MODULE 37 – EARTHQUAKES AND DISASTER MANAGEMENT

OBJECTIVES

By the end of the session, the students will be able to know:

1. Difference between Hazard and Disaster, Know about the disaster and its types.
2. Learn about the earthquake terminology and their types, earthquake waves, causes, recording instruments, measurement and determination of epicenter of Earthquakes etc.
3. Disaster Management: Disaster Prevention, Disaster Preparedness, Disaster Mitigation, Disaster Management System in India, Existing Disaster Management System.
4. Earthquakes and Disaster Management : Seismic Zoning, Earthquake Resistant Buildings, Role of Remote Sensing and Aerial Photography, Predictability, Forecasting and Warning of Earthquakes, Public Awareness Campaigns, Relief Measures, Shelters for Victims, Clearance of Debris, Disposal of Dead bodies, Fire accidents, Damage Assessment, Earthquake Safety Rules etc.

SUMMARY

Disasters are always injurious to lives and properties. About 75 percent of the world's population lives in areas affected by various disasters like Earthquakes, Cyclones, Hurricanes, Floods, Drought, Tsunami, Landslides etc. These disasters affect annual growth of many countries including India. Some recent disasters have brought massive economic and life losses, affected regions and hindered socio-economic development.

Disasters are classified mainly into two categories :

[A] ***Natural Disasters*** **:** Sudden or major natural calamities which disrupt normal functioning of life, are the natural disasters.

[B] ***Man-made Disasters*** **:** Human-induced hazards are the man-made disasters.

Whether disasters are natural or man-made, they negatively affect life, property, etc. and many times permanently change the societies, ecosystems and environment.

Earthquakes are very dangerous and destructive natural hazards. The impact of the earthquakes is sudden with hardly any warning. Till date it is not possible to predict the major earthquakes in terms of place, time, magnitude etc.

An earthquake is a shaking of part of the Earth surface due to sudden release of energy beneath the earth surface because of displacement of rocks along active faults.

When earthquakes originate on the ocean floor and generated seismic waves reach to the surface they are termed **tsunami**.

Earthquakes are also two types : broadly classified into two categories :

[I] ***Tectonic Earthquakes*** **:** The earthquakes that generate due to sudden movement of rocks within the earth along faults, are called the Tectonic Earthquakes.

[II] ***Artificial Earthquakes*** **:** The earthquake vibrations caused by human activities, are called the Artificial Earthquakes.

During earthquakes, elastic waves generate from focus which are termed ***Seismic Waves***. Broadly, seismic waves are two types :

[1] ***Body Waves*** **:** Primary and Secondary waves are the body waves as they travel deep into the body of the earth from their origin.

[2] ***Surface Waves*** : Love and Rayleigh Waves are the surface waves as they travel at or near to the ground surface

Earthquake scientists have observed number of causes and activities which are responsible for the earthquakes. The important are :

[1] ***Tectonic causes,***
[2] ***Volcanic activities,***
[3] ***Reservoir-triggered activities,***
[4] ***Human activities etc.***

At present, the strength of earthquakes is measured internationally in the form of ***magnitude***. The ***Richter Magnitude Scale*** measures earthquake magnitude [*M*] which is the total amount of energy released by an earthquake at its source. It is a 10-point open-ended scale with numerals begin with 1 [which is the lowest] to 10 [which is the highest].

Whenever and wherever earthquakes occur, the life badly interrupts. The after effects of an earthquake are more harmful than the disaster event. Hence, efforts are increasing to lessen the impact of earthquake disasters on all sectors of the society. Some of the critical issues of ***Disaster Management from the Earthquake*** point of view, are as :

[1] Seismic Zoning,
[2] Earthquake Resistant Buildings,
[3] Role of Remote Sensing and Aerial Photography,
[4] Predictability, Forecasting and Warning of Earthquakes,
[5] Public Awareness Campaigns,
[6] Relief Measures,
[7] Shelters to Victims,
[8] Clearance of Debris,
[9] Disposal of the Dead bodies,
[10] Fire accidents,
[11] Damage Assessment etc.

There are certain ***Earthquake Safety Rules*** which can be adopted before, during and after any earthquake event by the people of the region. Though, the technology has

not yet been developed to predict the earthquakes; and forecast the time, place and magnitude of any next seismic event but through proper Disaster Management programs, the losses and damages can be minimized.

TRANSCRIPTION

Introduction :

Disaster is always injurious to lives and properties. About 75 percent of the world's population lives in areas affected at least once by Earthquake, Cyclone, Hurricane, Flood, Drought, Tsunami, Landslide etc. Thousands billion currency losses every year and affects annual growth of many countries. Recently, multifarious and frequently occurred natural disasters and some man-made disasters have brought about massive economic and life losses to the affected regions, and hindered the regional socio-economic development.

Before elaborating disaster and its management, it is very essential to understand – **Disaster**, its **Types**, **Causes**, **Effects** etc.

What is Disaster ? ***Disaster*** is a Greek word meaning *bad star*. Disaster occurs when hazards meet vulnerability. A disaster is the result of an immediate situation or the result of a long set process which disrupts normal human life as well as environment which is caused by extraordinary destructive phenomenon or human-induced hazards resulting in human hardship and suffering beyond recovery until external aid is brought in.

Types of Disaster : Broadly, disasters are classified into *two categories :*
[A] Natural Disasters, and
[B] Man-made Disasters.

[A] Natural Disasters : United Nations has defined the Natural disaster as - *It is the occurrence of a sudden or major misfortune which disrupts the basic fabric and normal functioning of a society [or community]*.

India's unique Geoclimatic position make the country vulnerable to a variety of *natural disasters*. India has 7,517 kms. long coastline on three sides and has the Himalayan Range [one of the world's youngest folded mountain ranges and extend almost uninterrupted for 2,500 kms] on the fourth side. That is why India has to face variety of natural disastrous events every year.

Types of Natural Disasters

Phenomenon	Disasters
Wind and/or Water related disasters	**1. Typhoons** **2. Hurricanes** **3. Cyclones** **4. Sheet flooding** **5. Marine and River-based floods** **6. Droughts**

Climate related disasters	**1. Heat and Cold Waves** **2. Global Warming** **3. Sea-level Changes** **4. Ozone Depletion** **5. El Nino** **6. Forest fires**
Mountainous disasters	**1. Landslides** **2. Snow Avalanches**
Geological disasters	**1. Volcanic Eruptions** **2. Earthquakes** **3. Tsunamis**

Almost all parts of India experience one or more above mentioned disasters. Based on the frequency and vulnerability, the entire country may be classified into three regions :

1. The Himalayan Region : This region covering an area of about 5,00,000 sq. kms. and prone mainly to Earthquakes, Landslides, Avalanche and Bush fires.

2. The North and Central Indian Region : This region is having some great river systems and during Monsoon period, they cause floods of high degree. Parts of this region also experience droughts when the rains are insufficient.

3. The Coastal Region : This region is also very sensitive to cyclones, hurricanes emerging in the oceans.

[B] Man-made Disasters : Human-induced hazards come in this category. The major reason behind the large number of such disasters is the failure of human beings, mistake, malfunctions in one form or the other. The types of Man-made disasters and the phenomenon which causes them are….

Types of Man-made Disasters

Phenomenon	Disasters
Industrial and Technological disasters	**1. Industrial accidents** **2. Explosions** **3. Radioactivity leakages in reactors**
Fire accidents	**1. Fires in cities and towns** **2. Fire accidents in industries** **3. Coal mine fires** **4. Forest fires**
Rail and Road accidents	**1. Human failures** **2. Equipment failures** **3. Washing away of tracks** **4. Collapse of bridges** **5. Landslides due to blasting** **6. Unmanned railway crossings** **7. Sabotage**

	8. Tampering with the tracks
Air and Sea accidents	**1. Aircraft and ship accidents** **2. Machinery breakdown of these** **3. Overloading of boats/ships** **4. Poor quality of equipments** **5. Poor maintenance of machinery**
Biological phenomenon	**1. Plague, Dengue, Malaria, Diarrhea** **2. Chikungunya, Encephalitis** **3. HIV/AIDS, Hepatitis** **4. Famine** **5. Diseases in animals** **6. Destruction of crops**
Complex disasters	**1. Terrorism** **2. Nuclear tests** **3. Spacecraft failures** **4. Fall of Satellite garbage**

Whether disaster is natural or man-made, it is event that negatively affects life, property, livelihood or industry often resulting in permanent changes to human societies, ecosystems and environment.

Earthquakes are one of the most frightening, dangerous and destructive natural hazards. The impact of the earthquake is sudden with hardly any warning. Their results are terrifying. Rivers may change their course. Earthquakes never kill people directly. Instead, many deaths and injuries result from falling objects and the collapse of structures. Till date it is not possible to predict the earthquakes in terms of exact place and time of occurrence, magnitude etc. Therefore, it is very necessary to understand about the earthquakes which are experiencing too frequently.

Earthquakes :

An ***earthquake*** can be defined as a shaking of a part of the Earth surface because of the series of shock waves through the rocks. The vibrations caused by the sudden release of energy beneath the earth surface, usually as a result of displacement of rocks along active faults. Under stress, rocks can be bent but beyond tolerance limit, rocks break with a net displacement across the fault, energy releases and earthquake generates.

According to a latest information by the US Geological Survey National Earthquake Information Center, considerable number of earthquakes have been recorded. Last year [i.e. in 2011], 2477 earthquakes of Magnitude 5 or above, have been experienced.

Frequency of Occurrence of Earthquakes

Magnitude	Average Annually
8 and above	1 [1]

7 to 7.9	15 [1]
6 to 6.9	134 [2]
5 to 5.9	1319 [2]

[1] *Based on observations since 1900* [2] *Based on observations since 1990*

When an earthquake generates on the sea floor/ocean floor, seismic waves travel through the column of the water and reach to the surface. These are called ***tsunami***. Tsunami travel at speeds of several hundred kilometers per hour and are commonly not noticed in an open ocean because their weigh height is usually less than 1 meter and the distance between the wave crests is several kilometers. When tsunami approach sea coast, the waves slow down and rise up to heights of 20 – 30 meters with tremendous velocities of more than 500 kms. per hour, and create great destructions. It is also noted that earthquakes generally of magnitude greater than 6.5 on Richter Scale that occur on the ocean floor and cause *vertical displacement* on the oceanic crust, produce tsunami.

Epicenter : The point or place on the surface of the earth vertically above the focus is the *Epicenter*. It is geographical location on the surface of the earth where *vibrations* of an earthquake reach *first*, which is also the area of *maximum damage* during an earthquake.

Focal Depth : The depth of the focus from the epicenter, is called focal depth.

Classification of Earthquakes :

Earthquakes broadly classified into two categories :
I – Natural Earthquakes and
II – Man-made Earthquakes.

I – Natural Earthquakes : Majority of earthquakes are natural and disastrous. They generate due to sudden movement of rocks within the earth along faults. They are also known as *Tectonic Earthquakes.* ***Focus :*** The location or area below the surface of the earth where rupture begins and energy releases, is referred to as the *Focus* or *Hypocenter*. It may lies few hundred meters to several kilometers below the surface.

Depending upon the **depth of focus**, three classes of earthquakes are recognized :

Sr. No.	Earthquake Type	Depth of Focus
1	Shallow-focus Earthquakes	up to 60 kms.
2	Intermediate Earthquakes	between 60 and 300 kms.
3	Deep-focus Earthquakes	more than 300 kms.

Magnitude : It is a *quantitative measurement* of the amount of energy released during an earthquake. It is based on the actual recorded vibrations on a seismograph.

On the basis of **magnitude**, the earthquakes are grouped into five classes :

Class	Magnitude
A	more than 7.8
B	between 7.0 and 7.8
C	between 6.0 and 6.99
D	between 5.3 and 5.99
E	less than 5.3

II – Man-made Earthquakes : Earthquake vibrations caused by human activities are come in this category. They are also called *Artificial Earthquakes.*

Seismic Waves:
During earthquakes number of seismic waves are generate, first **Primary** or **P** waves- they are also called Push and Pull waves. They are fastest in their velocities and that is why they reach first at seismic stations. They are like sound waves and can transmit through solid, liquid and gaseous media.
Secondary or **S** waves- They are also called sheer waves. They are slower than the Primary waves and they reach after the Primary waves. They are like light waves and can transmit through solids only.
After these waves **Longitudinal** or **Surface** waves reach at the recording station. They are slowest in their velocities and they travel at or near the surface of the earth. Because of their slow velocity they cause maximum damage during the earthquakes.

Causes of the Earthquakes:

Seismologists have observed number of causes and activities which are responsible for the earthquakes. The important are:

1. Tectonic causes
2. Volcanic activities
3. Reservoir-triggered activities
4. Human activities etc.

1. **Tectonic causes :** The main cause of the earthquakes is the structural disturbances resulting within the parts of the earth crust or mantle. Most of such earthquakes are *Tectonic Earthquakes* which are highly disastrous. Vertical and lateral displacement along the active faults, plate boundaries etc. are the causes of severe earthquake activities.

2. Volcanic activities : During volcanic activities, the surrounding area experiences seismic shocks. Although most of the shocks of this type are not sever, but local and nearby areas may damage disastrously. It is not necessary that all volcanic eruptions give rise to earthquakes but when eruptions are of explosive and blasting type,

tremors generate. When huge quantity of lava are thrown out suddenly under great pressure and roof of the empty magma chambers collapse, surrounding region experiences shocks.

3. Reservoir-triggered activities : Seismicity associated with impounding of water in artificially created reservoirs, come in this category. Earthquakes associated with Koyna Reservoir, western Maharashtra, is unique because it is one of the few sites in the world where triggered earthquakes of magnitude 6.0 continue to occur nearly four decades after the first major activity in 1967. The annual filling cycles continue to weaken the fault zone at Koyna and changes in stresses are introduced by reservoir fluctuations. Values of pore fluid pressure change every time which cause continuing seismicity at Koyna.

4. Human activities : On-ground and underwater nuclear tests, blasting in open and underground mines, working of heavy machines in industrial areas, movement of locomotives along railway tracks, transportation of heavy vehicles on the highways, landslides along hill slopes etc. generate weak as well as severe vibrations.

