Component-I (A) - Personal Details

Role	Name	Affiliation
Principal Investigator	**Prof. Masood Ahsan Siddiqui**	Department of Geography, Jamia Millia Islamia, New Delhi
Paper Coordinator, if any	**Dr. Rajnish Ranjan**	Vice President, Skymet
Content Writer/Author (CW)	**Dr. Lubna Siddiqui**	Department of Geography, Jamia Millia Islamia, New Delhi
Content Reviewer (CR)	**Dr. Rajnish Ranjan**	Vice President, Skymet
Language Editor (LE)		

Component-I (B) - Description of Module

Items	Description of Module
Subject Name	**Geography**
Paper Name	**Disaster management**
Module Name/Title	**Disaster Management for Earthquakes**
Module Id	DM-16
Pre-requisites	
Objectives	To understand the basic concept of earthquakes and associated ha To explore the possibilities of managing earthquake hazard - miti redness, response and recovery to earthquake hazard and associate dary impacts
Keywords	

Module 16 Disaster Management for Earthquakes

Rationale

Earthquakes are among the most devastating disasters. They not only cause deaths and injuries but also bring about massive damage to infrastructure and economy. Management of Earthquake must be robust and should mainly focus on mitigation strategiesthrough proper identification and taking necessary precautions. This module is mainly focusing on to learn that loss of lives and property due to Earthquakes could be reduced and explore the way to ensure the same.

Unit- 1 Earthquakes and the Earth System

Earthquake is a geo-physical phenomenon whichis considered as the interplay of geological and geo-morphological dynamism of Earth. The earth as a whole is composed of three main layers (figure-1) the Crust, the Mantle and the Core.

According to the Plate Tectonic Theory, the crust, which is the outermost layer of the earth, is made up of lithospheric plates (figure-2) that float over the viscous mantle layer and remains in 'isostasy' The plates forming the crust move away, towards or past each other (figure- 3) very slowly over the mantle. Whenfriction/interaction between two plates occur, itresults in the sudden release of energy in the form of waves that move along the earth crust and is termed as **seismic activity or earthquakes**. The boundary between two plates is generally encountered with faults or other structural deformities. Faults are not continuous but usually consist of a fault zone or discontinuity that is present due to the rock-mass movement.

