact of disaster. Possible risk reduction measures are:-

- Engineered structures (designed and built) to withstand ground shaking. Architectural and engineering inputs put together to improve building design and construction practice. Develop earthquake resistant construction techniques.
- Analyze soil type before construction and do not build structures on soft soil. To accommodate on weak soils adopt safety measures in design.
  Note: Buildings built on soft soils are more likely to get damaged even if the earthquake is not particularly strong in magnitude. Similar problem persists in the alluvial plains and conditions across the river banks. Heavy structural damages are concentrated when ground is soft.
- Follow Indian Standard Code for construction of buildings
- Enforcement of building code in the byelaws
- Land use control and restriction on density and heights of buildings
- Strengthening of important buildings, which need to be functional after a disaster. Upgrade level of safety of buildings.
- Public awareness, sensitization and training programmes for Engineers, Architects, Structural designers, Builders, Masons etc.
- Reduce possible damages from secondary effects. e.g., identify potential landslide sites and restrict construction in those areas.
- In earthquake prone areas insurance should be obtained for buildings under construction and those in use. Insurance policies for natural disasters should be made compulsory and priced specifically on available scientific data of hazards in the region.

Successful mitigation brings about a fundamental change in the attitude of the people at risk and modifies the earlier physical environment of the society. These changes take time and many times it's learnt in a hard way after facing a disaster

RESOURCES:

- **Earthquake by Anup Karanth www.ndma.nic.in**
- www.nicee.org: website of The National Information Center of Earthquake Engineering (NICEE) hosted at Indian Institute of Technology Kanpur (IITK) is intended to collect and maintain information resources on Earthquake Engineering and make these available to the interested professionals, researchers, academicians and others with a view to mitigate earthquake disasters in India. The host also gives IITK-BMTPC Earthquake Tips.

Earthquakes: DOS AND DON'TS

Earthquakes

An earthquake is a sudden, rapid shaking of the Earth caused by the breaking and shifting of rock beneath the Earth's surface. This shaking can cause buildings and bridges to collapse; disrupt gas, electric, and phone service; and sometimes trigger landslides, avalanches, flash floods, fires, and huge, destructive ocean waves (tsunamis). Buildings with foundations resting on unconsolidated landfill, old waterways, or other unstable soil are most at risk.

BEFORE THE EARTHQUAKE STRIKES

Develop a Family Disaster Plan. If you are at risk from earthquakes:

- **Pick "safe places" in each room of your home.** A safe place could be under a sturdy table or desk or against an interior wall away from windows, bookcases, or tall furniture that could fall on you. The shorter the distance to move to safety, the less likely you will be injured. Injury statistics show that people moving as little as 10 feet during an earthquake's shaking are most likely to be injured. Also pick safe places, in your office, school and other buildings you are frequently in.
- **Practice drop, cover, and hold-on in each safe place.** Drop under a sturdy desk or table and hold on to one leg of the table or desk. Protect your eyes by keeping your head down. Practice these actions so that they become an automatic response. When an earthquake or other disaster occurs, many people hesitate, trying to remember what they are supposed to do. Responding quickly and automatically may help protect you from injury.
- **Practice drop, cover, and hold-on at least twice a year.** Frequent practice will help reinforce safe behavior.
- **Wait in your safe place until the shaking stops, then check to see if you are hurt.** You will be better able to help others if you take care of yourself first, then check the people around you. Move carefully and watch out for things that have fallen or broken, creating hazards. Be ready for additional earthquakes called "aftershocks."
- **Be on the lookout for fires.** Fire is the most common earthquake-related hazard, due to broken gas lines, damaged electrical lines or appliances, and previously contained fires or sparks being released.
- **If you must leave a building after the shaking stops, use the stairs, not the elevator.** Earthquakes can cause fire alarms and fire sprinklers to go off. You will not be certain whether there is a real threat of fire. As a precaution, use the stairs.
- **If you're outside in an earthquake, stay outside. Move away from buildings, trees, streetlights, and power lines. Crouch down and cover your head.** Many injuries occur within 10 feet of the entrance to buildings. Bricks, roofing, and other materials can fall from buildings, injuring persons

nearby. Trees, streetlights, and power lines may also fall, causing damage or injury.

- **Inform guests, babysitters, and caregivers of your plan.** Everyone in your home should know what to do if an earthquake occurs. Assure yourself that others will respond properly even if you are not at home during the earthquake.