Earthquakes and Disaster Management :

Among all the natural calamities, earthquakes are the most unpredictable and destructive natural hazards. Within few seconds, a havoc can be seen on a massive scale in the form of deaths, injuries and destruction. Without early warning or very little warning, it is impossible to make all necessary arrangements against great damages and losses due to earthquakes. Hence, there are increasing efforts to lessen the impact of disasters on all sectors of the society. In the case of earthquakes, following happenings are common for management efforts :

- drilling equipments and heavy lifting machineries are needed for Search of living beings,
- rescue, hospitalization and emergency medical aid to injured people,
- large number of people are forced to leave home with little of their personal belongings to safer locations,
- communication and transportation facilities in the affected region,
- needs for shelters with minimum requirements of toilet facilities to the people,
- providing food and water to the affected people,
- trained rehabilitation teams etc.

Some of the critical issues of Disaster Management form the Earthquake point of view, are discussed here :

[1] Seismic Zoning : Disasters Mapping is a tool for assessing, storing and conveying information on the geographical location and spread of the effects of disasters. Disaster maps usually show disaster impact zones. Preparation of seismic zone maps is a highly technical task and requires collection of data of several decades or even centuries.

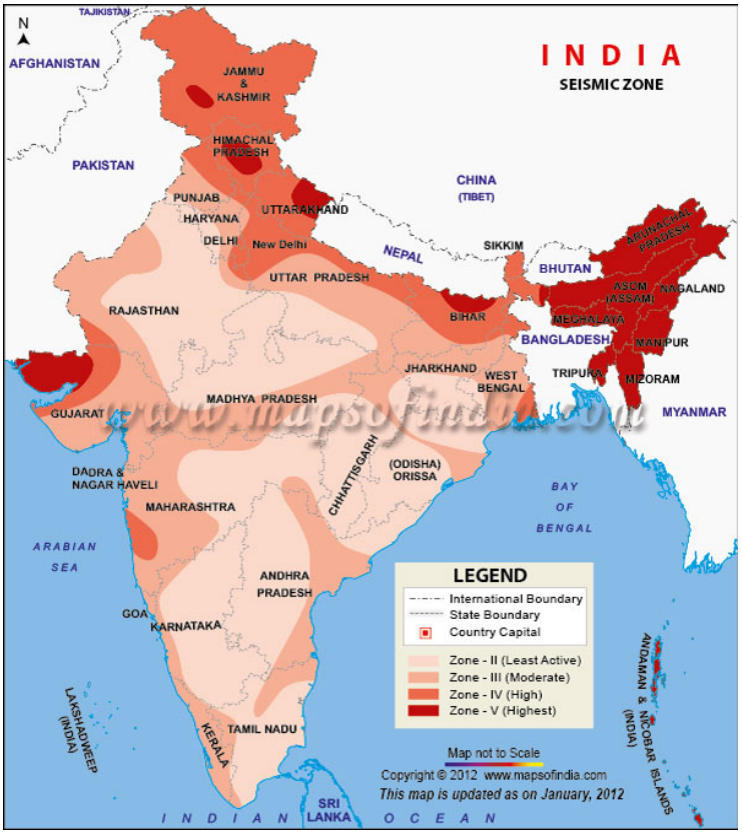
At present India has been divided into four damage risk zones:

Zone II- This zone covers major parts of the country and it is the Low Damage Risk zone. Earthquakes of magnitude between 4 to 4.6 fall in this zone.

Zone III- This is moderate damage risk zone in our country. Earthquakes of magnitude 4.7 to 5.3 come in this zone.

Zone IV- This is high damage risk zone covers extra peninsular parts of India, parts of Gujarat, Koyna region of Maharashtra. Earthquakes of magnitude between 5.4 and 6 have been observed in this zone.

Zone V- This is the very high damage risk zone in our country. This zone covers parts of Himalaya, North Eastern parts of India and portions of Gujarat. This is one of the seismically prone areas of the world. Earthquakes of magnitude more than 6 come in this zone



[2] Earthquake Resistant Buildings : Considering that most human losses are due to collapse of buildings, the problem of safety could best be taken care of through a pre-disaster *prevention* approach. After some of the disastrous earthquakes in the country, number of actions are being taken :

Hazard evaluation and risk assessment
Hypothetical Building Damage Scenario

Strictness to follow By-laws for Damage-resistant
Techno-legal Regime for the Country
Technology transfer Provisions
Strengthening of Information Technologies
Human Resource Development

Upgrading and Strengthening of Seismological Instrumentation Network
Preparation of Seismotectonic Atlas of India
Suggestions for Future

[3] Role of Remote Sensing and Aerial Photography: Remote sensing and Aerial photography by satellites and aircrafts are valuable information-gathering tools for disaster managers and ideally suited for disaster management.
They provide database from which the evidence left behind by past disasters could be interpreted. With other information combinations, one can indicate the areas that are potentially dangerous.

[3] Predictability, Forecasting and Warning of Earthquakes : Earthquakes cannot be forecast yet because there is no accurate warning system at present. On the basis of past seismic records, the areas which are prone to seismic activities, could be taken as a general warning because the exact time and place of the next earthquake, particularly major event, cannot be indicated.

In some cases, certain warning signals occur before an earthquake such as unusual behavior of birds, animals and reptiles, sudden change in water levels in wells [lowering or rising], widening of existing natural cracks on the earth's surface etc.

[4] Public Awareness Campaigns : Awareness remains one of the major tools for preparing communities for risk reduction and it is most effective through:

Face to Face Interactions
Electronic Media &
Print Media

[5] Relief Measures : Relief measures are the immediate need in the post-disaster scenario when unknown number of victims are affected and even their locations are not clearly known. In such type of circumstances, *Search* and *Rescue*, *Evacuation* etc. are the processes which carried out immediately after the disaster.

[6] Shelters for Victims : Various types of disasters need different shelter strategies.
Varying shelter strategies may be as :

Shelter Types	
Large Shelter Space	
Temporary Relief Camps	
Rehabilitation Settlements	
Repair and Restoration	

[7] Clearance of Debris : Debris from collapsed buildings, bridges and other structures as well as uprooted trees, electric poles and wires, hoardings, damaged vehicles, goods, accumulated solid waste [which may be of bio-degradable and non-degradable nature] etc. are the biggest hindrance to search, rescue and relief operations. They create disruption in communication services and transportation. Debris clearance is the first step towards re-establishment of transport and communication network. Apart from this we will have to take care of:

[8] Disposal of the Dead bodies:

[9] Fire accidents:

[10] Damage Assessment:

Earthquake Safety Rules

What to do Before an Earthquake:

If the moment of an earthquake can be anticipated, it is safest to remain out of doors immediately before the onset of the earthquake. One should leave the house and stay out in the open or in the temporary camps till the scare is over.

1. Keep stock of drinking water, some foodstuffs, first-aid equipments, clothing, radios, emergency medicines, blankets, a crow bar, shovel, pick and rope, electric torch, some candles and a helmet ready for you and for every member of the family. Use plastic bottles in preference to glass bottles for carrying water or other liquids.

2. Ensure that water heaters, and other gas appliances are firmly fixed and shut off when not in use, as broken gas pipes or appliances are likely to cause fire hazards.

3. Secure all heavy objects like furniture, refrigerators storage cabinets etc. to the walls and place large and heavy objects on the lower shelf. Top heavy objects should be braced or anchored.

4. Find out the location of the nearest first-aid post, Police station and Fire station and approach it for help if required.

5. Join the Civil Defense Organization and train yourself and members of your family in first-aid, rescue, fire fighting etc., which will help you, your family and neighbors.

6. Conduct occasional home earthquake drills so that your family has the knowledge to avoid unnecessary injuries and panic in the event of an earthquake.

7. The more responsible members of the family may be taught how to turn off electricity, gas and water at the main switches or valves.

8. Educate all members of the family as to what to do in such emergencies so that you are prepared in the event of earthquake, i.e. at home, while driving a car, at work in shop, in a cinema hall etc.

What to do During an Earthquake:

Since earthquakes last for only few seconds, the earthquake can be all around you before you are aware of it.

1. Keep cool. Don't panic. Panic causes heavy injuries. The ground motion frightening to all.

2. In the event, the safest place is an open space building. If this is not suitable, do not try to run from a building during earthquake.

3. If it catches you indoors, take cover under a desk, table, and bench; avoid standing just outside the main door or near the outside walls. This is usually an unsafe place.

4. Watch for falling plasters, bricks, ceiling fixtures, and other loose objects. Stay away from glass.

5. Do not use candles, matches, or other open flames, either during or after the earthquake.

6. If the earthquake catches you outside, move away from buildings and utility wires. Stay in the open area until the tremor stops.

7. Do not run through or near buildings. The greatest danger from falling debris is just outside doorways and close to outer walls.

8. If you are in a moving car, stop as quickly as safety permits, away from buildings or trees, but stay in the vehicle. A car is an excellent seismometer, and will jiggle on its springs during an earthquake, but it is a good place to stay until the earthquake stops.

9. Avoid escalators even stair-cases may be crowded by escapees. Take your turn.

What to do After an Earthquake:

After the earthquake is over, there will be tremendous rush of rescue work. Those who have escaped injuries will be trying to rescue persons who have been trapped. If you are one of the trapped, wait patiently for your turn. Remain calm; conserve your energy after the earthquake

1. Check your utilities, but do not turn them on. Earth movement may have cracked water, gas and electrical conduits.

2. If you smell gas, open windows and shut off the main valve. Then leave the building and report gas leakage to authorities. Do not re-enter the house until a Civil Defense Official says it is safe.

3. Check for fire and fire hazards and secure fire extinguishers. Do not strike match-sticks unless you are sure there is no gas leak around.

4. If mains of water damaged, shut off the supply at the main valves.

5. If electrical wiring is shorting, close the switch at the main meter box.

6. Check your electric, gas, water and sewerage connections. They may have damaged beyond immediate repair. You will have to live without them for some time.

7. Turn on the transistor, radio or television to get the latest information/bulletin and aftershock warnings.

8. Stay off the telephone except to report an emergency.

9. Stay out of severely damaged buildings, aftershocks can crash them further.

10. Keep away from hanging portions of buildings or overhanging cliffs, as they may fall due to after-shocks which may continue for some time.

11. Look for the injured in your family or neighbor's families because you know where they were and probably still are. Render such assistance as you can, until medical aid arrives.

At present whatever technologies are available, on the basis of them, the prediction of earthquakes is not possible but through proper Disaster Management Programs the losses and damages can be minimized.

Additional Material

Disaster Management : In an Earthquake Perspective

Introduction :

Disaster is always injurious to lives and properties. About 75 percent of the world's population lives in areas affected at least once by Earthquake, Cyclone, Hurricane, Flood, Drought, Tsunami, Landslide etc. Thousands billion currency losses every year and affects annual growth of many countries. Recently, multifarious and frequently occurred natural disasters and some man-made disasters have brought about massive economic and life losses to the affected regions, and hindered the regional socio-economic development.

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Mountainous disasters	**1. Landslides** **2. Snow Avalanches**
Geological disasters	**1. Volcanic Eruptions** **2. Earthquakes** **3. Tsunamis**

Almost all parts of India experience one or more above mentioned disasters. Based on the frequency and vulnerability, the entire country may be classified into three regions :

1. The Himalayan Region : This region covering an area of about 5,00,000 sq. kms. and prone mainly to Earthquakes, Landslides, Avalanche and Bush fires.

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Types of Man-made Disasters

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According to a latest information by the US Geological Survey National Earthquake Information Center, considerable number of earthquakes have been recorded. Last year [i.e. in 2011], 2477 earthquakes of Magnitude 5 or above, have been experienced. On the basis of worldwide record of number of earthquakes, annual frequency has also been averaged.

Number of Earthquakes Worldwide between 2007 and 2011

Magnitude Ranging Between	2007	2008	2009	2010	*2011*
8 to 9.9	4	0	1	1	*1*
7 to 7.9	14	12	16	21	*19*

6 to 6.9	178	168	144	151	*185*
5 to 5.9	2074	1768	1896	1963	*2272*
Total	**2270**	**1948**	**2057**	**2136**	***2477***

Frequency of Occurrence of Earthquakes

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Earthquakes :

An ***earthquake*** can be defined as a shaking of a part of the Earth surface because of the series of shock waves through the rocks. The vibrations caused by the sudden release of energy beneath the earth surface, usually as a result of displacement of rocks along active faults. Under stress, rocks can be bent but beyond tolerance limit, rocks break with a net displacement across the fault, energy releases and earthquake generates.

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The mechanisms behind these activities are explained in ***elastic rebound theory*** of earthquakes.

Elastic-rebound Theory : H. F. Reid of Johns Hopkins University proposed the *Elastic rebound Theory* based on the studies conducted after the 1906 San Francisco earthquake of California [USA]. Reid taken some measurements across a portion of the

San Andreas fault [*the biggest laboratory in the world*], and revealed that rocks on one side of the fault had moved relative to rocks on the other side. This movement caused the gradual bending of rocks across the San Andreas fault. Accordingly, the strength of the rocks was exceeded, the rocks on opposite sides of the fault rebounded to their former undeformed shape, and the stored energy was released as earthquake waves radiating outward from the break. Additional field and laboratory studies concluded that *elastic rebound* is the mechanism that generates earthquakes.

The vibrations often induce the actual movements in the ground [i.e. acceleration] which are generally of some seconds [rarely exceed 1 minute]. The vibrations greatly vary in intensity, magnitude and direction. Number of feeble earthquakes may occur before the main earthquake, are called *foreshocks*. Following the major/main earthquake, adjustments along a fault commonly generate a series of smaller earthquakes known as *aftershocks*. Most of these are less intensive than the main shock, but they can cause considerable damages to already weakened structures.

The word ***Seismic*** is commonly used for any matter related to an earthquake. To locate, record and analyze the earthquakes, several terminologies are used. The important are :

Seismology : The science dealing with the study of the earthquakes in all respects, is the *Seismology*. The scientists carried out all investigations related to earthquakes are called *Seismologists*.

Seismograph : The instrument that detects, records and measures any earth motion caused due to earthquake waves, is called *Seismograph*.

Seismogram : Any record of earth motion produced by a seismograph is a *Seismogram*. Since during a earthquake, ground is accelerated in both horizontal and vertical directions, a seismograph may be designed to record either the vertical or horizontal component of ground motion.

Seismic Waves : When an earthquake begins, energy radiates in the form of waves in all directions from the point of release. Such waves are called *Seismic Waves*.