Figure 1 Layers of Earth

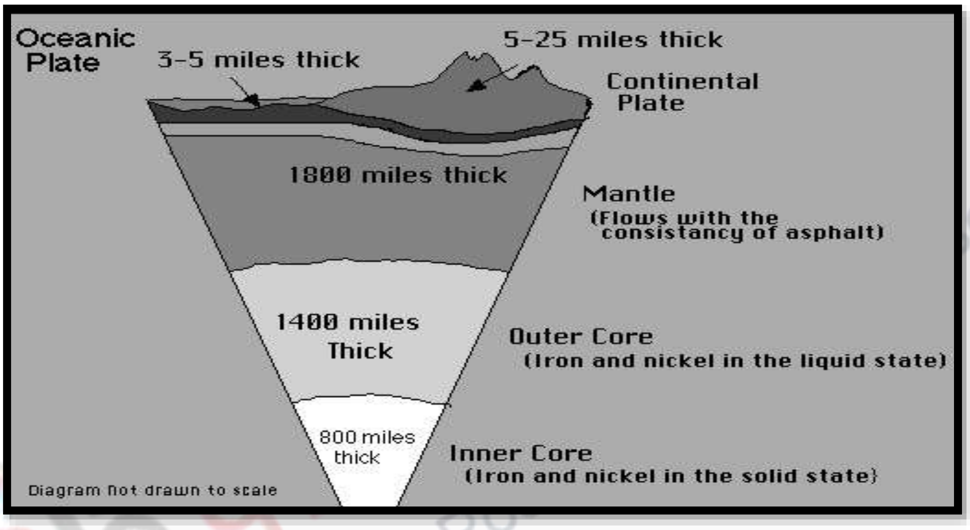


Figure 2 Plates according to Plate Tectonic Theory

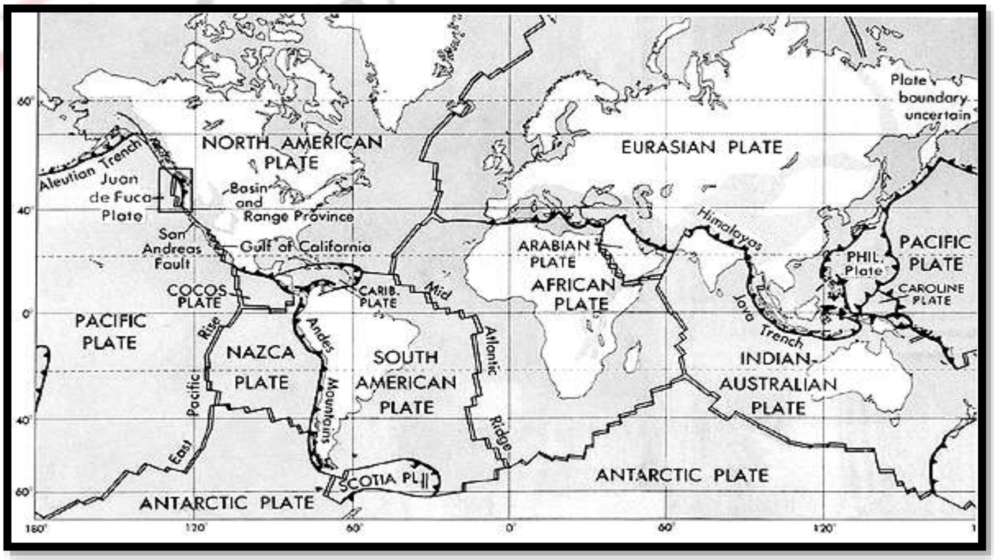
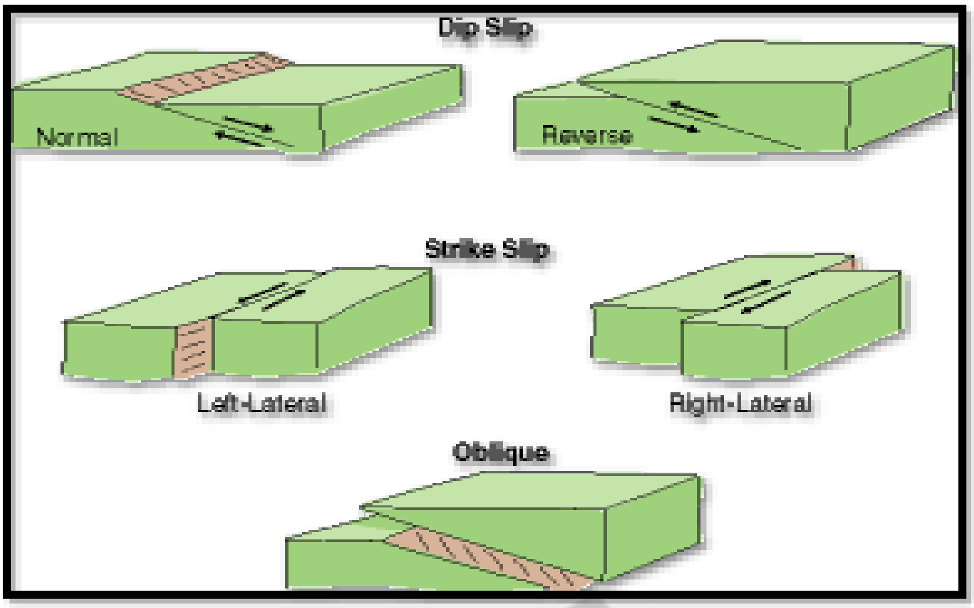


Figure 3 Types of Faults

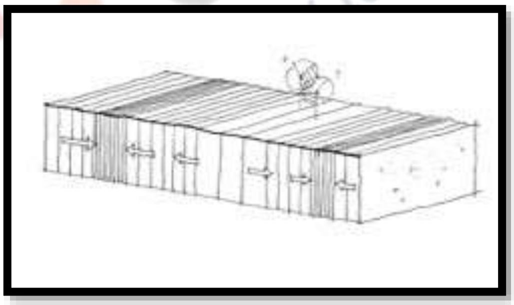


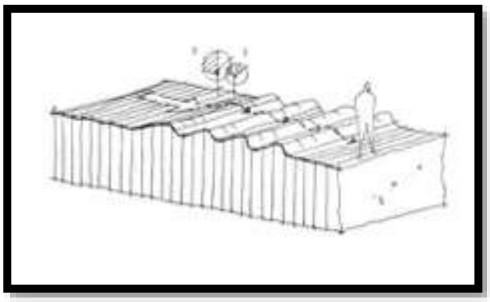
During an earthquake, the movement of rock blocks along the fault or line of weakness gives rise to seismic waves spreading outwards along the surface of the earth, in all directions simultaneously. These waves are grouped into two main types:

(a) **Body waves** consisting of P-**Wave**and **S-Wave**. The former moves in solid and liquid medium and are having greatest velocity, similar to sound waves,**S-Wave**travel slower than P-wave and are more destructive than P-Wave. Though it cannot travel through water.

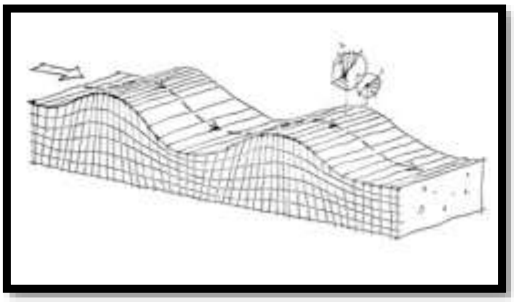
(b) **Surface Waves** consisting of **Rayleigh**and **Love Waves.** In **Rayleigh**or Ground Roll the surface moves vertically and horizontally leading to vehicles and stationary objects moving up and down. They are slower than S-waves. **Love Waves** move ground from side to side resulting in horizontal ground motion.

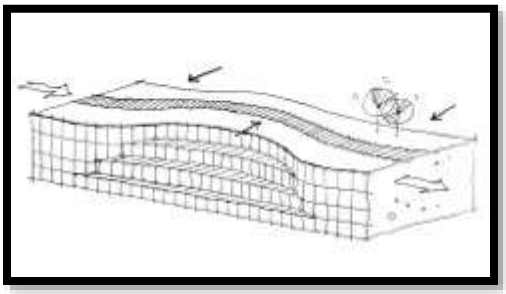
Figure 4 Ground Motion during Earthquakes