- **Get training.** Take a first aid class from your local Red Cross chapter. Get training on how to use a fire extinguisher from your local fire department. Keep your training current. Training will help you to keep calm and know what to do when an earthquake occurs.
- **Discuss earthquakes with your family.** Everyone should know what to do in case all family members are not together. Discussing earthquakes ahead of time helps reduce fear and anxiety and lets everyone know how to respond.
- **Talk with your insurance agent.** Different areas have different requirements for earthquake protection. Study locations of active faults, and if you are at risk, consider purchasing earthquake insurance.

Assemble a Disaster Supplies Kit

- A flashlight and sturdy shoes by each person's bedside.
- Disaster Supplies Kit basics
- Evacuation Supply Kit.

PROTECT YOUR PROPERTY

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- **Bolt bookcases, china cabinets, and other tall furniture to wall studs. Brace or anchor high or top-heavy objects.** During an earthquake, these items can fall over, causing damage or injury.
- **Secure items that might fall (televisions, books, computers, etc.).** Falling items can cause damage or injury.
- **Install strong latches or bolts on cabinets.** The contents of cabinets can shift during the shaking of an earthquake. Latches will prevent cabinets from flying open and contents from falling out.
- **Move large or heavy objects and fragile items (glass or china) to lower shelves.** There will be less damage and less chance of injury if these items are on lower shelves.
- **Store breakable items such as bottled foods, glass, and china in low, closed cabinets with latches.** Latches will help keep contents of cabinets inside.
- **Store weed killers, pesticides, and flammable products securely in closed cabinets with latches, on bottom shelves.** Chemical products will be less likely to create hazardous situations from lower, confined locations.
- **Hang heavy items, such as pictures and mirrors, away from beds, couches, and anywhere people sit.** Earthquakes can knock things off walls, causing damage or injury.
- **Brace overhead light fixtures.** During earthquakes, overhead light fixtures are the most common items to fall, causing damage or injury.

- **Strap the water heater to wall studs.** The water heater may be your best source of drinkable water following an earthquake. Protect it from damage and leaks.
- **Bolt down any gas appliances.** After an earthquake, broken gas lines frequently create fire hazards.
- **Install flexible pipe fittings to avoid gas or water leaks.** Flexible fittings will be less likely to break.
- **Repair any deep cracks in ceilings or foundations. Get expert advice if there are signs of structural defects.** Earthquakes can turn cracks into ruptures and make smaller problems bigger.
- **Check to see if your house is bolted to its foundation.** Homes bolted to their foundations are less likely to be severely damaged during earthquakes. Homes that are not bolted have been known to slide off their foundations, and many have been destroyed because they are uninhabitable.
- **Consider having your building evaluated by a professional structural design engineer.** Ask about home repair and strengthening tips for exterior features, such as porches, front and back decks, sliding glass doors, canopies, carports, and garage doors. Learn about additional ways you can protect your home. A professional can give you advice on how to reduce potential damage.
- Follow local seismic building standards and safe land use codes that regulate land use along fault lines. Some municipalities, counties, and states have enacted codes and standards to protect property and occupants. Learn about your area's codes before construction.

DURING AN EARTHQUAKE

- **Drop, cover, and hold on!** Move only a few steps to a nearby safe place. It is very dangerous to try to leave a building during an earthquake because objects can fall on you. Many fatalities occur when people run outside of buildings, only to be killed by falling debris from collapsing walls.
- **If you are in bed, hold on and stay there, protecting your head with a pillow.** You are less likely to be injured staying where you are. Broken glass on the floor has caused injury to those who have rolled to the floor or tried to get to doorways.
- **If you are outdoors, find a clear spot away from buildings, trees, streetlights, and power lines. Drop to the ground and stay there until the shaking stops.** Injuries can occur from falling trees, street-lights and power lines, or building debris.
- **If you are in a vehicle, pull over to a clear location, stop and stay there with your seatbelt fastened until the shaking has stopped.** Trees, power lines, poles, street signs, and other overhead items may fall during earthquakes. Stopping will help reduce your risk, and a hard-topped vehicle will help protect you from flying or falling objects. Once the shaking has stopped, proceed with caution. Avoid bridges or ramps that might have been damaged by the quake.
- **Stay indoors until the shaking stops and you're sure it's safe to exit.** More injuries happen when people move during the shaking of an earthquake. After the

shaking has stopped, if you go outside, move quickly away from the building to prevent injury from falling debris.