Focus : The location or area below the surface of the earth where rupture begins and energy releases, is referred to as the *Focus* or *Hypocenter*. It may lies few hundred meters to several kilometers below the surface.

Epicenter : The point or place on the surface of the earth vertically above the focus is the *Epicenter*. It is geographical location on the surface of the earth where *vibrations* of an earthquake reach *first*, which is also the area of *maximum damage* during an earthquake.

Focal Depth : The depth of the focus from the epicenter, is called focal depth.

Epicentral Distance : The distance from epicenter to any point of interest on the earth's surface is called epicentral distance.

Isoseismal Lines : These are the hypothetical lines passing through the values of same intensity in a particular earthquake record.

Intensity : It is a *qualitative assessment* of the kinds of damage [i.e. effects on living and non-living objects] done by an earthquake as well as people's reaction to it.

Magnitude : It is a *quantitative measurement* of the amount of energy released during an earthquake. It is based on the actual recorded vibrations on a seismograph.

Fault : It is a fracture along which movement and displacement of rocks occurred.

Aftershocks : After an earthquake, adjustment of rocks takes place and a series of smaller earthquakes commonly generate known as aftershocks.

Foreshocks : Number of feeble earthquakes may occur before the main earthquake, are called foreshocks.

Plate : A plate is a large, continuous piece of Lithosphere [crust and upper mantle] which moves as an unit along the surface of the earth over a yielding mantle.

Tsunami : These are destructive seismic sea/ocean waves that are usually produced by an earthquake on the ocean floor [sometimes by submarine landslides or volcanic eruptions].

Classification of Earthquakes :

Earthquakes broadly classified into two categories :
I – Natural Earthquakes and
II – Man-made Earthquakes.

I – Natural Earthquakes : Majority of earthquakes are natural and disastrous. They generate due to sudden movement of rocks within the earth along faults. They are also known as *Tectonic Earthquakes*. Depending upon the **depth of focus**, three classes of earthquakes are recognized :

Sr. No.	Earthquake Type	Depth of Focus
1	Shallow-focus Earthquakes	up to 60 kms.
2	Intermediate Earthquakes	between 60 and 300 kms.
3	Deep-focus Earthquakes	more than 300 kms.

On the basis of **magnitude**, the earthquakes are grouped into five classes :

Class	Magnitude
A	more than 7.8
B	between 7.0 and 7.8
C	between 6.0 and 6.99
D	between 5.3 and 5.99

E	less than 5.3

Most of the disastrous earthquakes of the world are associated with the plate movements. On the basis of the **association with the plates**, the earthquakes are two types :

Type	Association with the Plates
1	Earthquakes occur along the boundaries of the tectonic plates are called *Inter-plate Earthquakes*.
2	Earthquakes occur within the plate itself away from the plate boundaries are called *Inter-plate Earthquakes*.

II – Man-made Earthquakes : Earthquake vibrations caused by human activities are come in this category. They are also called *Artificial Earthquakes.*

Seismic Waves :

During each earthquake, elastic waves are generated at the focus. These waves are called *Seismic Waves*, which travel in all directions with characteristic velocities, refraction and reflection. The shaking and destruction during earthquakes are caused by seismic waves only. Broadly, seismic waves are two types : **1. Body Waves** and **2. Surface Waves**.

1. Body Waves : These waves travel deep into the body of the earth before reaching on the surface , hence called *body waves*. An earthquake generates two types of body waves :

A. Primary or P-waves : These seismic waves are the fastest in their velocities, similar to sound waves and can transmit through rigid rocks, liquid and gaseous media. These are also called the *Compressional* or *Push-pull Waves* in which particles vibrate forward and backward in the direction of movement of waves. P-waves always arrive first at the seismic stations.

B. Secondary or S-waves : These waves are comparatively slower than the primary waves, similar to light waves and transmit only through solids [i.e. rigid rocks]. These are also called the *Shear* or *Transverse* or *Distortional Waves* in which particles vibrate perpendicular to the direction of movement of waves. These waves reach after the reaching of P-waves at the recording stations.

The velocities of seismic waves depend upon the density and elasticity of the materials through which they pass. These waves travel more slowly through rocks of greater density but more rapidly through rocks with greater elasticity.

2. Surface Waves : These waves travel at or near to the ground surface, slowest in velocity than the body waves and cause great damage on the earth's surface. Surface waves are also of two types :

A. Love Waves : In these waves, the movement of particles is horizontal in the direction of movement of waves.

B. Rayleigh Waves : In these waves, the displacement of particles is of complex nature. Particle move partly in the direction of propagation and partly perpendicular to it. In other words, particles travel in elliptical orbits.

Causes :

Seismologists have observed number of causes and activities which are responsible for the earthquakes. The important are :

1. **Tectonic causes**
2. **Volcanic activities**
3. **Reservoir-triggered activities**
4. **Human activities etc.**

1. Tectonic causes : The main cause of the earthquakes is the structural disturbances resulting within the parts of the earth crust or mantle. Most of such earthquakes are *Tectonic Earthquakes* which are highly disastrous. Vertical and lateral displacement along the active faults, plate boundaries etc. are the causes of severe earthquake activities. *Elastic rebound* is the mechanism for tectonic activities which occurs in *three steps* :

In the *first step* which is the *preparatory step*, a non-hydrostatic stress-field is created in s certain region around an active fault. The time duration of this step ultimately decides the *size* of the main earthquake. Number of *foreshocks* are often recorded during this step.

In the *second step* which is the *rupture step*, during which rupture [development of weak planes and bending of rocks] takes place along the faults and all or part of the *stored elastic energy is released* in the form of *main shock*, which is the characteristic if this step.

In the *third step* in which *post-failure adjustment* takes place, rocks restored to a state of equilibrium and remaining stored energy releases from the rocks in the form of *aftershocks*.

In recent years, the concept of *Plate Tectonics* also helped to understand the origin of tectonic earthquakes. It is observed that interaction of plates at their boundaries accounts for most of the *Inter-plate earthquakes*. These boundaries are the areas where lithospheric plates are either diverging or converging or sliding laterally. Along convergent plate boundaries, earthquakes caused due to *subduction* of one plate under another plate and even during *colliding* of two continental plates from opposite directions. Transform plate boundaries occur along fractures in the seafloor [known as Transform Faults] where plates slide laterally one another, generates numerous shallow-focus earthquakes.

As far as the cause of *Intra-plate earthquakes* is concerned, geologists think that they are due to reactivation of ancient faults and rifts.

2. Volcanic activities : During volcanic activities, the surrounding area experiences seismic shocks. Although most of the shocks of this type are not sever, but local and nearby areas may damage disastrously. It is not necessary that all volcanic eruptions give rise to earthquakes but when eruptions are of explosive and blasting type, tremors generate. When huge quantity of lava are thrown out suddenly under great pressure and roof of the empty magma chambers collapse, surrounding region experiences shocks.

3. Reservoir-triggered activities : Seismicity associated with impounding of water in artificially created reservoirs, come in this category. Earthquakes associated with Koyna Reservoir, western Maharashtra, is unique because it is one of the few sites in the world where triggered earthquakes of magnitude 6.0 continue to occur nearly four decades after the first major activity in 1967. The annual filling cycles continue to weaken the fault zone at Koyna and changes in stresses are introduced by reservoir fluctuations. Values of pore fluid pressure change every time which cause continuing seismicity at Koyna.

4. Human activities : On-ground and underwater nuclear tests, blasting in open and underground mines, working of heavy machines in industrial areas, movement of locomotives along railway tracks, transportation of heavy vehicles on the highways, landslides along hill slopes etc. generate weak as well as severe vibrations.

Recording Instruments :

Earthquakes generate seismic waves which disturb the ground through which they travel. *Seismograph* is the instrument that record the various elastic vibrations caused by an earthquake.

One of the earliest earthquake detecting devices called *Seismoscope*, was made-up of decorated jar. Eight dragon mouths with movable jaws were arranged symmetrically in a circular fashion around a pendulum suspended at the centre. The jaws were attached to the pendulum with spokes to act as levers. This set-up resembling a *chakra* was mounted on a jar with each of the jaws holding a bronze ball. Bellow each jaw were placed carved toads with their mouths open as if waiting for the ball to fall into their mouth. When earthquake occurs,

One of the balls is ejected to fall into the mouth of a waiting toad. The impact sounds alarm bell and the position of the fallen ball gives some idea of the direction from which the earthquake came.

A traditional and simplest analog seismograph consists of a *seismometer* which senses the ground motion, and a *recorder* to record the seismic waves on the rotating drum. In a *vertical component seismograph*, a heavy mass is made to hang through a spring from a rod fixed to the ground. With the movement of the ground, the rod as well as the recorder move, but the mass does not move initially due to its inertia and therefore the spring extends. Thus, relative to the recorder, the mass moves up or down in a vertical direction and the marker marks this relative motion on the drum. Using the same principle, *horizontal components* of the ground i.e. north-south and east-west directions can be recorded with suitable arrangements.

Sometimes it is necessary to observe the recording of a seismograph continuously. In a modern *visible recording seismograph*, the output from the electromagnetic seismometer is fed to an amplifier. The amplified voltage is fed to a galvanometer attached to a pen for recording on a plain paper.

The analogue graphical recording of seismic waves made by a seismograph is called a *Seismogram*. It is in the form of wavy lines on the paper that repeats the amplified seismic waves which have reached the seismic station. The first wave-like forms on the seismogram

are due to ***primary waves***, which are followed, after a small interval of time, by outlines due to ***secondary waves*** and in last, high-amplitude ***surface waves*** of large periods.

The analog instruments have evolved over time, but today *digital instruments* using modern computing technology are more commonly used. The digital instruments record the ground motion in terms of digital counts on the memory of the microprocessors that are in-built in the instrument. Nowadays, *Digital Recording Seismographs*, *Broadband Digital* Seismographs, *Strong Motion Digital Accelerographs*, *Teleseismic Broadband Seismographs*, *Ocean Bottom Seismographs* etc. are used. With the availability of digital waveform data, several standard software packages have been developed in recent years for processing and analysis of data. The International Association for Seismology and Physics of the Earth's Interior [IASPEI] has developed a library of standard programs for various kinds of seismological data processing and analysis, which is used extensively by the seismological community, the most important of these are PITSA, SEISGRAM etc. SEISmic ANalysis software [SEISAN], SEISmic NETwork automation software [SEISNET] etc. are some of the software that widely used for the estimation of earthquake hypocentral parameters [i.e. origin time, epicenter, focal depth etc.], magnitude of the event, times of arrival of various phases recorded at different stations, structures of earth's interior etc.

Measurement of Earthquakes :

Seismologists measure the strength of an earthquake in two different ways :
[1] Intensity, and
[2] Magnitude

[1] Intensity : It is the qualitative assessment of damage done by an earthquake as well as people's reaction on it. It is obvious that a larger earthquake will produce greater intensity value than the smaller one. Depending upon the distance from the epicenter, depth of the focus, population density, local geology of the area, type of building construction, duration of shaking etc., intensity of an earthquake varies. The most common intensity scale used, is the ***Modified Mercalli Intensity Scale*** [MMI], revised by an Italian Volcanologist - *Giuseppe* Mercalli, in which *Roman Capital Numerals* are assigned ranging from I [least perceptive] to XII [most severe] :

No.	Intensity	Earthquake Effects
I	Instrumental	Generally not felt by people unless in favorable circumstances.
II	Weak	Felt only by a few people at rest, especially on the upper floors of the buildings. Suspended objects may swing.
III	Slight	Felt quite noticeably by people indoors, especially on the upper floors of buildings. Many do not recognize it as an earthquake. Standing automobiles may rock slightly. Vibration similar to the passing of a truck.
IV	Moderate	Felt indoors by many people, outdoors by few people during the day. At night, some awakened. Dishes and windows rattle alarmingly, walls make cracking sound. Sensation like heavy truck striking building. Standing automobiles rocked noticeably.
V	Rather Strong	Felt by nearly everyone. Dishes and windows may break and large bells will ring. Disturbance of trees, poles etc. Vibrations

		like large train passing close to house.
VI	Strong	Felt by all; many frightened and run outdoors. Windows, dishes, glassware broken; books fall off shelves. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very Strong	Everybody runs outdoors. Difficult to stand. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Noticed by people driving automobiles.
VIII	Destructive	Damage slight in specially designed structures; considerable in normally constructed buildings with possible partial collapse. Great damage in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts.
IX	Violent	General panic; damage considerable in specially designed structures. Buildings shifted off foundations. Ground noticeably cracked. Underground pipes broken.
X	Intense	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundation. Ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Water splashed over river banks.
XI	Extreme	Few, if any [masonry] structures remain standing. Bridges destroyed. Broad fissures in ground. Rails bent greatly. Underground pipelines completely out of service.
XII	Cataclysmic	Total destruction – everything is destroyed. Objects thrown upward into the air. Waves seen on ground surfaces. Large amounts of rock move position. Landscapes altered. In some cases, the routes of rivers are changed.