(a) P-Wave (b) S-Wave



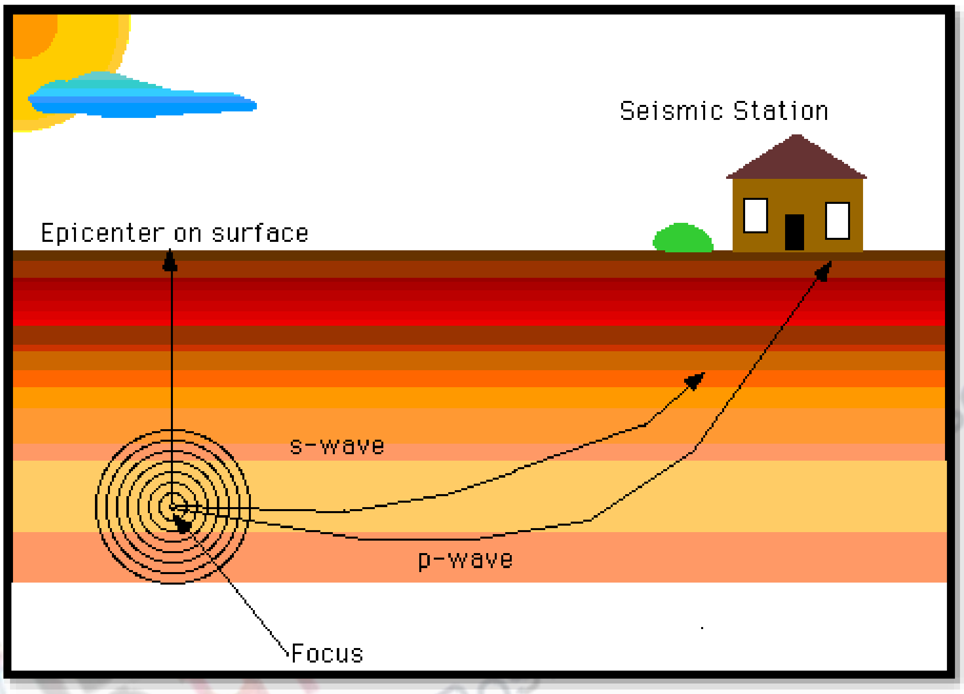


(c) Rayleigh Wave (d) Love Wave

Measuring Earthquake

Based on the differences in velocity and motion of the waves, instruments like Seismograph and Accelerometer could be used to measure Earthquakes. These instruments measure the resultant displacement, velocity and acceleration of the ground movement, arising out of the seismic waves. By measuring these waves, the center of release of energy and its distance from the location of the instruments can be found. This center of release of the energy in the interior of earth is the **Focus or Hypocenter,** and the corresponding point on the Earth's surface lying perpendicular to the Focus is the **Epicenter.**

Figure 5 Focus (Hypocenter), Epicentre



The **Magnitude** of the earthquake is the relative size of the earthquake and is arrived based on the maximum motion recorded by the seismograph. The size of earthquake is measured using the Moment Magnitude (M_W) scale (Figure-6). The scale is derived by modeling earthquake recordings from different recording stations. Magnitudes are represented on logarithmic scale with base 10 thereby a difference between a magnitude 4 and a magnitude 5 is about 10 times more ground shaking and about 32 times the energy released.

Figure 6 Earthquake magnitude scale and estimated occurrences per year

Earthquake Magnitude Scale

Magnitude	Earthquake Effects	Estimated Number Each Year
2.5 or less	Usually not felt, but can be recorded by seismograph.	900,000
2.5 to 5.4	Often felt, but only causes minor damage.	30,000
5.5 to 6.0	Slight damage to buildings and other structures.	500
6.1 to 6.9	May cause a lot of damage in very populated areas.	100
7.0 to 7.9	Major earthquake. Serious damage.	20
8.0 or greater	Great earthquake. Can totally destroy communities near the epicenter.	One every 5 to 10 years

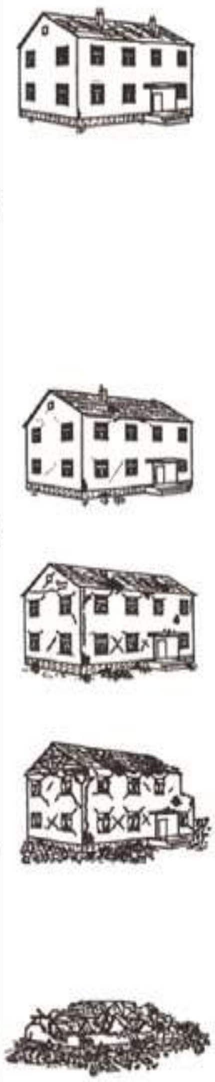
The impact or effects (degree of destruction) of the earthquake of a particular magnitude on the earth's surface is the **Intensity**of the Earthquake. It is measured using scales consisting of increasing levels of intensity from "not felt" to "damaging buildings and structures" (figure-7). **Modified Mercalli Intensity** is the predominantly used scale. The relation between the Magnitude and the Intensity varies. A 7.0

M_wEarthquake in a desert region would have limited intensity, whereas even a 6.5 M_w shallow earthquake near an urban center would have higher intensity due to the absence of settlements in the desert.

Iso- Seismal lines are imaginary lines joining places that experience same earthquake intensity. **Co-Seismal** are imaginary lines joining places that experienced the earthquake at the same time. They are plotted for each earthquake.On the basis of such lines and data collected over the years, statistically backed deterministic models are developed estimating future earthquakes to help in better preparedness and risk reduction measures(Vere-Jones, 1995). Due to the unavailability of decade or century old data as required, deterministic models are difficult to arrive at. Thus, a more realistic approach is the prediction of earthquake with a probability associated with it. It is known as E*arthquake Forecasting*. This forecasting is done by S*eismic Hazard* analysis by estimating the probability of ground motion exceeding a certain value at a certain location (Snieder & Eck, 1997). These hazard analyses help in estimating future earthquakes and thereby in the generation of **Seismic Hazard Maps**and other predictive models.