- **Stay away from windows and falling objects.** Windows can shatter with such force that you can be injured several feet away.
- **In a high-rise building, expect the fire alarms and sprinklers to go off during a quake.** Earthquakes frequently cause fire alarm and fire sprinkler systems to go off even if there is no fire. Check for and extinguish small fires, and, if exiting, use the stairs.
- **If you are in a coastal area, move to higher ground.** Tsunamis are often created by earthquakes.
- **If you are in a mountainous area or near unstable slopes or cliffs, be alert for falling rocks and other debris that could be loosened by the earthquake.** Landslides commonly happen after earthquakes.

AFTER THE EARTHQUAKE

- **Check yourself for injuries.** Often people tend to others without checking their own injuries. You will be better able to care for others if you are not injured or if you have received first aid for your injuries.
- **Protect yourself from further danger by putting on long pants, a long-sleeved shirt, sturdy shoes, and work gloves.** This will protect your from further injury by broken objects.
- **After you have taken care of yourself, help injured or trapped persons.** If you have it in your area, call emergency, then give first aid when appropriate. Don't try to move seriously injured people unless they are in immediate danger of further injury.
- **Look for and extinguish small fires. Eliminate fire hazards.** Putting out small fires quickly, using available resources, will prevent them from spreading. Fire is the most common hazard following earthquakes. Fires followed the San Francisco earthquake of 1906 for three days, creating more damage than the earthquake.
- **Turn off gas on supply from the cylinder**. Explosions have caused injury and death when homeowners have improperly turned their gas back on by themselves.
- **Switch off all electrical appliances**.
- **Clean up spilled medicines, bleaches, gasoline, or other flammable liquids immediately and carefully.** Avoid the hazard of a chemical emergency.
- **Open closet and cabinet doors cautiously.** Contents may have shifted during the shaking of an earthquake and could fall, creating further damage or injury.
- **Inspect your home for damage. Get everyone out if your home is unsafe.** Aftershocks following earthquakes can cause further damage to unstable buildings. If your home has experienced damage, get out before aftershocks happen.
- **Help neighbors who may require special assistance.** Elderly people and people with disabilities may require additional assistance. People who care for them or who have large families may need additional assistance in emergency situations.

- **Listen to a portable, battery-operated radio (or television) for updated emergency information and instructions.** If the electricity is out, this may be your main source of information. Local radio and local officials provide the most appropriate advice for your particular situation.
- **Expect aftershocks.** Each time you feel one, drop, cover, and hold on! Aftershocks frequently occur minutes, days, weeks, and even months following an earthquake.
- **Watch out for fallen power lines or broken gas lines, and stay out of damaged areas.** Hazards caused by earthquakes are often difficult to see, and you could be easily injured.
- **Stay out of damaged buildings.** If you are away from home, return only when authorities say it is safe. Damaged buildings may be destroyed by aftershocks following the main quake.
- **Use battery-powered lanterns or flashlights to inspect your home.** Kerosene lanterns, torches, candles, and matches may tip over or ignite flammables inside.
- **Inspect the entire length of chimneys carefully for damage.** Unnoticed damage could lead to fire or injury from falling debris during an aftershock. Cracks in chimneys can be the cause of a fire years later.
- **Take pictures of the damage, both to the house and its contents, for insurance claims.**
- **Avoid smoking inside buildings.** Smoking in confined areas can cause fires.
- **When entering buildings, use extreme caution.** Building damage may have occurred where you least expect it. Carefully watch every step you take.
- **Examine walls, floor, doors, staircases, and windows to make sure that the building is not in danger of collapsing.**
- **Check for gas leaks.** If you smell gas or hear a blowing or hissing noise, open a window and quickly leave the building. Turn off the gas, using the outside main valve if you can, and call the gas company from a neighbor's home. If you turn off the gas for any reason, it must be turned back on by a professional.
- **Look for electrical system damage.** If you see sparks or broken or frayed wires, or if you smell burning insulation, turn off the electricity at the main fuse box or circuit breaker. If you have to step in water to get to the fuse box or circuit breaker, call an electrician first for advice.
- **Check for sewage and water line damage.** If you suspect sewage lines are damaged, avoid using the toilets and call a plumber. If water pipes are damaged, contact the water company and avoid using water from the tap. You can obtain safe water from undamaged water heaters or by melting ice cubes.
- **Watch for loose plaster, drywall, and ceilings that could fall.**
- **Use the telephone only to report life-threatening emergencies.** Telephone lines are frequently overwhelmed in disaster situations. They need to be clear for emergency calls to get through.
- **Watch animals closely. Leash dogs and place them in a fenced yard.** The behavior of pets may change dramatically after an earthquake. Normally quiet and friendly cats and dogs may become aggressive or defensive.