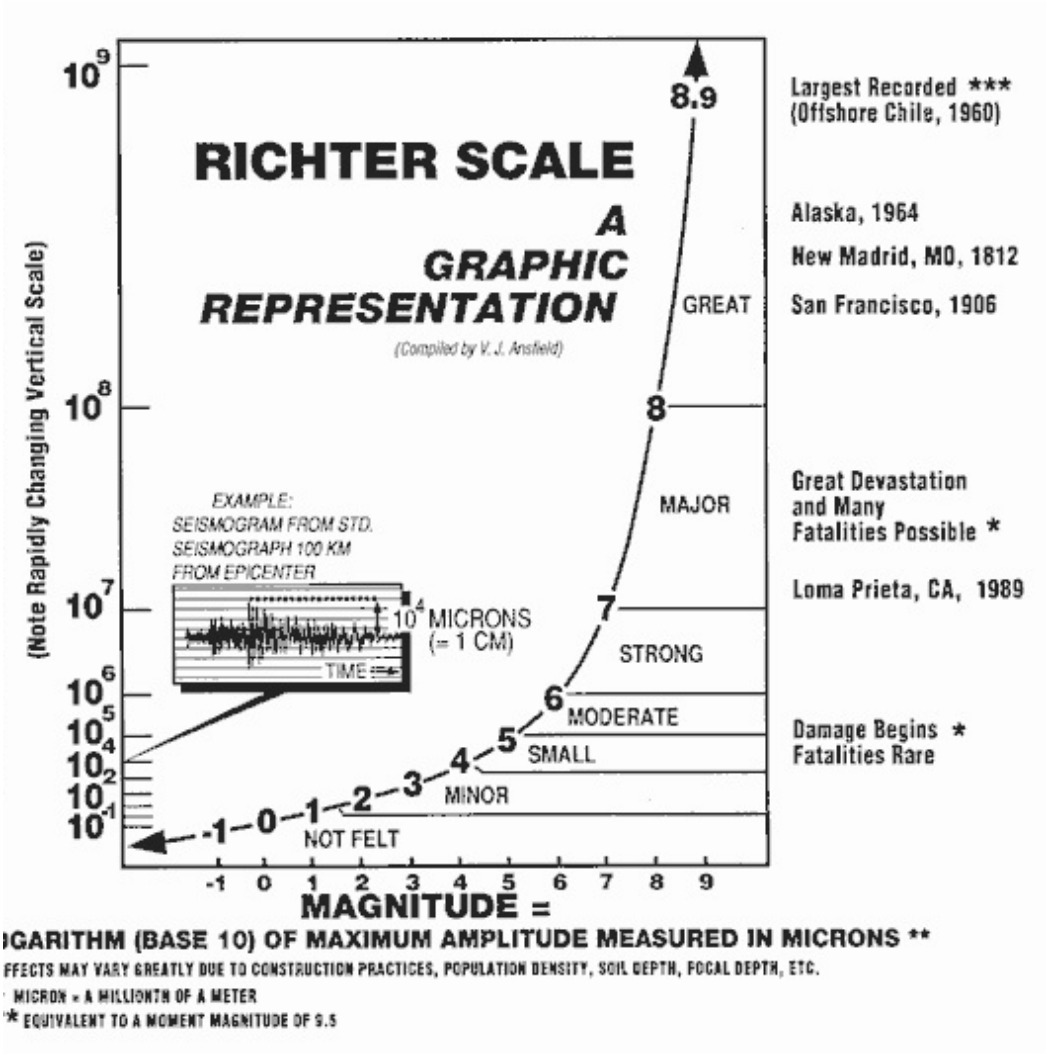
[2] Magnitude : This scale was introduced by Charles F. Richter – a seismologist at the California Institute of Technology. The ***Richter Magnitude Scale*** [RMS] measures earthquake magnitude [M] which is the total amount of energy released by an earthquake at its source. It is presently used internationally for describing size of an earthquake. It is a 10-point open-ended scale with numerals begin with 1 [which is the lowest]. Till date, the highest magnitude recorded, is 9.5 *[May 22, 1960, Valdivia Earthquake, Chile]*. Earthquakes of magnitude greater than 9, are highly improbable because rocks are not able to store the energy necessary to generate earthquakes of this magnitude.

Magnitude	Description	Earthquake effects
< 2.0	Micro	Not felt.
2.0 – 2.9	Minor	Generally not felt but recorded.
3.0 – 3.9		Often felt, but rarely causes damage.
4.0 – 4.9	Light	Noticeable shaking of indoor items, rattling noises. Significant damage unlikely.

5.0 – 5.9	Moderate	Can cause major damage to poorly constructed buildings over small regions. Slight damage to well-designed buildings.
6.0 – 6.9	Strong	Can be destructive in areas up to about 160 kilometers across in populated areas.
7.0 – 7.9	Major	Can cause serious damage over large areas.
8.0 – 8.9	Great	Can cause serious damage in areas several hundred kilometers across.
9.0 – 9.9		Devastating in areas several thousand kilometers across.
10 +	Massive	Never recorded, widespread devastation across very large areas.

Richter used a conventional base-10 logarithmic scale to convert the amplitude of the largest recorded seismic wave to a numerical magnitude value. Therefore, each integer increase in magnitude represents a 10-fold increase in wave amplitude. For example, the amplitude of the largest seismic wave for an earthquake of magnitude 6 is 10 times that produced by an earthquake of magnitude 5, 100 times as large as a magnitude 4 earthquake, and 1000 times that of an earthquake of magnitude 3 [10 x 10 x 10 = 1,000].

While each increase in magnitude represents a 10-fold increase in wave amplitude, each magnitude increase corresponds to about 30-times increase in the amount of energy released. Most of the energy released goes into heat and fracturing the rocks and only a small fraction of it goes into the seismic waves that travel to large distances causing shaking of ground en-route and damage the structures.



Determination of Epicenter :

The various seismic waves travel with different velocities and arrive at different times at a seismographic station. At every seismograph, the first waves to arrive are *Primary waves* [because they are the fastest in velocity], then *Secondary waves*. Both P and S waves travel directly from the focus to the recording station through the earth's interior. The *Surface waves* are the last to arrive [because they are the slowest] and also travel the longest route along the surface.

Seismologists determine the *P-S time interval* [the difference between the arrival time of P and S waves] between the place of origin and the recording station for each seismograph location. For locating the epicenter, P-S time interval data are required from at least *three properly located seismographic stations* that have recorded the *same* earthquake. Then a graph is plotted between *time* and *distance* for each P-S time interval, indicating how far away each seismic station is from the focus of the earthquake. Then a circle, whose radius equals the distance shown on the *time-distance graph*, is drawn on the map for each station as the center at a convenient scale. The intersection of the three circles is the location of the earthquake's epicenter. For epicenter determination, minimum three locations of seismographs are needed because, two locations will provide two possible epicenters.

Disaster Management

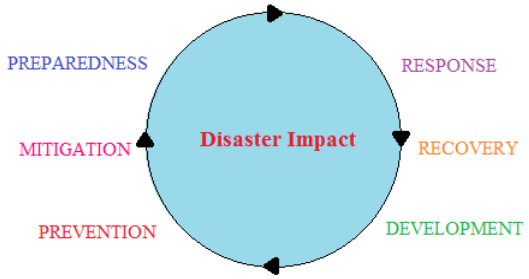
Before understanding *Disaster Management*, it is very essential to distinguish between ***hazards*** and ***disasters***. There is also a close relation between hazards and disasters. A *hazard* is a natural event whereas the *disaster* is the consequence of a hazard. It is not certain that a hazard will always lead to a disaster. This all depends upon the conditions and area / location where a hazard is hitted. Whenever a hazard hits a populated area, effecting life, property and infrastructure with serious damages, it is considered as a disaster. So, a hazard is a pre-disaster situation in which some risk of disaster exists, because of its vulnerable effects over the human population.

The increasing incidence of disasters, natural as well as man-made, across the globe is creating a devastating impact on the lives, property and livelihoods of people. Besides developments, in science and technology, the losses are increasing. Disasters create mass destruction, affect development and consume resources which kept for growth and welfare. For example, the Indian government spends nearly 2 percent of the Gross Domestic Product [GDP] towards relief and rehabilitation. Earlier, the entire approach towards management of disasters, was *relief-based*. But recurrence of disasters is not in our control, there are certain limitations of relief measures, hence, this approach is now changing. The efforts world over, during the last two decades centered around minimizing the severity of disaster impact through a holistic approach.

Now disaster management is being looked at in a very comprehensive manner. Several interrelated components work in an orderly and coordinated manner. This includes before or pre-disaster, during and after the occurrence of a disaster. Disaster management is a joint and collaborative activity that involves to :

- *Reduce the risk associated with disasters through timely measures, short-term and long-term policies,*
- *Provide required assistance to communities during and after the disasters, and*
- *Ensure rapid, sustained recovery and rehabilitation after the occurrence of disaster.*

Disaster management comprises certain key components such as *prevention*, *preparedness*, *response* and *mitigation* etc. which can be represented diagrammatically :



The above cycle indicates that the various components jointly integrate to manage disasters. *Prevention* aims at impending the occurrence of a disaster event while *mitigation* attempts to reduce the effects. *Preparedness* comprises measures, which equip governments at various levels, organizations, communities and individuals to handle and respond effectively to disaster situations. The phase of *response* begins after the disaster impact, which is aimed at saving the lives and property, disruption and damage caused by disasters. The *recovery* covers restoration, rehabilitation and reconstruction to bring back the people to their normal functions. *Developmental plans* include disaster management as one of the components.

Disaster management is now adopting a preventive and mitigation-based approach. It is becoming multi-disciplinary covering wider aspects such as forecasting, warning, search and rescue, evacuation, relief, reconstruction and rehabilitation, education, training, and awareness. Disaster management, thought earlier to be the primary responsibility of the government, now it is diversified, and Armed forces, Police, Para-military forces, International agencies, Non-governmental organizations, Community-based organizations, Educational institutions, Media etc. are also contributing the activities of the government in managing disasters.

In 1989, The United Nations General Assembly [UNGA] through its resolution, launched the International Decade for Natural Disaster Reduction [IDNDR, 1990 – 2000]. The Decade, it was envisaged, would enables governments to focus on hazard vulnerability risk assessment, disaster prevention, sustainable development, effective early warning system, sharing of knowledge and transfer of technology. It emphasized on international action, particularly in developing countries, to handle loss of life, property damage, social and economic disruption caused by natural disaster. *This had laid the basis for the shifting of focus from rescue and relief to preparedness and mitigation*.

The International Strategy for Disaster Risk Reduction [ISDRR] formulated by the United Nations in 2000 aims towards reducing the impact of disasters through prevention, preparedness and mitigation measures.

Disaster Prevention :

The experience of handling disasters all over the world indicates that the after effects of a disaster are more harmful than the disaster event. Hence, there are increasing efforts towards taking *preventive measures* to lessen the impact of disasters on all sections of the society. Following point should be considered for disaster management :

[1] Disaster prevention is of primary importance in reducing the need for disaster relief.

[2] Disaster prevention should be considered an integral part of the developmental policy and planning at the regional, national, bilateral, multilateral and international levels.

[3] Early warning of severe disasters and their effective dissemination using telecommunication are the key factors to successful prevention.

[4] Preventive measures are most effective when they involve participation of all levels i.e. from local, community, national to the regional and international levels.

[5] Preventive measures tend to be large due to the varied nature of disasters. Prevention along with appropriate preparedness and mitigation measures shall prove effective.

Disaster Preparedness :

Disaster Preparedness is an effective way of lessening the impact of disasters, which occur on a small as well as large-scale. It acts as an effective link between emergency response and rehabilitation. Disaster Preparedness mechanisms and processes neutralize and
And reduce vulnerability of people and minimize loss of lives and property.

The United Nations Disaster Relief Office [UNDRO] defines Disaster Preparedness as a series of measures designed to organize and facilitate timely and effective rescue, relief and rehabilitation operations in cases of disaster. Measures of preparedness include setting of disaster relief machinery, formulation of emergency relief plans, training of vulnerability communities to undertake rescue and relief, stock piling supplies funds for relief operations.

The concept for disaster preparedness is presently gaining increasing recognition, as it is being realized that investing in disaster preparedness can save lives and property and reduce relief assistance costs. The preparedness activity is not limited to short-term measures, which are taken during a warning period before the onset of a disaster event. Its activities extend to, during and post-disaster situations. The more effectively the activities are carried out in advance, the more readily will it be possible to take required action during the emergency phase and reconstruction, rehabilitation and recovery phases.

The World Health Organization [WHO] in its report of the Regional Meeting on Health aspect of Disaster Preparedness indicated that India is among the five countries in the South Asian region that meet many of the criteria for Disaster Preparedness. Preparedness involve various activities before, during and after the disaster :

Preparedness Activities before the Disaster :

[1] Formulation of disaster preparedness plans at national, state, local and community levels.

[2] Generation and disseminating information through mass media about the potential hazards, their frequency of occurrence and associated risks.

[3] Installation of appropriate forecasting and warning systems.

[4] Strengthening of physical infrastructure.

[5] Evacuation of people to safer areas.

Preparedness Activities during the Disaster :

[1] Provision of food, shelter, medical and first-aid services.
[2] Security arrangements to prevent occurrence of untoward incidents.

Preparedness Activities during the Disaster :

[1] Rescue operations for affected people.
[2] Proper relief distribution including food, clothes and medicines.
[3] Restoration of communication system.
[4] Damage assessment and immediate financial assistance.

Disaster preparedness is a multifaceted activity. It involves preparation and operationalisation of preparedness plans, community-based preparedness plans, appropriate use of information technology, remote sensing disaster mapping, Geographical Information System [GIS], and other mitigation strategies.

Disaster Mitigation :

Mitigation refers to action taken in advance to reduce the risks arising out of disasters. Mitigation involves taking short-term as well as long-term measures, to reduce the community's, location's, property's vulnerability to damage. It is concerned with prevention of occurrence of disasters, reduction of risks consequences associated with them, and dispersal of risks.

The significance of mitigation arises from the notion that adequate investment in mitigation activities reduces the amount to be spent on emergency, assistance, repair, reconstruction and rehabilitation after a disaster. Mitigation also ensures socio-economic continuity in a community as it is lessens the disruption causing to lives, property, communication, transportation systems, and social and economic infrastructure. Carefully planned mitigation activities facilitate the process of sustainable development, strengthening the economic and social well beings of the community. Following principles provide valuable guide to mitigation activities :

[1] Initiation : This includes introducing disaster mitigation initiations within three diverse contexts of reconstruction, new investments and existing environment.
[2] Management : Mitigation measures are complex, interdependent and involve widespread responsibility. This requires effective leadership and coordination, incentives, spread of safety measures through diverse activities and integrated with preparedness, relief and reconstruction.
[3] Prioritization : Where resources are limited, priority should be given to the protection of key-social groups, critical services and vital economic sectors.
[4] Monitoring and Evaluation : Mitigation measures should be continually monitored and evaluated so as to respond to changing patterns of hazards, vulnerability and resources.
[5] Institutionalization : Mitigation measures should be sustainable and political commitment is vital to the initiation and maintenance of mitigation.

Approaches to Mitigation : There are two approaches to mitigation – *Structural* and *Non-Structural :*

Structural Approach : This refers to structural measures restored to tackle the disaster threats. This applies both Engineered and Non-engineered structures.

Engineered structures include infrastructure and buildings, built as per necessary structural safety standards, advice of architects, engineers, with mitigation practices incorporated in their structures. Engineered structures are built according to structural specifications, site layout and planning, suitable materials etc.