Figure 7 Intensity of Earthquake- Modified Mercalli Intensity
Source: (The Geographer Online)

EMS-98 Intensity	Felt	Impact	Magnitude (Approximat Value)	Building Damage (Masonry)
I	Not felt	Not felt	2	
II-III	Weak	Felt indoors by a few people. People at rest feel a swaying or light trembling.	3	
IV	Light	Felt indoors by many people, outdoors by very few. A few people are awakened. Windows, doors and dishes rattle.		
V	Moderate	Felt indoors by most, outdoors by few. Many sleeping people wake up. A few are frightened. Buildings tremble throughout. Hanging objects swing considerably. Small objects are shifted. Doors and windows swing open or shut.	4	
VI	Strong	Many people are frightened and run outdoors. Some objects fall. Many houses suffer slight non-structural damage like hair-line cracks and falling of small pieces of plaster.		
VII	Very strong	Most people are frightened and run outdoors. Furniture is shifted and objects fall from shelves in large numbers. Many well-built ordinary buildings suffer moderate damage: small cracks in walls, fall of plaster, parts of chimneys fall down; older buildings may show large cracks in walls and failure of in-fill walls.	5	
VIII	Severe	Many people find it difficult to stand. Many houses have large cracks in walls. A few well built ordinary buildings show serious failure of walls, while weak older structures may collapse.		
IX	Violent	General panic. Many weak constructions collapse. Even well built ordinary buildings show very heavy damage: serious failure of walls and partial structural failure.	6	
X+	Extreme	Most ordinary well built buildings collapse, even some with good earthquake resistant design are destroyed.	7	



© Swiss Seismological Service

Cascading Hazards

The complexities with seismic risk do not only stop with Earthquakes. The different cascading hazards arising from earthquake are as follows-

- The observed unhygienic conditions prevalent in the urban poor areas due to lack of basic facilities like sanitation and sewerages and unplanned construction lead tosecondary health issues post earthquakes disaster .
- Fire is another associated secondary hazard. Unplanned and dense construction impedes fire fighting also especially when most of the local capacities for response focus on urban search and rescue, and when enough space is not available between buildings for the fire fighting equipment to reach the fire affected areas.
- Earthquakes also pose significant threat to lifeline or critical infrastructure like Roads, Power Supply Lines and Power stations, water supply, Sewage lines, Bridges, Schools, Hospitals etc. Strengthening of critical infrastructures and immediate revival of supply to ensure relief to chronic patients, disaster affected injuries and casualties.
- Earthquakes in ocean/ seas could also bring trigger tsunamis or giant waves. The Indian Ocean Tsunami on Dec 26th, 2004 occurred due to an earthquake of magnitude 9.1 M_w near Sumatra Islands. It brought about giant waves in the Indian Ocean that affected fourteen countries, killed more than 2 lakh people and displaced thousands more.
- Earthquakes in mountainous areas bring about landslides/ rock fall. Earthquake generates a large number of induced landslides in close proximities to the epicentre region.

Figure 8 - Planet Team (2017) image of the epicentre region of the Jiuzhaigou earthquake, dated 8th August 2017
Source: (Petley, 2017)

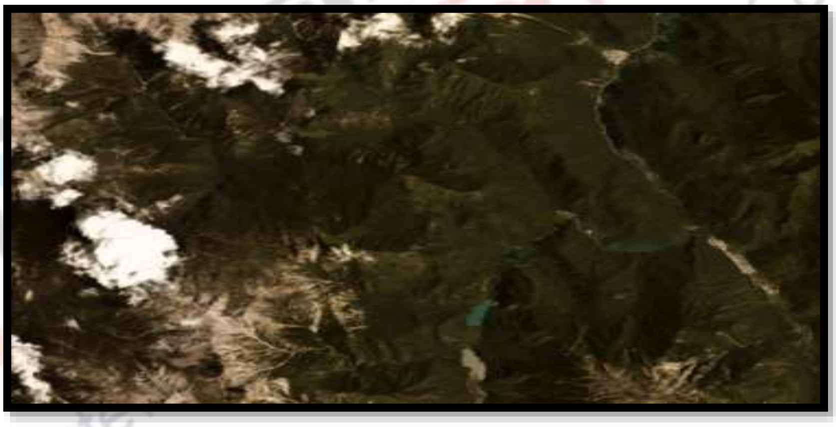
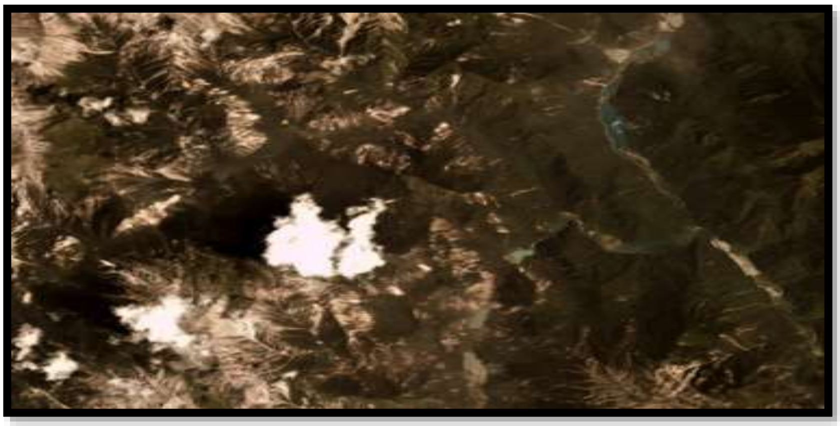


Figure 9- Planet Team (2017) image of the epicentre region of the Jiuzhaigou earthquake, dated 9th August 2017 showing the landslides induced due to Earthquake
Source: (Petley, 2017)