Non-engineered structures include those buildings and infrastructures built with local knowhow, not in accordance with prescribed specifications. These are generally constructed as per the convenience of local community, in a traditional manner. These include houses lying on steep slopes, which can be subject landslides. Hence these are prone to hazards.

Non-structural Approach : This approach refers to :

Appropriate Administrative/Regulatory Framework : This includes planning and zoning, application of building codes, hazard-resistant design and construction. For this, proper legislative framework with administrative arrangements are necessary which can go a
Long way to guide future developmental activities.

Public Education, Training and Awareness : Mitigation needs appropriate dissemination of information to the people with a view to educating them about potential hazards and ways of reducing them. This involves training of government officials, elected representatives, local government members, community-based organizations, youth, children and different sectors of community.

The quality of mitigation measures depends a lot on the inter-departmental coordination and teamwork. This activity involves mock drills, exercises, awareness campaigns, simulation exercises, carrying out worst scenario analysis [what worse can happen] etc. These activities need to be supplemented by training and education programs.

Community Participation : Any mitigation plan need to be accompanied by community participation. The communities are the first to respond when disaster strikes. Since communities are familiar with the local area vulnerabilities, available resources, facilities, demography etc., it needs to be assisted with disaster mitigation plans.

Incentives : The continued sustainability of any mitigation activity depends on effective incentives to ensure proper implementation. Incentives for retrofitting of structures, construction of buildings and structures outside the disaster-prone areas, disaster insurance, constituting vulnerability relief fund at local level etc.

Disaster mitigation is an ongoing and continuous process. It requires cooperation and networking several communities. Effective mitigation needs strengthening the capacities of communities along with the administrative machinery. The entire process needs to ensure sustainable development.

Disaster Management System in India :

Disaster management in India is the responsibility Central, State, District and local administration. The central government set up a National Disaster Management Authority [NDMA] in January 2005 and the Disaster Management Act has been passed by the

Parliament in December 2005. A High Powered Committee [HPC] on Disaster Management has also been set-up by central government. This was the first attempt in India towards evolving a systematic, comprehensive and holistic approach to natural and man-made disasters. The Committee provided a new conceptual framework of disaster management by focusing on preparedness, prevention, reduction and mitigation. It was felt that prevention is more cost-effective than post-disaster relief and rehabilitation.

The High Powered Committee [HPC] provided a new culture and approach to the area of disaster management by indicating that there are four key pillars to this activity, namely :

[a] Culture of Preparedness – The Committee expressed that, though it is not possible to completely do away with the devastation being caused by natural hazards, the destruction arising out of it can be minimized. It can be done through warning systems, community preparedness and other precautionary and mitigatory measures.

[b] Culture of Quick Response – Response has been considered a new feature of disaster management. The principle of quick response by the government is having an appropriate organizational set up, and plans at national, state and district levels. To achieve this, various state governments have also constituted separate nodal agencies.

[c] Culture of Strategic Thinking – The HPC emphasized the significance of strategic thinking to handle disasters and appropriate networking of institutions engaged in the pursuit of knowledge. This also includes, having National Disaster Knowledge Network [NDKN] and National Centers of Excellence [NCE] which would facilitate handling disaster situations.

[d] Culture of Prevention – It was felt that a culture of prevention should be installed in all segments of disaster management. This requires active involvement of all groups of society, national, international organizations, government and private sectors. Early warnings and conscious development planning are the key elements of preventive planning.

Review of Existing Disaster Management System :

In India, various ministries have been assigned nodal responsibilities for specific disasters. Detailed organizational setup is as :

At the level of Central Government

At Central Government level, depending on the type of disaster, a nodal ministry is assigned the task of coordinating all activities of the state and district administration and the other supporting departments/ministry.

Type of Disaster and the Nodal Central Ministry

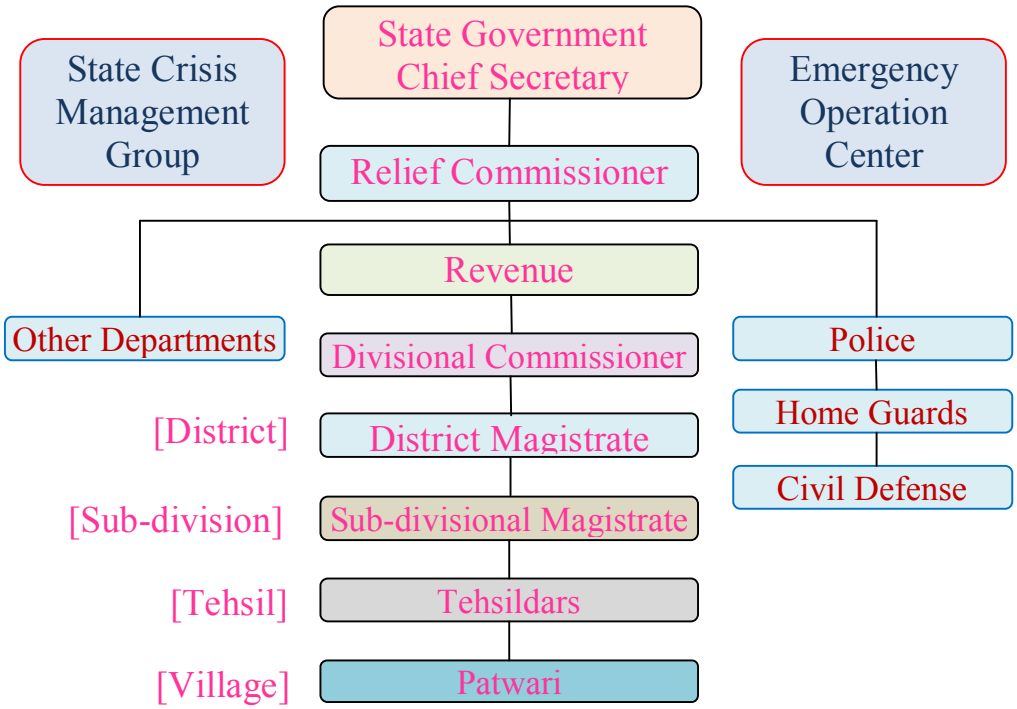
Type of Disaster	Nodal Ministry / Department
Air accidents	Ministry of Civil Aviation
Biological Disasters	Ministry of Health
Chemical Disasters	Ministry of Environments
Natural Disasters [except Drought]	Ministry of Home Affairs
Drought	Ministry of Agriculture

Nuclear Accidents	Department of Atomic Energy

At the level of State Government

State Government is responsible to formulate its responses to a disaster situation and also for long term preparedness and rehabilitation measures :

Disaster Management at the State Level



Earthquakes and Disaster Management :

Whenever a disaster occurs, life goes out of gear and the basic factors that support life for a large number of people, are no longer available. The experience of handling disasters across the globe indicates that the after effects of a disaster are more harmful than the disaster event.

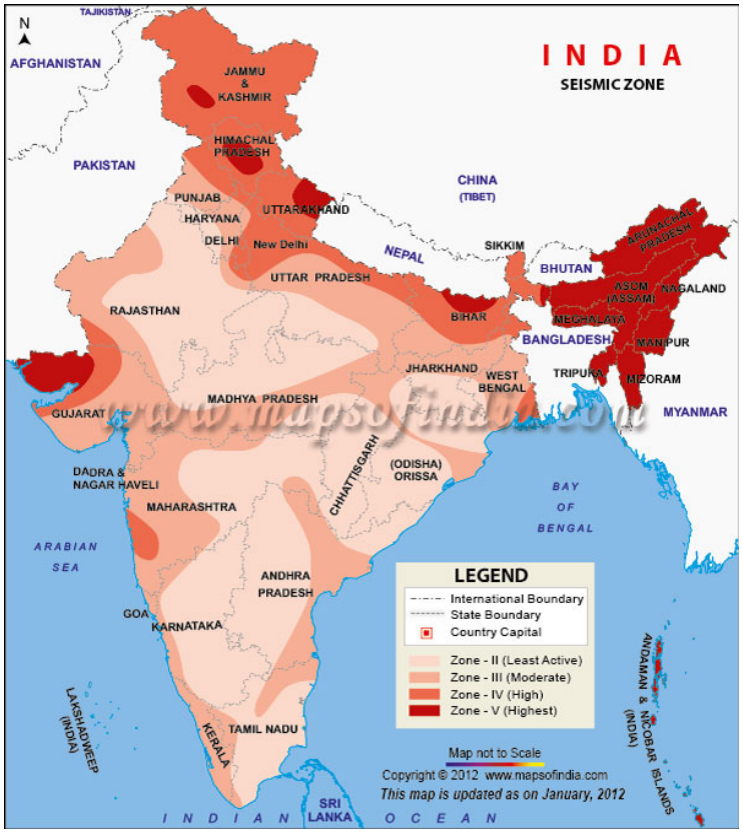
Among all the natural calamities, earthquakes are the most unpredictable and destructive natural hazards. Within few seconds, a havoc can be seen on a massive scale in the form of deaths, injuries and destruction. Without early warning or very little warning, it is impossible to make all necessary arrangements against great damages and losses due to earthquakes. Hence, there are increasing efforts to lessen the impact of disasters on all sectors of the society. In the case of earthquakes, following happenings are common for management efforts :

- drilling equipments and heavy lifting machineries are needed for Search of living beings,

- rescue, hospitalization and emergency medical aid to injured people,
- large number of people are forced to leave home with little of their personal belongings to safer locations,
- communication and transportation facilities in the affected region,
- needs for shelters with minimum requirements of toilet facilities to the people,
- providing food and water to the affected people,
- trained rehabilitation teams etc.

Some of the critical issues of Disaster Management form the Earthquake point of view, are discussed here :

[1] Seismic Zoning : Earthquake hazard of the country is monitored mainly by Geological Survey of India [GSI] and the Indian Meteorological Department [IMD]. Disasters Mapping is a tool for assessing, storing and conveying information on the geographical location and spread of the effects of disasters. Disaster maps usually show disaster impact zones. Preparation of seismic zone maps is a highly technical task and requires collection of data of several decades or even centuries. The seismic history of an entire region has to be analyzed in detail, and depending on the frequency and magnitude of the seismic activity in different parts of the region, seismic zoning is carried out.



A macro-level seismic zone map has already been prepared, which divides the country into *four zones*, II to V, of various probable intensities on an increasing scale. Zone – II is the least active seismic zone, Zone – III is the moderate, Zone – IV is the high, and Zone – V is the highest seismic zone. This kind of map is mainly used by the

Department of Disaster Management of the different state governments in the country. This map helps them in planning for natural disaster of earthquake. The seismic zoning map assists in identifying the lowest, moderate as well as highest earthquake prone areas in India.

Earlier, Peninsular India was considered free from seismic activities but Jabalpur [Madhya Pradesh] and Latur [Maharashtra] activities have shown that region is unsafe and active present time. Such maps are used for preparing Seismic hazard map. Seismic zoning Map is used in coding and designing earthquake resistant structures.

[2] Earthquake Resistant Buildings : Considering that most human losses are due to collapse of buildings, the problem of safety could best be taken care of through a pre-disaster *prevention* approach. After some of the disastrous earthquakes in the country, number of actions are being taken :

Hazard evaluation and risk assessment : In India, variety of building practices and social and economic structures are available and seismic hazard evaluation strategies which are strictly followed in many developed countries, are not followed here. Traditional building materials and construction practices are generally used in India. Earthquake risk is the product of the hazard intensity and the vulnerability of buildings and the output of a seismic risk analysis cold give the probability of damage and losses from next earthquake.

With help of Seismic Zoning Map, District-wise Census Housing Data, Vulnerability and Risk Tables, *Vulnerability Atlas of India* has been prepared under the initiatives of the Ministry of Urban Development. In this Atlas, Earthquake, Cyclone and Flood hazard maps of every State and Union Territory of India have been prepared. In these maps, the boundaries of the districts are clearly shown so that the areas of the districts prone to the various hazards are clearly visible. The vulnerability of the buildings, as per the census of housing, has also been given district wise. As an extension, state-wise vulnerability atlases also have been prepared, including an action plan that the State may adopt for achieving disaster reduction. *But it is observed that day-by-day, number of highly vulnerable buildings are increasingly considerably*.

Hypothetical Building Damage Scenario : In order to develop realistic prepared plans, as a first step, development of damage scenarios under the likely major earthquakes, needs to be done. A hypothetical recurrence of earthquake of *M* 8.0 in Kangra Valley of Himachal Pradesh [like that of 1905], has been taken as case study. The results are obtained for two cases for all buildings being of traditional construction – [i] without earthquake safety features, and [ii] with earthquake-resistant features as per the Indian Standard Building Codes. It is studied that, in comparison to without safety features, *the amount of direct losses will be just half* [a net saving of about 50 %], *the lives lost will only be one-fifth*, *totally ruined houses reduced to about one-fourth*, *the trauma and relief costs will also be reduced to about one-fourth*.

This damage scenario brings out clearly the economy and other social benefits of pre-earthquake preventive measures. Also, disaster managers will have an estimate of what situation they may have to face and make management plans before the actual disaster occurs.

Strictness to follow By-laws for Damage-resistant Structures : Disaster prevention involves engineering intervention in buildings and structures to make them to strong enough to withstand the impact of probable earthquakes. Restrictions on land use are also imposed, so that the exposure of the society to disastrous situations is avoided or minimized. So far, land use restrictions are not strictly followed in the towns, country planning laws and master plan rules. The municipal by-laws are also silent about earthquake safety requirements of buildings. The result is that, the cities are expanding in all directions, occupying even hazard-prone areas, and more and more unsafe buildings, high-rise apartments, townships are being constructed, adding to the already thick concentration of unsafe constructions.

The revised, updated and expanded Indian Standard Building Codes and guidelines for earthquake-resistant design and construction of building and structures are already developed. The recent earthquake activities of Uttarkashi [*M* 7.0, 1991], Latur-Killari-Osmanabad [*M* 6.2, 1993], Jabalpur [*M* 6.0, 1997], Chamoli [*M* 6.8, 1999], Bhuj [*M* 7.7, 2001], Kashmir [*M* 7.6, 2005], Sikkim [*M* 6.9, 2011], have already shown that implementation of these codes and guidelines have not been followed satisfactorily, mainly because these standards are not mandatory and do not yet form part of the by-laws of the local bodies.

IIT Roorkee [through Department of Research and Training in Earthquake Engineering, DRTEE], IIT, Kanpur, IIT Bombay, IIT Chennai [through Structural Engineering Research, SERC] etc., have built design and construction of earthquake resistant structures from small to tall buildings, all types of dams, bridges and tunnels, atomic power plants, petro-chemical industrial structures, power transmission towers etc. Some Central Government Departments follow the norms in the construction of these engineering structures.

Techno-legal Regime for the Country : The Town and Country Planning Acts governing the planning of settlements and preparation of Master Plans were studied and found deficient in regard to safety from natural disasters. A complete techno-legal regime has been proposed amending the by-laws and acts to include the safety aspects from natural disasters. In addition, several states have taken up review of relief manuals and preparation of calamity preparedness guidelines to suit local needs and geo-climatic conditions.

Technology transfer Provisions : It is realized that majority of the constructions in India are not disaster-resistant, they are made up of walls of clay, stones, bricks, concrete-blocks etc., built in traditional ways, without hazard-safety provisions. Transfer of better construction technologies is being affected through Building Centers established by Housing and Urban Development Corporation [HUDCO] and Building Materials and Technology Promotion Council [BMTPC] in the country.

Strengthening of Information Technologies : The Ministry of Agriculture [MOA], which is the nodal Ministry for Disaster Management in India, has laid great emphasis on using the various state-of-the-art technologies such as Remote Sensing [RS], Geographical Information System [GIS], Global Positioning System [GPS], Computer Modeling and Expert Systems [CMES], Electronic Information Management System [EIMS] etc. in managing the situation caused by natural disasters. Active and ongoing efforts are being made for modernizing the control rooms to make more effective

community friendly. In addition, databases are compiled to keep track of earlier events and benefits from the past experience.

Human Resource Development : The Department of Agriculture and Cooperation under the Ministry of Agriculture, initiated a Central Sector Scheme, including human resource development, research, consultant services, and documentation of various natural disasters. Under this Scheme, a National Center for Disaster Management [NCDM] was established at the Indian Institute of Public Administration [IIAP], New Delhi and different States of India set up faculties in different institutions of disaster management. Investments are being made on building capacity of NGOs, Community Based Organizations [CBOs] etc., for working with the communities and government.

The research and development work, education and training programs, national and international conferences, symposia, workshops etc. are organized under knowledge-exchange programs.

Upgrading and Strengthening of Seismological Instrumentation Network : Department of Science and Technology [DST] coordinated a World Bank-assisted Project through which the seismological stations in the Peninsular region have been strengthened. Under this program, 20 existing observatories of India Meteorological Department [IMD] in full operations [10 Global Seismographic Network [GSN] Stations, 10 stand-alone broadband digital stations] have been strengthened and 10 new observatories have been established. These will provide state-of-the-art station network.

Besides telemeter clusters at Koyna and Latur [Maharashtra], and Khandwa [Madhya Pradesh], have been installed which will provide information from these three important stations in the Peninsular India. The ongoing strong motion accelerograph arrays and network program through DEQ-UOR have been expanded and strengthened.

DST has also launched a nationally coordinated project on the study of seismicity and seismotectonics in the Himalayan region involving several research organizations. The strong motion data collection programs are being expanded and number of tall buildings are being instrumented to study their behavior during future earthquakes, including soil structure interaction effects. GPS-aided geodetic studies are being initiated with DST support and a national GPS program has been evolved and planned for monitoring the seismotectonic provinces of India. Number of projects have been initiated in various parts of the country involving palaeoseismology as tool to date pre-historic earthquakes. Palaeoseismic record may help in prediction of earthquakes.

Preparation of Seismotectonic Atlas of India : The Geological Survey of India [GSI] has prepared Seismotectonic Atlas [SEISAT] of India. It consists of 43 sheets of maps covering 3^{o} longitude and 4^{o} latitude in each to scale of 1 : 1 million. The maps included earthquake data, gravity data, magnetic data, stress-field data, geodetic data, geological faults, lineaments etc. These maps could be used for the seismic hazard risk assessment and preparation of reliable seismic zoning map of India.

Suggestions for Future Activities : For rapid progress towards appreciable reduction in the disastrous impact of natural hazards, following points may be suggested :

- To invest on global observations, and to give a boost to the science of observation and measurement on which the real progress depends.

- To enhance the scientific content of prediction methodologies and reliability of forecast, if and when it becomes feasible.
- To map the earthquake hazards on a large scale and link the maps intemitently with the process of development planning
- To conduct micro-zonation of urban areas at earthquake risk.
- To closer partnerships with financial and legal institutions, insurance companies, community-based organizations and industry.
- To create an All India Institutional Network, to involve in disaster preparedness, mitigation management and prevention.
- To invest more on public awareness, education, training and human resource development in the area of disaster mitigation.

[3] Role of Remote Sensing and Aerial Photography : *Remote Sensing* is the acquisition of information on disasters. Remote sensing information valuable in determining the extent of cataclysmic disasters.

The technique in which aircrafts, jet planes etc. are used with imaging systems that produce computer generated images is called *Aerial Photography*. Small Format Aerial Photography [SFAP] is being used to take aerial photographs.

Remote sensing and Aerial photography by satellites and aircrafts are valuable information-gathering tools for disaster managers and ideally suited for disaster management.

They provide database from which the evidence left behind by past disasters could be interpreted. With other information combinations, one can indicate the areas that are potentially dangerous. Pre-disaster data used in risk analysis and mapping, and monitoring land-use changes in the aftermath of a disaster. Satellite imageries and aerial photographs are used for hazard analysis and mapping, vulnerability analysis, damage assessment, quantitative base for relief operations and reconstruction planning. These tools provide suitable strategy for disaster preparedness, monitoring, assessment and mitigation.

The disasters may affect large areas and no other tools than Remote sensing and Aerial photography would provide a *matching spatial coverage*. These tools also offer the data of remote regions or areas which are inaccessible by disruption of normal transportation and communication systems. They provide comprehensive view of a large region over a short period of time. These tools also allow for the monitoring of the event during the time of occurrence while the disaster forces are in full swing. The impact and departure of the disaster event leaves behind a trail of mass devastation.

Requisition and interpretation of remote sensing data and aerial photographs require trained scientists. The main users of these are government and inter-governmental organizations. Damages to public facilities, lifelines, forests, agriculture etc. are of immense important government and inter-governmental agencies. Research works are in progress to enhance the capabilities of these technologies in order yo cope with the earthquake and landslide situations in future.

[3] Predictability, Forecasting and Warning of Earthquakes : The various tectonic activities and processes which take place deep inside the earth, are not yet fully understood. Therefore, earthquakes are not predictable to the extent that the place and time of their occurrence. However, the areas where earthquake activities frequently occur, areas of stored energy inside and on a statistical basis, it is possible to indicate that a

major earthquake could perhaps occur sometime somewhere within a large region. But, still there is no technique available by which the place and time of occurrence of an earthquake can be predicted in a practical sense.

Earthquakes cannot forecast yet because there is no accurate warning system at present. On the basis of past seismic records, the areas which are prone to seismic activities, could be taken as a general warning because the exact time and place of the next earthquake, particularly major event, cannot be indicated.

Continued occurrence of tremors at some places, is another warning indication before earthquake but, it is not sure whether the tremors are indicative of an impending earthquake or nature's method of releasing the earth's internal energy and stress in short bursts of tremors.

In some cases, certain warning signals occur before an earthquake such as unusual behavior of birds, animals and reptiles, sudden change in water levels in wells [lowering or rising], widening of existing natural cracks on the earth's surface etc.

[4] Public Awareness Campaigns : Awareness remains one of the major tools for preparing communities for risk reduction and it is most effective when used in combination other means. Awareness Campaigns could be carried out in number of ways such as :

Face to Face Interactions : Face to face interaction is the most effective tool of public awareness. In India, most of the rural people are affected by the natural disasters. These people have very low literacy rate. They can be educated through following ways :

- *Lectures,*
- *Public meetings,*
- *Street plays,*
- *Group discussions,*
- *Door to door campaign,*
- *Debates,*
- *Panchayat meetings etc.*

This kind of awareness can be provided by the local government functionary, NGO's or Panchayat members. Schools can also play important role in this type of interaction. These discussions should be very well designed/prepared to meet the local requirements. They should be in simple local language and their impact should be monitored. These programs should be a continuous activity.

Electronic Media : In India, the use of electronic media is becoming very effective tool of creating mass awareness. In providing disaster warnings also, this tool has given positive results. Television and radio are reaching to almost every village having electricity. Transistor radios have made the facility available even where there is no electricity. There are two advantages of use of electronic media :

[a] *The awareness may be given number of times [repeatedly] so that it can reach every person of the area,*

[b] *It is a more effective way of mass education.*

On television and radio, special programs can be prepared on various natural disasters to educate people regarding :

- *Basic preparations are made in the pre-disaster period like rescue tents, medical aids, supply of daily needs etc.,*
- *Warnings regarding particular disaster,*
- *What they should do at the time of disaster,*
- *What type of help Government is likely to provide at the time of disaster ?*
- *Disasters are not discriminative. They affect individuals, families, community, government infrastructure, emergency services and paralyze daily routine,*
- *The community should work with the government machinery to restore the basic facility and bring normal life quickly back after the disaster,*
- *The concept of self-reliance and self-help in the disaster situation should be taught,*
- *Some good examples of community participation can be shown,*
- *Media can show the negative impacts of dependency and expectancy of the people in relief and recovery,*
- *Use of local knowledge, experience etc. may be highlighted through media,*
- *Some good case studies of proper relief, recovery and rehabilitation of earlier disasters should also be shown,*
- *Video films with footages of community along with animated guidelines on do's and don'ts could be telecasted etc.*

Print Media/Materials : This is one of the traditional tools to create public awareness among the literate people. Special type of awareness material can be prepared which can provide :

- *Basic needs requirements of the community for disaster prevention as well as in relief work,*
- *About the safe places at the time of early warning,*
- *Clear instructions about do's and dont's in a particular situation,*
- *Other disaster related education in suitable form such as : Notices, Posters, Banners, Pamphlets, Cartoons, Photographs etc.*

Where resources allow, audio-visual tools such as *Documentary films* are very effective. *Calendars* carrying visuals of the earthquake losses could prove very effective. They constantly keep reminding the people of the upcoming dangers. *T-shirts* for participants which could graphically depict some key maps of the area with mobile phone contact numbers of emergency services usually attract a lot of attention.

[4] Effective Community Participation : A [CDM-1 No. 5 pages 12 to 18]

[5] Relief Measures : Relief measures are the immediate need in the post-disaster scenario when unknown number of victims are affected and even their locations are not clearly known. In such type of circumstances, *Search* and *Rescue*, *Evacuation* etc. are the processes which carried out immediately after the disaster. These are most important operations, which are usually performed by the local volunteers, voluntary organizations and the district and state agencies. If the conditions are worsen, and these groups are not

able to control the situation, then the defense and paramilitary services are also called in to help.

Search and *Rescue* [SAR] : It is the process of identifying the location of disaster victims who may trapped or isolated, and bringing them to safety and providing them with medical attention. The basic aim of search, rescue and evacuation is to ensure the survival of the maximum possible number of victims. With the help of local people and through aerial surveys, a plan is worked out and then appropriate step are taken by the various team involved, to carry out the operations. SAR team teams also depend on sniffer dogs and heavy machines such as cranes and earthmovers etc., to search out the victims from difficult situations such as collapsed buildings etc.

Evacuation involves the relocation of a population from the affected area to a safer location. It also measures by which they could survive at the affected place, by providing necessary aid to them, till such time and they can be rescued. Post evacuation relief through emergency supplies and services is also part of the relief operations.

[6] Shelters for Victims : Various types of disasters need different shelter strategies.
Varying shelter strategies may be as :

Shelter Types	Characteristics
Large Shelter Space	To accommodate large number of people in one place, sometimes school buildings may be used for the purpose.
Temporary Relief Camps	Camping sites may be set up in proximity to the affected settlements.
Rehabilitation Settlements	These may be rebuilt settlements in new sites on permanent basis using construction technology which could provide for proofing against future disasters.
Repair and Restoration	These could be carried out in the existing areas if the extent of damage is not very high.
Retrofitting and Strengthening	Retrofitting as a measure to reduce vulnerability of the existing structure to future disasters.

The bulk of the housing in the country is constructed by the people themselves with varying standards and specifications without resistance to earthquakes and lower durability. In the case of earthquakes, large community shelters provided because of collapse of houses. Removal of damaged structures including debris and recovery of injured people is also a very major task that is required after an earthquake. Rehabilitation is usually required in case of earthquakes in which virtually all existing structures suffer damage and may be unfit for living.

If appropriate earthquake resistant construction features are introduced, this would go a long way in reducing the damages during the occurrence of an earthquake. This is for normal housing and for structures which are constructed by local people or what it generally called *non-engineered* buildings. Therefore, the level of technology inputs have to be left to a locally manageable level by giving the earthquake resistant constructions.

[7] Clearance of Debris : Debris from collapsed buildings, bridges and other structures as well as uprooted trees, electric poles and wires, hoardings, damaged

vehicles, goods, accumulated solid waste [which may be of bio-degradable and non-degradable nature] etc. are the biggest hindrance to search, rescue and relief operations. They create disruption in communication services and transportation. Debris clearance is the first step towards re-establishment of transport and communication network.

Search operations for trapped survivors are the first concern after the disaster. In such cases, debris removal has to be taken up in a very caution and scientific manner. Any mistake during debris removal can lead to further problems for any survivors trapped underneath. This is the reason only technical and trained persons are allowed in the area and carried out
such operations.

Technical and material support is also very critical for debris removal operations. Use of earthmoving equipments, lifts and cranes, removal trucks, cutters and drills etc. are useful
in removal of debris.

Earthquakes direct do not kill people. Building collapse are widespread in the case of earthquakes. These kill many people. Even partially damaged buildings are a potential threat, as they may collapse any time. Therefore it is essential not only to remove the debris of collapsed buildings but attention is needed to the partially damaged structures as well. In cases where they are repairable, repairing should be carried out as soon as possible, and till that, the buildings should not be occupied. In case of building damage is beyond repair, tthey should be demolished to avoid further mishap. A structural damage assessment is required immediately after the earthquake in order to identify the extent of damaged and partially damaged buildings for further action.