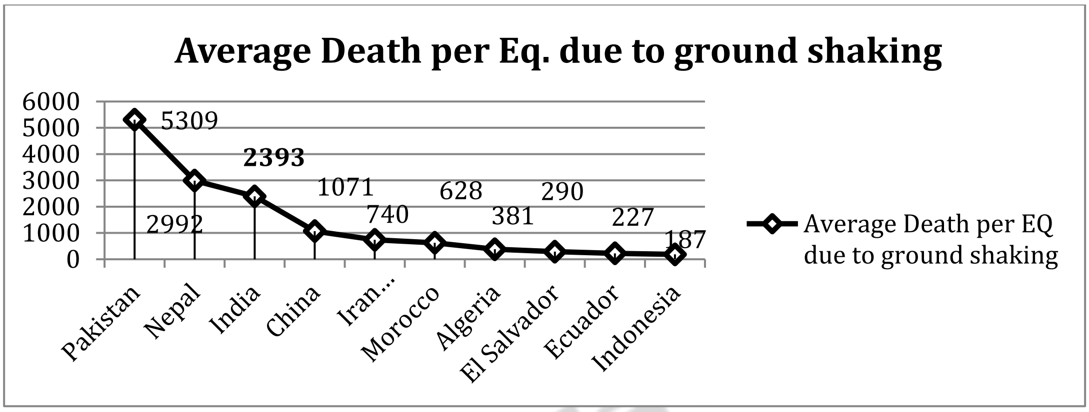


Earthquake preparedness and mitigation measures must, therefore , not only consider the ground shaking but must also incorporate mitigation measures and response to multiple cascading hazards associated with it.

Unit 2 – Earthquake Risk Management

Earthquakes bring about great distress to individual and communities. An analysis of the CRED Data from 2000 to 2016 reveals India as the fourth highest number of deaths (due to ground motion) at **2393** per earthquake. For representative purposes, Haiti with 2,22,570 deaths due to a single earthquake is not shown in the graph below.

Figure 10 Average death per earthquake (due to ground shaking)- analysis of CRED data

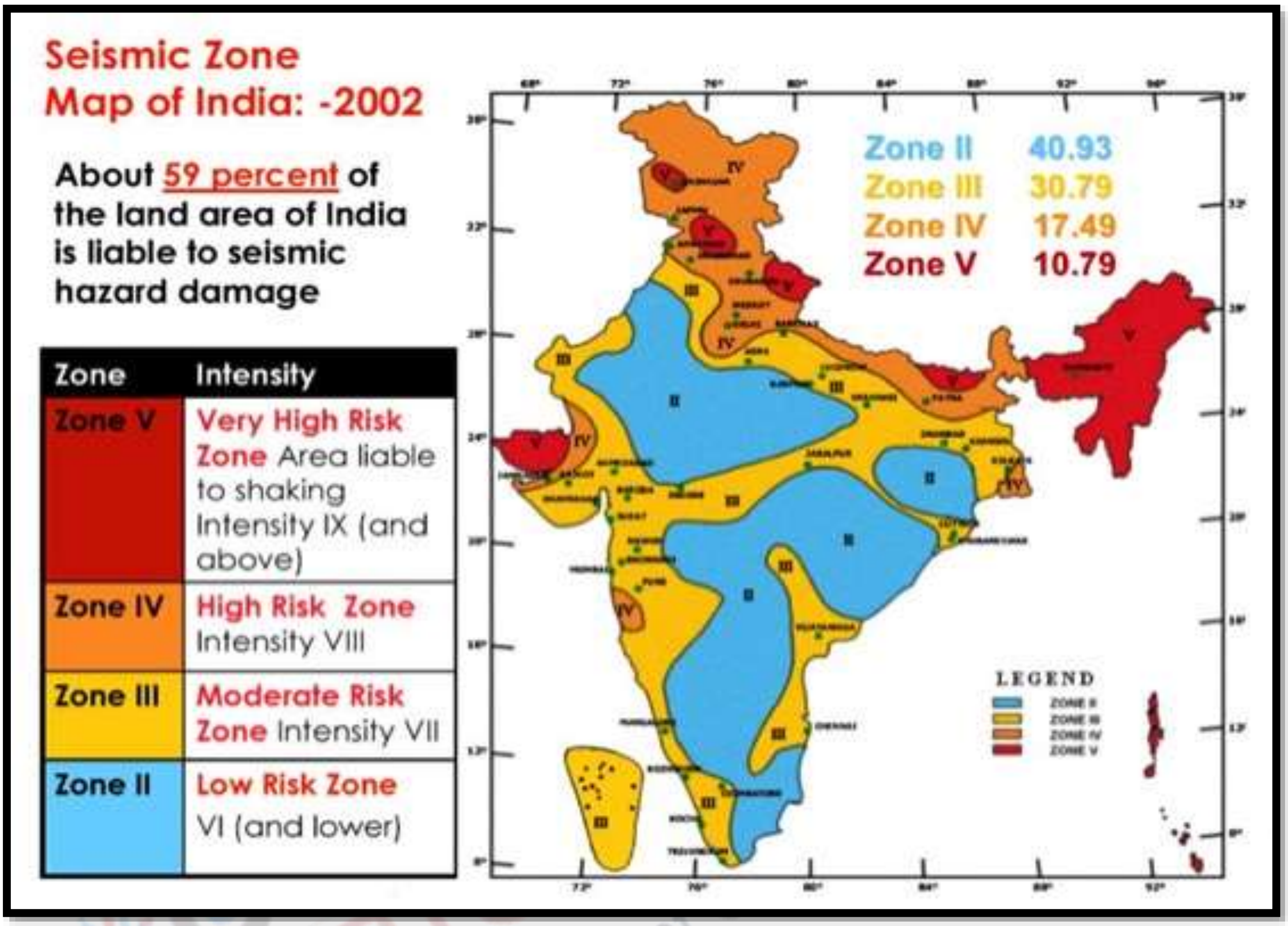


Considering the devastating impacts of earthquakes not only due to the high number of casualties, but also due to associated destruction to property. Several measures have been undertaken to minimize the impacts of earthquakes and develop earthquake resilient structures. It is significant to note that the event of earthquakes as a ground motion doesn’t create destruction. It’s their effects on buildings (residential, commercial) that causes the collapse of buildings or building components that impact the occupants of the buildings.
This section is an introduction to the efforts to recognize and minimize Earthquake risks.

Earthquake Zonation

Seismic Hazard Maps help in classification of areas according to observed and predictive past seismicity. India is divided into four zones- Zone-II to Zone V with respect to the observed and probable seismicity according to **IS:1893:2002**. No locations in India exists in zone-1 as no location in the country is considered completely free from Seismic hazard.

Figure 11 Seismic Zonation and Intensity Map {Source: (NIDM)}



IS:10 893, 2002 is the Indian standard pertaining to macro zonation for seismic hazard. It has been modified on at least five occasions- with the major ones post Latur (1993) and Bhuj (2001) earthquakes. Macro zonation, thus, at a national level is not sufficient to assess and prepare for Seismic hazard. Tremors were felt in Delhi in correspondence with Earthquakes as far away as Nepal or Afghanistan. Thus, the changes observed in Intensity of earthquakes due to the changes in geological and geo-morphological configuration within the macro zones led to the requirement for**Micro zonation** for seismic hazard. Micro zonation involves the incorporation of seismological, geotechnical and geologic considerations along with the Land Use planning for estimating earthquake effects on the area under consideration(Dr.P.Anbazhagan). It thereby aids in site/ design considerations in order to be less susceptible to earthquake damages. Better equipment, motion stations, and advent in interpretive sciences and probabilistic and deterministic assessments led to a better understanding of seismic hazard in maps of smaller scale (even up to 1:5000).
While macro zonation gives an indication about the most credible earthquake in a particular area and the probability of its occurrence, micro zonation helps in identifying areas within a district or a metropolitan city that could be more susceptible to damages (for example due to the liquefaction potential of the soil, or the construction practice in place in the areas being unsuitable to the most credible earthquake probability).

Construction Codes

Any building must consider the following forces:
(i) Wind
(ii) Dead Load (the weight of the building components)
(iii) Live Load (the variable weight due to the occupancy- people, furniture, machinery etc.)
(iv) Earthquake Load

The building must stand stiff under normal conditions by taking into consideration, the first three loads, while during ground shaking associated with earthquakes, the building must be 'ductile' enough to dissipate input energy and not collapse completely. The extent to which the building must be ductile would depend on the location of the building and the geological constituents of the ground in these locations. Wind and Earthquake load is only during the occurrence of extreme wind conditions or during ground motion, whereas the design of the building taking into consideration the Dead Load and Live load is completely under the control of the building designers and construction workers. The fact that a building is not tested for its durability or for its capacity to withstand wind or earthquake loads unlike automobiles or other products sold in market post obtaining fitness certificates from concerned authorities. For buildings the *Occupation Certificate (OC)* issued by the local administration certifies the compliance of the buildings to the local health and safety requirements. OC is issued on the basis of the construction codes in place. These are developed to identify suitable building construction materials and methods for earthquake resilience of buildings based on the seismic hazard maps and the macro and micro zonation.

There are instances of traditional ways of building houses and commercial structures that have an understanding of the local geological and geomorphological consideration and thereby developing an understanding about the geotechnical concepts to utilize appropriate construction materials in an appropriate manner so that the buildings built do not collapse and cause damage to property/ lives during earthquakes. The Koti Banal architecture of Uttarakhand is one such example(Saraswat & Mayuresh, 2017).

In India, the Bureau of Indian Standards (BIS) develops construction codes that act as mandates for safe ‘seismic resistant’ construction ensuring the buildings maystand firmly despite seismic activity. The Iso-seismal and corresponding Peak Ground Velocity (greatest speed reached by the ground during the earthquake) and Peak Ground Acceleration (rate of change of speed of movements- both horizontally and vertically)are considered in Building Codes. Thus it serves as a bridge between the earth system and the built environment consisting of the buildings and habitat built by humans.

National Building Code

The National Building Code of India (NBC) is a comprehensive building code that provides guidance for regulating construction activities across the country. It serves as a model code by all agencies involved in building and construction activities including the Public Works Department, Local bodies or private construction agencies. The codes contain regulations, development control rules, building requirements, stipulations regarding materials, fire safety requirements, structural design and construction (including safety), building and plumbing services, approaches to sustainability and facility management (BIS, 2016) etc.