[8] Disposal of the Dead bodies : Quick disposal of dead bodies is very important for control the spread of diseases due to their quick decay. Besides, decomposing *human dead bodies* on the site with fast spreading stench, present a very unpleasant environment for the rescue workers as well as surviving victims.

Human dead bodies need to be disposed with great care because sentimental values are attached to the dead and human dignity even in death to be respected. Process and manner of their disposal are of great importance. The first step in this regard has to be the identification of the dead bodies. This is also required for compliance with police formalities. Once the ethnic background of the victims has been identified, then they should be suitably disposed in accordance with their religious and cultural practices.

Rescues such as fuel need to be mobilized for cremation purposes. Those whose ethnic background prescribes burial, have to be buried in accordance. If the family members of the dead are available, and are willing to take the body for individual disposal, this may be done. Otherwise, in case where there are no claimants, or where bodies cannot be recognized, they should be collectively disposed through mass burial or cremation. In certain cases, if formalities and legalities are involved, such as post mortem, medical examinations, filling of forms, assistance is needed to be provided to the relatives of the dead.

The location of the disposal site is of importance because this land is always identified as the dead body disposal site by the local residents. In instances in the past, where mass cremations of human dead bodies were carried out in the villages open space, the local villagers later refused to live in the villages as it had acquired the reputation of being a cremation ground, and came to be regarded as a ghost village.

In the natural disaster like earthquake, the number of animal deaths, particularly in rural areas, are very high because they are kept in groups and tied up. Disposal of dead animals is as important as that of humans because decaying dead bodies can be a potential health and environment threat. Still, this aspect is usually accorded lower priority but, this must be done on priority by local volunteers and authorities. Disposal is best done by burial, at some places outside the residential areas and nobody should be allowed to hold on to the dead bodies for extraction of skins or bones or horns or any other recoverable material, because the health threat is very high and quickest disposal of the dead bodies is desirable.

[9] Fire accidents : Fire is a major threat after many earthquake disasters. Densely populated urban and industrial sectors are the main areas of fire accidents. Electrical short circuits, cooking gas cylinders, disruption of and gas pipelines, damages of fuel pumps in the cities, petroleum refineries, oil and gas depots, tankers of inflammable liquids etc. are chief sources of fire accidents.

Detection of fire after disaster, earliest extinguish of fire is very essential, it will minimize the losses as well as atmospheric pollution. There are fire brigades in the cities and towns but till then, people should try to control over the fire. With the help of sprinklers and extinguishers of water and sand, controls should be made over the fire. In the case of an oil fire, Compressed Air Foam [CAF] Extinguishing Systems are used whereas for electric fire, Carbon dioxide, Halon, Nitrogen Inert Gas Fire Extinguishing Systems are used to control the fire.

[10] Damage Assessment : Assessment is the process of determining the impact of a disaster on the society. Damage assessment include the preparation of estimates of physical damage resulting from a disaster. Damage assessment is a prerequisite for all disaster management practices.

The official agency foe reporting estimates of disaster damages is the Revenue Departments of the State Governments. They are also the authority for distributing relief to the affected persons.

First, quick damage assessment is carried out and on this basis, the amount of medical relief and food stock to reach the disaster area. At the second stage, detailed damage assessment carried out which includes :

- Damage caused to Buildings,
- Damage to Land,
- Damage to Human lives.
- Damage to Live Stock etc.

Earthquake Safety Rules

What to do Before an Earthquake :

If the moment of an earthquake can be anticipated, it is safest to remain out of doors immediately before the onset of the earthquake. One should leave the house and stay out in the open or in the temporary camps till the scare is over.

1. Keep stock of drinking water, some foodstuffs, first-aid equipments, clothings, radios, emergency medicines, blankets, a crow bar, shovel, pick and rope, electric torch, some candles and a helmet ready for you and for every member of the family. Use plastic bottles in preference to glass bottles for carrying water or other liquids.

2. Ensure that water heaters, and other gas appliances are firmly fixed and shut off when not in use, as broken gas pipes or appliances are likely to cause fire hazards.

3. Secure all heavy objects like furniture, refrigerators storage cabinets etc. to the walls and place large and heavy objects on the lower shelf. Top heavy objects should be braced or anchored.

4. Find out the location of the nearest first-aid post, Police station and Fire station and approach it for help if required.

5. Join the Civil Defense Organization and train yourself and members of your family in first-aid, rescue, fire fighting etc., which will help you, your family and neighbors.

6. Conduct occasional home earthquake drills so that your family has the knowledge to avoid unnecessary injuries and panic in the event of an earthquake.

7. The more responsible members of the family may be taught how to turn off electricity, gas and water at the main switches or valves.

8. Educate all members of the family as to what to do in such emergencies so that you are prepared in the event of earthquake, i.e. at home, while driving a car, at work in shop, in a cinema hall etc.

What to do During an Earthquake :

Since earthquakes last for only few seconds, the earthquake can be all around you before you are aware of it.

1. Keep cool. Don't panic. Panic causes heavy injuries. The ground motion frightening to all.

2. In the event, the safest place is an open space building. If this is not suitable, do not try to run from a building during earthquake.

3. If it catches you indoors, take cover under a desk, table, bench; avoid standing just outside the main door or near the outside walls. This is usually an unsafe place.

4. Watch for falling plasters, bricks, ceiling fixtures, and other loose objects. Stay away from glass.

5. Do not use candles, matches, or other open flames, either during or after the earthquake.

6. If the earthquake catches you outside, move away from buildings and utility wires. Stay in the open area until the tremor stops.

7. Do not run through or near buildings. The greatest danger from falling debris is just outside doorways and close to outer walls.

8. If you are in a moving car, stop as quickly as safety permits, away from buildings or trees, but stay in the vehicle. A car is an excellent seismometer, and will jiggle on its springs during an earthquake, but it is a good place to stay until the earthquake stops.

9. Avoid escalators even stair-cases may be crowded by escapees. Take your turn.

What to do After an Earthquake :

After the earthquake is over, there will be tremendous rush of rescue work. Those who have escaped injuries will be trying to rescue persons who have been trapped. If you are one of the trapped, wait patiently for your turn. Remain calm, conserve your energy after the earthquake

1. Check your utilities, but do not turn them on. Earth movement may have cracked water, gas and electrical conduits.
2. If you smell gas, open windows and shut off the main valve. Then leave the building and report gas leakage to authorities. Do not re-enter the house until a Civil Defense Official says it is safe.
3. Check for fire and fire hazards and secure fire extinguishers. Do not strike match-sticks unless you are sure there is no gas leak around.
4. If mains of water damaged, shut off the supply at the main valves.
5. If electrical wiring is shorting, close the switch at the main meter box.
6. Check your electric, gas, water and sewerage connections. They may have damaged beyond immediate repair. You will have to live without them for some time.
7. Turn on the transistor, radio or television to get the latest information/bulletin and aftershock warnings.
8. Stay off the telephone except to report an emergency.
9. Stay out of severely damaged buildings, aftershocks can crash them further.
10. Keep away from hanging portions of buildings or overhanging cliffs, as they may fall due to after-shocks which may continue for some time.
11. Look for the injured in your family or neighbor's families because you know where they were and probably still are. Render such assistance as you can, until medical aid arrives.

Some Damaging Earthquakes in India - Case Studies

India has a very long history of earthquakes. The occurrence of earthquakes is not a new phenomenon for most of the northern earthquakes in India [Interplate Earthquakes]. In the past, our country has faced some major disastrous earthquakes like :

No.	Date	Name	Magnitude [*M*]
1	12.06.1897	Assam Earthquake	*8.1*
2	15.11.1934	Bihar Earthquake [Largest ever earthquake recorded in mainland India]	*8.7*
3	15.08.1950	Assam Earthquake [Largest earthquake recorded in mainland India since Independence]	*8.5*
4	19.01.1975	Kinnaur Earthquake	*6.8*
5	20.10. 1991	Uttarkashi Earthquake	*7.0*
6	29.03.1999	Chamoli Earthquake	*6.8*
7	26.12.2004	Indian Ocean [Sumatra] Earthquake [Third largest earthquake ever recorded]	*9.0 – 9.3*
8	18.09.2011	Sikkim Earthquake	*6.9*

Besides these events, few major and moderate earthquakes have also been experienced in different parts of the country [Intraplate Earthquakes] :

No.	Date	Name	Magnitude [*M*]
1	16.05.1819	Rann of Kutch Earthquake [Formed the Allah Bund and Lake Sindri]	*7.7 - 8.2*
2	31.12.1881	Nicobar Islands Earthquake [Earliest earthquake for which rupture parameters have been estimated instrumentally (from tide gauges)]	*7.9*
3	11.12.1967	Koyna Earthquake	*6.3*
4	30.09.1993	Latur Earthquake	*6.4*
5	22.05.1997	Jabalpur Earthquake	*5.8*
6	26.01.2001	Gujarat [Kutchh] Earthquake	*7.7*

Case Studies

In the following paragraphs, some case studies of earthquakes are presented :

[Uttarkashi Earthquake]

Magnitude of Earthquake	7.0 [on Richter Scale]

Intensity	IX [on Modified Mercalli Scale]
Date of Occurrence	October 20, 1991
Time of Occurrence	02h 53m 16s
Focal Depth	15 Kms.
Epicenter	Village Agora
People Killed	About 2000
Association	Main Central Thrust of Himalaya
People Injured	About 5000
Cattle Lost	About 3100
House Destroyed [fully]	About 20200
House Destroyed [partially]	About 74750
Villages affected	About 2100

[Besides the housing, other infrastructural facilities also received severe damage]

[Latur Earthquake]

Magnitude of Earthquake	6.4 [on Richter Scale]
Intensity	VIII $^{+}$ [on Modified Mercalli Scale]
Date of Occurrence	September 30, 1993
Time of Occurrence	023h 55m 47.5s
Focal Depth	15 Kms.
Epicenter	Village Killari
Association	Kurdawari Rift
People Killed	About 10000
Cattle Lost	About 14900
House Destroyed [fully]	About 34400
House Destroyed [partially]	About 16.5 lakh
Villages affected	About 95.8 lakh

[Besides the housing, other infrastructural facilities also received severe damage]

[Jabalpur Earthquake]

Magnitude of Earthquake	5.8 [on Richter Scale]
Intensity	VII $^{+}$ [on Modified Mercalli Scale]
Date of Occurrence	May 22, 1997
Time of Occurrence	21h 55m 31s
Focal Depth	32 Kms.
Epicenter	20 kms. NNW of Jabalpu
Association	Narmada-Son Lineament
People Killed	About 150
People Injured	About 400
House Destroyed [partially]	About 40000
Villages affected	About 150

[Besides the housing, other infrastructural facilities also received severe damage]

[Chamoli Earthquake]

Magnitude of Earthquake	6.8 [on Richter Scale]
Intensity	VIII $^{+}$ [on Modified Mercalli Scale]
Date of Occurrence	March 29, 1999
Time of Occurrence	00h 35m 13.4s
Focal Depth	21 Kms.
Epicenter	25 kms. east of Chamoli
No. of Aftershocks	204
People Killed	About 110
House Destroyed [partially]	About 50000
Villages affected	About 2000

[Besides the housing, other infrastructural facilities also received severe damage]

[Gujarat (Kutchh) Earthquake]

Magnitude of Earthquake	7.7 [on Richter Scale]
Intensity	X [on Modified Mercalli Scale]
Date of Occurrence	January 26, 2001
Time of Occurrence	08h 46m
Focal Depth	16 kms.
Epicenter	09 kms. SW of Village Chobari
People Killed	About 19800
People Injured	167000
House Destroyed [fully]	35000
House Destroyed [partially]	400000
District affected	21

[Besides the housing, other infrastructural facilities also received severe damage]

[Sikkim Earthquake]

Magnitude of Earthquake	6.9 [on Richter Scale]
Intensity	VII [on Modified Mercalli Scale]
Date of Occurrence	September 18, 2011
Time of Occurrence	18h 10m
Focal Depth	19.7 kms.
Epicenter	68 kms. NW of Gangtok
People Killed	About 120

[Besides the housing, other infrastructural facilities also received severe damage]

GLOSSARY

1. **Disaster :** It is the consequence of a hazard, which may be natural and/or man-made.

2. **Earthquake :** Shaking of certain part of the earth's surface due to sudden movement of rocks along active faults within the earth.

3. **Cyclone :** Very high speed spiral winds / storms having an average speed of above 120 km / hour.

4. **Hurricane :** A hurricane is a tropical storm with winds that have reached a constant speed of 74 miles per hour or more.

5. **Flood :** Large volume of water from heavy rainfall, dam failure, rapid snow melting, river/channel blockages, cloud bursts, etc. and rivers are unable to drain off water quickly through their channels.

6. **Drought :** A temporary scarcity in water availability in an area for unusually long period which affects normal needs for agriculture and drinking purpose.

7. **Tsunami :** Destructive seismic sea/ocean waves that are usually produced by an earthquake on the ocean floor.

8. **Landslide :** Wide range of ground movement, such as rock-falls, deep failure of slopes and shallow debris flows, which can occur when gravity exceeds the strength of the earth materials.
9. **Vulnerability :** Any community which can be affected by the adverse impact of a hazard.

10. **Magnitude :** It is a quantitative measurement of the amount of energy released during an earthquake at its source.

11. **Intensity :** It is a qualitative assessment of the kinds of damage done by a earthquake as well as people's reaction to it.

12. **Seismic Waves :** Energy radiates in the form of waves in all directions from the point of release of an earthquake.

13. **Primary Waves :** Fastest velocity seismic waves which arrive first at the seismic stations, similar to sound waves which can transmit through solid, liquid and gaseous media. Particles vibrate forward and backward in the direction of movement of these waves

14. **Secondary Waves :** Comparatively slower seismic waves which reach after P-waves at the recording stations, similar to light waves which transmit only through solids. Particles vibrate perpendicular to the direction of movement of waves.

15. **Love Waves :** These are the slowest in velocity, travel at or near to the ground surface. The movement of particles is horizontal in the direction of movement of waves.

16. **Rayleigh Waves :** In these waves, the particles travel in elliptical orbits.

17. **Tectonic Earthquakes :** Structural disturbances resulting within the parts of the earth crust or mantle. Most of such earthquakes are highly disastrous.