The list of standards pertaining to Earthquake as per the BIS are tabulated in Table below:

Table 1 Standards pertaining to Earthquake
Source: (Minister of State, 2014)

S. No.	IS No	Title
1	IS 1893:1984 (Reaffirmed in 2013)	Criteria for earthquake resistant design of structures (fourth revision)
2	IS 1893 (Part I): 2002 (Reaffirmed in 2012)	Criteria for earthquake resistant design of structures: Part I of General Provisions and buildings (fifth revision)
3	IS 1893 (Part 4): 2005 (Reaffirmed in 2010)	Criteria for earthquake resistant design of structures: Part 4 Industrial structures including stack like structures
4	IS 4326:2013	Code of practice for earthquake resistant building and construction of buildings (third revision)
5	IS 13827: 1993 (Reaffirmed in 2013)	Improving earthquake resistance of earthen buildings- Guidelines
6	IS 13828:1993 (Reaffirmed in 2013)	Improving earthquake resistance of low strength masonry buildings- Guidelines
7	IS 13930: 1993 (Reaffirmed in 2013)	Ductile detailing of reinforced concrete structures subjected to seismic forces- Code of practice
8	IS 13935: 2009 (Reaffirmed in 2013)	Seismic evaluation, repair and strengthening of masonry buildings- Guidelines (first revision)
9	IS 15988:2013	Seismic Evaluation and Strengthening of Existing Reinforced Concrete Buildings- Guidelines

Role of Reconnaissance Missions in updating Building codes

Post-Earthquake, Reconnaissance Missions have been undertaken by formal institutions to gather the extent and reasons of losses post devastating earthquakes. The recce missions played a very important role in learning from past failures. The impact studies undertaken post the Great Kanto Earthquake in Japan (1923) and Great Nobi Earthquake (1891) were among the first recorded post disaster missions that led to introduction of the mandatory requirement for all buildings to incorporate a seismic coefficient of 0.1 as per the Urban Building Law(Whittaker, Moehle, & Higashino, 1998). Nicholas Ambraseys summarizes the scope of reconnaissance missions post earthquake: "It is increasingly apparent that the site of a damaging earthquake is undoubtedly a full-scale laboratory, in which significant discoveries can be made by keen observers- seismologists, geologists, engineers, sociologists and economists."(Spence, 2015) At present there are six recognized formal scientific institutions across the globe that are primarily dealing with post-earthquake reconnaissance missions-

(i) EERI (Earthquake Engineering Research Institute)
(ii) EEFIT (The Earthquake Engineering Field Team)
(iii) GTF (German Task Force)
(iv) UNESCO Task Force
(v) AFPS (French Association for Earthquake Engineering)
(vi) JSCE (Japan Society of Civil Engineers)

Building Codes and Informal construction

Establishment of model Building Codes and byelaws is the key step towards seismic risk mitigation. A major part of the success of building codes is in its implementation.Generally housing is segregated into formal and informal categories. An accepted understanding of informality in construction practice is that informal construction does not recognize or regard the local-rules and laws in place, in its design and construction. The informal construction includes slum construction in urban localities that are considered most vulnerable during earthquakes; given that the slum areas are generally situated in the flood plains or in other areas that are repeatedly affected by multiple hazards. Flood plains are usually made of loose soil and the liquefaction potential of loose soil is generally higher than the adjoining soils. Further, the dense concentration of buildings also impede in evacuation or urban search and rescue.

Institutional Framework for Seismic Risk Management in India

The National Disaster Management Plan, 2016(National Disaster Management Authority, Government of India, 2016)lays down important steps and recommendations for seismic risk assessment and disaster preparedness.

The Plan has entrusted India Meteorological Department (IMD) to monitor earthquakes and form a real time seismic monitoring network and disseminate information to agencies involved in earthquake tracking, research, mitigation and response. Geological Survey of India in coordination with IMD is responsible for hazard zonation and micro seismic zonation of vulnerable areas . The National Disaster Management Authority, National Institute of Disaster Management and other Science and Technology departments and institutions have been entrusted with the task of Earthquake hazard risk and vulnerability assessment. The BMTPC (Building Materials & Technology Promotion Council) in coordination with the Bureau of Indian Standards (BIS) and other institutions formulate and update the National Building Code and other standards. The state departments are required to act accordingly and ensure measures to understand and mitigate seismic risk.

The Ministry of Home Affairs, Govt of India is identified as the nodal agency for coordinating Earthquake Response and central assistance, while the State Disaster Management Authorities, Revenue Department and Commissioner for Relief along with the Panchayats and Urban Level Bodies are responsible for the organization of immediate response and to seek further assistance if necessary from central agencies.

Special Housing Schemes, retro fitment of prioritized lifeline structures and buildings and hazard resistant construction, model codes for town planning, civil and public works, and conduction of safety audits have been given due importance and the Ministry of Rural Development, Ministry of Urban Development along

with other relevant ministries are responsible to devise strategies and plans in this regard. The implementation and compliance activities are the responsibilities of state departments.
Capacity Development for Earthquake related training, curriculum development have been tagged to NIDM,NDMA, Ministry of Earth Sciences, Ministry of Human Resources and Development, University Grants Commission and other institutions. Awareness Generation plays a key role in the earthquake preparedness and NDMP has identified NDMA, NIDM, Central Armed Police Forces and National Disaster Response Force (NDRF) as the central agencies in charge of carrying out mass media campaigns, promoting the culture of earthquake risk prevention, mitigation and management, promoting attitude and behavioral changes in the awareness campaigns, the promotion of risk transfers and insurance, community radio and the strengthening of civil society organizations. All State departments including State disaster Response Forces and Fire and emergency Services, Civil Defense, Police, DDMA and Panchayats/ ULBs are to assist and enhance the awareness campaigns and promotion of culture of earthquake risk consciousness in the public. Mock Drills are also to be conducted by the Central and State Agencies regularly.

Earthquake Preparedness& Response

The first priority in Earthquake response is to minimize loss of lives, by undertaking effective search and rescue operations and the evacuation of affected people. Evacuation is categorized as Preventive (post early warning before materialization of hazard), Protective (as a precaution), Rescue- oriented falls under Search and rescue and Reconstructive- resettlement in safe locations. Search and Rescue (SAR) is a technical activity undertaken by trained personnel who rescue and attend to casualties under adverse conditions(National Disaster Management Authority and Indira Gandhi National Open University, 2011). Specific response during Earthquake hazards include:

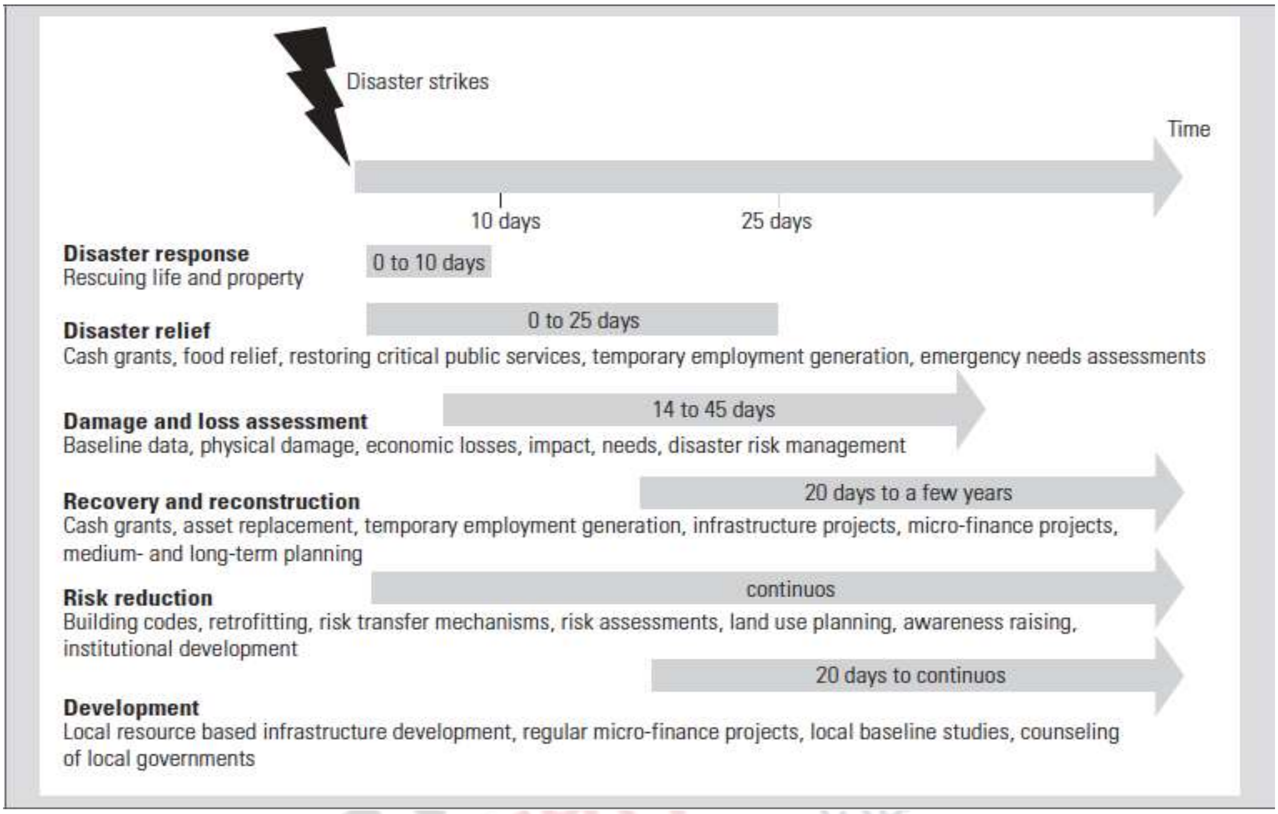
(a) Rescuing victims from rubble
(b) Special care in case of fire
(c) Evacuation of at risk people in safe locations
(d) Rendering first aid
(e) Positioning of ambulances

Earthquake Recovery

The planning for earthquake recovery ideally begins immediately after the earthquake event. Decisions regarding institutional mechanisms for managing rehabilitation and reconstruction activities, allocation of financial resources, identifying and prioritizing reconstruction activities with a robust monitoring and evaluation and community information and communication program are essential in the post-earthquake recovery framework. The framework should be based on thorough analysis of reliable data pertaining to disaster impact and the post disaster recovery needs(GFDRR, 2011). Alignment of disaster recovery with the national development goals aids in better sustainability and the mainstreaming of Disaster Risk reduction efforts into development agenda. Key components of Post-Earthquake Recovery include:

(a) Managing post disaster funds
(b) Monitoring and management of recovery process
(c) Transitional shelter programs
(d) Environmental and social assessment
(e) Decision pertaining to relocation or rebuilding
(f) Debris management
(g) Focus on vulnerable segments (Women, Children, Elderly, differently abled etc.)
(h) Proper seismic assessment
(i) Decisions pertaining to Land Tenure and regularization of slums
(j) Income support/ Livelihood recovery programs

Figure 12 Post Earthquake Risk Management
Source: (GFDRR, 2011)



Summary

Earthquake is a geo-physical phenomenon. Seismic activity or Earthquake is a sudden release of energy in the form of waves that move along the earth crust. It causes the collapse of improperly designed/constructed buildings or building components that cause impactson the occupants of buildings and bring about great devastation. Establishment of model Building Codes and byelaws is a key step towards seismic risk mitigation. The National Disaster Management Plan, 2016(National Disaster Management Authority, Government of India, 2016)lays the plan for seismic risk assessment and addressal. Earthquake preparedness and mitigation measures must not only consider the ground shaking but must also incorporate mitigation measures and response to multiple cascading hazards associated with earthquakes like Landslides, Fire and damage to critical infrastructure.