18. **Reservoirs-Triggered Seismicity :** Seismicity associated with impounding of water in artificially created reservoirs.

19. **Epicenter :** The point or place on the surface of the earth vertically above the focus.

20. **Focus :** The location or area below the surface of the earth where rupture begins and energy releases.

21. **Focal Depth :** The depth of the focus from the epicenter, is called focal depth.

22. **Seismic Zoning :** A tool for assessing, storing, conveying information of the effects of disasters on the geographical location in the form of impact zones.

23. **Hazard :** It is pre-disaster situation.

24. **Risk Assessment :** The methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihood and the environment.

25. **Damage Assessment :** Study about the nature, extent, pattern and intensity of damage by different methods and techniques. It helps in the disaster management plans and strategies.

26. **Remote Sensing :** The acquisition of information on disaster related subjects through weather radar, weather satellite etc.

27. **Aerial Photography :** Small format Aerial Photography [SFAP] by aircrafts and satellites that helps in mapping, vulnerability analysis, disaster assessment and reconstruction planning after earthquakes.

28. **Prediction :** System that gives information about an earthquake of a specific magnitude will occur in a particular place at a particular time.

29. **Warning System :** Earthquake early warning systems (EEWS) estimate earthquake prediction related to specific information such as timing, location and size of future earthquakes.

Frequently Asked Questions

Q. 01 ***What are Earthquakes ?***

Ans. Shaking of certain part of the earth's surface because of the series of the shock waves pass through the rocks which generate within the earth caused by sudden movement along active faults.

Q. 02 ***What is the difference between Earthquake and Tsunami ?***

Ans. Earthquakes generate on the continental areas of the earth whereas tsunami occur on the ocean floor/sea floor.

Q. 03 ***What is the Focus of an Earthquake ?***

Ans. It is the actual point or area within the earth where rupture begins in the rocks. This is also called Hypocenter.

Q. 04 ***What is the difference between Focus and Epicenter ?***

Ans. Focus is point or area within the earth from where earthquake waves spread in all directions whereas the place on the surface of the earth vertically above the focus is the center. Epicentral zone is the area where maximum losses and damages occur during an earthquake.

Q. 05 ***What are Natural earthquakes ?***

Ans. The earthquakes which generate because of processes of nature such as displacement of rocks along faults, volcanic activities, heavy landslides etc. are the natural earthquakes.

Q. 06 ***What are Artificial earthquakes ?***

Ans. The earthquake vibrations which are caused by human induced activities such as nuclear tests, blasting in deep mines etc. are the man-made or artificial earthquakes.

Q. 07 ***What is the cause of most earthquakes ?***

Ans. Tectonic activities are responsible for most of the earthquakes. Sudden dislocations of rocks along new faults formed as a rock failure, or more commonly, movements along pre-existing active faults are the main reasons of most natural earthquakes. They are also known as Tectonic earthquakes.

Q. 08 ***What is Reservoir-triggered Seismicity ?***

Ans. Earthquakes associated with impounding of water in reservoirs of major dams, are the reservoir-induced earthquakes. When water level fluctuates in reservoir, pore-

fluid pressure changes every time, cause frequent seismic activities in the surrounding region. Koyna Reservoir in Maharashtra, is the finest Indian example of this category earthquakes in the world.

Q. 09 ***What is Elastic-rebound Theory of Earthquakes ?***

Ans. This theory states that the rocks of the crust and mantle behave as an elastic medium. When the rocks are deformed, they store energy and bend. When the inherent strength of the rocks is exceeded, they rupture and release the stored energy in the form of seismic waves. These earthquake waves radiate out in all directions and areas experience seismic shocks. Upon rupture, the rocks rebound to their original undeformed shapes, but with a net movement or displacement along the fault.

Q. 10 ***What are Seismic Waves ? Give their types.***

Ans. During each earthquake, *elastic waves* generate at the focus. These waves are called seismic waves which travel in all directions through the rocks with their characteristic velocities particle movements. Broadly, two types of seismic waves release :

1. *Body Waves :* which travel through different parts of the body of the earth, and
2. *Surface Waves :* which travel at or near the surface of the earth.

Q. 11 ***How do Primary waves differ from Secondary waves ?***

Ans. Primary or P-waves are the fastest in the velocity whereas Secondary or S-waves are slower than the P-waves. P-waves are similar to sound waves whereas S-waves are similar to light waves. P-waves can transmit through rigid rocks, liquid and gaseous media whereas S-waves transmit only through solids [i.e. rigid rocks]. In P-waves particles vibrate forward and backward in the direction of propagation of waves whereas in S-waves particles vibrate perpendicular to the direction of propagation of waves. P-waves always arrive first at the seismic stations whereas S-waves reach after the P-waves.

Q. 12 ***What is the difference between Rayleigh and Love Waves ?***

Ans. Both these are the surface waves but in Rayleigh waves, the movement of particles is horizontal in the direction of propagation of waves whereas in Love waves, particles travel in elliptical fashion in the direction of propagation of waves.

Q. 13 ***What is Magnitude of an Earthquake ?***

Ans. Earthquake magnitude [*M*] is the quantitative measurement of total amount of energy released during an earthquake at its source. It is presently used for describing size of an earthquake.

Q. 14 ***What is the difference between Intensity and Magnitude ?***

Ans. Intensity is the qualitative assessment of damage done by an earthquake as well as people's reaction on it whereas Magnitude is the quantitative measurement of total amount of energy released during an earthquake.

Q. 15 ***What is Richter Scale ?***

Ans. The Richter Magnitude Scale [RMS] measures earthquake magnitude [*M*] which is presently used internationally for describing size of an earthquake. It is an open-ended scale with numerals begin with 1 [which is the lowest] and goes up to 10 [which is the highest]. It is base-10 logarithmic scale used to convert the amplitude of the seismic wave to a numerical magnitude value. While each increase in magnitude represents a 10-fold increase in wave amplitude, each magnitude increase corresponds to about 30-times increase in the amount of energy released.

Q. 16 ***What are Disasters ?***

Ans. Disasters are the extreme events which cause great loss of life, property, livelihood, infrastructure, communication means and create severe disruption to human activities and other essential services of the society.

Q. 17 ***What is the difference between Hazard and Disaster ?***

Ans. There is a close relation between Hazard and Disaster. A hazard is a natural event whereas the disaster is the consequence of a hazard. It is not certain that a hazard will always lead to a disaster. One can say that a hazard is pre-disaster situation in which some risk of disaster exists, because of its vulnerable effects over the human population.

Q. 18 ***What are the key components of Disaster Management ?***

Ans. To make preparations against losses and damages, Prevention, Preparedness, Response and Mitigation etc. are certain key components of disaster management.

Q. 19 ***What is the meaning of Disaster Mitigation ?***

Ans. Disaster mitigation involves measures to reduce the effects of disaster causing phenomenon. All actions to reduce the impact of a disaster that can be taken prior to its occurrence, including preparedness and long term risk reduction measures, come in the mitigation programs. It also includes the planning and implementation of measures to reduce the risk, and the process of planning for effective response to disasters which may occur.

Q. 20 ***What could be role of Information technologies in Disaster Management ?***

Ans. The Ministry of Agriculture, which the nodal Ministry for Disaster Management in India, has laid great emphasis on using the various state-of-the-art technologies such as Remote Sensing [RS], Geographical Information System [GIS], Global Positioning System [GPS], Computer Modeling and Expert Systems [CMES], Electronic Information Management System [EIMS] etc. in managing the situation caused by natural disasters.

Q. 21 ***What will be the Mitigation strategies that can lessen the Earthquake impacts ?***

Ans. 1. To follow building codes,
2. Enforcement of compliance with building codes requirements and encouragement of higher standards of construction quality,
3. More emphasis should be given to engineering of structures to withstand earthquake vibrations,

4. High standards of engineering design of all public buildings like hotels, schools, hospitals,
5. Reduce urban densities in high-risk seismic zones,
6. Strengthening of existing buildings, monuments, in the vulnerable areas,
7. Encouraging insurance,
8. Community participation in constructing safe houses from seismic shocks,
9. Creating awareness of what to do and what not to do at the time of earthquakes,
10. Regular earthquake drills in the seismically prone areas etc.

Q. 22 ***What can be the Precursors of Earthquakes ?***

Ans. It is yet not possible to predict earthquakes. To make preparations against losses and damages, some indications are observed before an earthquake. Such indications are known as ***precursors***. These precursors can be measured with the help of instruments, known as *Instrumental Precursors* and those can only be perceived and not measured, known as *Non-instrumental Precursors*.

Q. 23 ***What are the characteristics of Earthquake Hazard Zoning Map of India ?***

Ans. At present, Indian subcontinent has been subdivided in to Four Seismic Risk Zones as :

1. *Zone – II* : This is Low Damage Risk Zone and covers major part of the country. Earthquakes of magnitude between 4.0 and 4.6 fall in this Zone.
2. *Zone – III* : This is Moderate Damage Risk Zone and earthquakes of magnitude 4.7 to 5.3 come in this Zone.
3. *Zone – IV* : This is High Damage Risk Zone and covers Extra-peninsular India, Part of Gujarat, Koyana region of Maharashtra etc. Earthquakes of magnitude between 5.4 and 6.0 observe in this Zone.
4. *Zone – V* : This is Very High Damage Risk Zone, covers some parts of Himalayas, North-eastern parts of India and portions of Gujarat. This is one of the seismically prone areas of the world. Earthquakes of magnitude more than 6.0 come in this Zone.

Some Damaging Earthquakes in India - Case Studies

India has a very long history of earthquakes. The occurrence of earthquakes is not a new phenomenon for most of the northern earthquakes in India [Interplate Earthquakes]. In the past, our country has faced some major disastrous earthquakes like :

No.	Date	Name	Magnitude [*M*]
1	12.06.1897	Assam Earthquake	*8.1*
2	15.11.1934	Bihar Earthquake [Largest ever earthquake recorded in mainland India]	*8.7*
3	15.08.1950	Assam Earthquake [Largest earthquake recorded in mainland India since	*8.5*

		Independence]	
4	19.01.1975	Kinnaur Earthquake	*6.8*
5	20.10. 1991	Uttarkashi Earthquake	*7.0*
6	29.03.1999	Chamoli Earthquake	*6.8*
7	26.12.2004	Indian Ocean [Sumatra] Earthquake [Third largest earthquake ever recorded]	*9.0 – 9.3*
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Besides these events, few major and moderate earthquakes have also been experienced in different parts of the country [Intraplate Earthquakes] :

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5	22.05.1997	Jabalpur Earthquake	*5.8*
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Case Studies

In the following paragraphs, some case studies of earthquakes are presented :

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Magnitude of Earthquake	7.0 [on Richter Scale]
Intensity	IX [on Modified Mercalli Scale]
Date of Occurrence	October 20, 1991
Time of Occurrence	02h 53m 16s
Focal Depth	15 Kms.
Epicenter	Village Agora
People Killed	About 2000
Association	Main Central Thrust of Himalaya
People Injured	About 5000
Cattle Lost	About 3100
House Destroyed [fully]	About 20200
House Destroyed [partially]	About 74750

Villages affected	About 2100

[Besides the housing, other infrastructural facilities also received severe damage]

[Latur Earthquake]

Magnitude of Earthquake	6.4 [on Richter Scale]
Intensity	VIII $^{+}$ [on Modified Mercalli Scale]
Date of Occurrence	September 30, 1993
Time of Occurrence	023h 55m 47.5s
Focal Depth	15 Kms.
Epicenter	Village Killari
Association	Kurdawari Rift
People Killed	About 10000
Cattle Lost	About 14900
House Destroyed [fully]	About 34400
House Destroyed [partially]	About 16.5 lakh
Villages affected	About 95.8 lakh

[Besides the housing, other infrastructural facilities also received severe damage]

[Jabalpur Earthquake]

Magnitude of Earthquake	5.8 [on Richter Scale]
Intensity	VII $^{+}$ [on Modified Mercalli Scale]
Date of Occurrence	May 22, 1997
Time of Occurrence	21h 55m 31s
Focal Depth	32 Kms.
Epicenter	20 kms. NNW of Jabalpu
Association	Narmada-Son Lineament
People Killed	About 150
People Injured	About 400
House Destroyed [partially]	About 40000
Villages affected	About 150

[Besides the housing, other infrastructural facilities also received severe damage]

[Chamoli Earthquake]

Magnitude of Earthquake	6.8 [on Richter Scale]
Intensity	VIII $^{+}$ [on Modified Mercalli Scale]
Date of Occurrence	March 29, 1999
Time of Occurrence	00h 35m 13.4s
Focal Depth	21 Kms.
Epicenter	25 kms. east of Chamoli
No. of Aftershocks	204
People Killed	About 110
House Destroyed [partially]	About 50000
Villages affected	About 2000

[Besides the housing, other infrastructural facilities also received severe damage]

[Gujarat (Kutchh) Earthquake]

Magnitude of Earthquake	7.7 [on Richter Scale]
Intensity	X [on Modified Mercalli Scale]
Date of Occurrence	January 26, 2001
Time of Occurrence	08h 46m
Focal Depth	16 kms.
Epicenter	09 kms. SW of Village Chobari
People Killed	About 19800
People Injured	167000
House Destroyed [fully]	35000
House Destroyed [partially]	400000
District affected	21

[Besides the housing, other infrastructural facilities also received severe damage]

[Sikkim Earthquake]

Magnitude of Earthquake	6.9 [on Richter Scale]
Intensity	VII [on Modified Mercalli Scale]
Date of Occurrence	September 18, 2011
Time of Occurrence	18h 10m
Focal Depth	19.7 kms.
Epicenter	68 kms. NW of Gangtok
People Killed	About 120

[Besides the housing, other infrastructural facilities also received severe damage]

The Indian Gujarat Earthquake 26 January 2001

On 26 January 2001 an earthquake registering 7.9 on the Richter scale devastated the Indian state of Gujurat. It was the second largest recorded earthquake in India, the largest being in 1737, and was the worst natural disaster in India in more than 50 years.

The earthquake struck at approximately 8.46am local time, its epicentre located 80 kilometres north-east of the city of Bhuj. The place in the earth's crust where an earthquake occurs is known as the focus. The epicentre of an earthquake is the place directly above the focus. The shock waves or tremors from the Gujurat earthquake lasted about two minutes, followed by aftershocks for more than a month.