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**VISVESVARAYA TECHNOLOGICAL UNIVERSITY
BELGAUM**



ENGINEERING GEOLOGY

(Subject Code: BCV303)

LECTURE NOTES

(MODULE-1)

III-SEMESTER

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SYLLABUS

Module /unit – 01 – Introduction, scope of earth science in Engineering, 8 hrs
Geohazards and disasters, Mitigation and management Earths internal dynamics
,Plate tectonics, Earth quakes types, causes iso-seismal line, seismic zonation map,
seismic proof structures, Numerical problems on location of epicenter; volcanic
eruption, types, causes, landslides, causes types, preventive measures; tsunamis
causesconsequences, mitigation; cyclones, causes management

INTRODUCTION

Geology is the science which deals with the study of the earth as a planet, it also includes the study of various physical, dynamic and physio chemical processes operating on or within the earth.

The scope of Engineering geology is best studies with reference to major activities of the profession of a civil engineer in civil projects like construction, water resource development, town and regional planning.

Application of Earth Science in Civil Engineering Practices

The engineering geologist has to observe and record geological information and then translate this data into practical engineering design, construction and maintenance of civil engineering projects.

The geological aspects of the civil engineering site have to be studied in detail before commencement of the project. The civil engineer and the engineering geologist have to work together in the field in various stages. However, in some stages they work separately, in other jointly. The responsibility and nature of work in which both engineering geologist and civil engineer are involved are listed below:

Engineering Geology and Civil Engineering

1. **Mapping:** The engineering geologist has to prepare a geological map of the area based on aerial photo and satellite imagery interpretation and field observation. Subsurface geological features are also mapped.
2. **Exploration:** In this stage the engineering geologist explore the area based on exploration techniques. The engineering geologist works from the planning stage. Supervise the exploration works and records the data for further interpretation.
3. **Surface water:** The engineering geologist and the civil engineer together prepare surface–water mapping. Both study the volume of total runoff, drainage basin

characteristics and sedimentary process in the basin. weathered areas, silting potential and erosion potential are also estimated before planning any hydraulic structure in the basin.

4. **Ground water:-** ground water is the major problem in the majority of civil engineering works. the engineering geologist studies in detail the occurrence, movement, structural control sand hydro geological properties of the rocks. Hydro geological maps are prepared for civil engineering purposes.
5. **Slope Stability:** Geological parameters of possible slide regions are studied
6. **Tunneling:** The tunnel site selected is based on a detailed study of the region. The civil engineer and the geologist have to conduct in-situ tests for estimation of weathered zone thickness, depth of hard rock, structural features etc.
7. **Earthquake:** The engineering geologist studies the seismic nature of the project site. He examines the seismic zoning map of the country, evaluates active and inactive faults and keeps the historical record of the earthquake of the region in which the civil engineer will prepare a seismic design of structure.
8. **Project Planning;** - project planning is the most important aspect in civil engineering. The civil engineer plans the various stages. the engineering geologists plans and prepare geologic feasibility and development parameters report, which are useful to civil engineer for planning the project schedule.
9. **Geological Structure:** - field investigation is carried out for selection of a suitable area. Detailed surface, sub-surface studies are conducted; surface and sub-surface maps are prepared. The engineering geologist and the civil engineering conduct in-situ test for foundation materials supervise the construction methods and monitor the structure after completion of the work.

Geological features of civil engineering have to be studied in detail before execution of the work. The engineering geologist must work from the exploration stage to the end of the project. The civil engineer and the engineering geologist have to work in the field together either good coordination in order to identify the field problem sand to suggest possible remedial measures in the case of problems of structures

INTERNAL DYNAMICS/ INTERIOR STRUCTURE OF THE EARTH

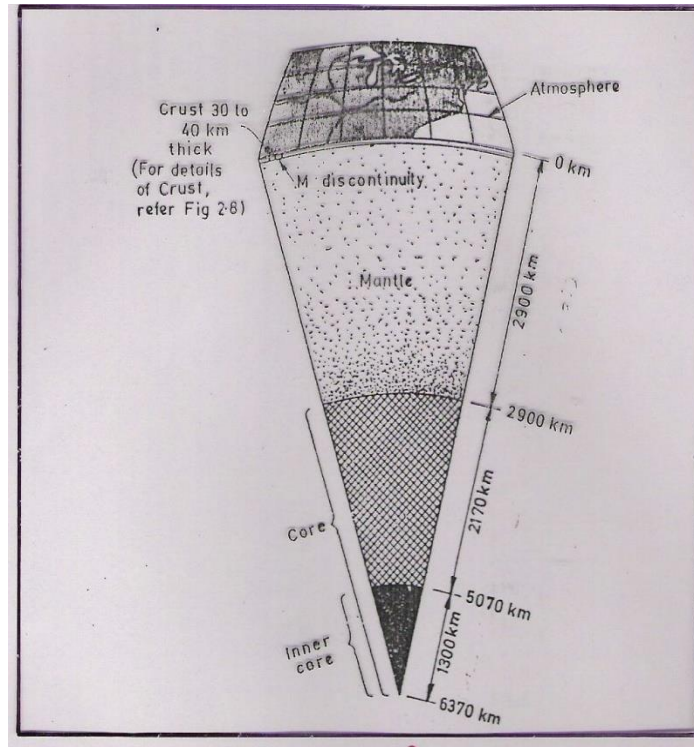


Fig: Internal Structure of Earth

The Crust: - Is the topmost shell of the earth, which has a thickness of 30-40 km in the continents and 5-6 km in oceans. There is a striking variation in the materials or rocks, as they are called, composing the crust over the continents and ocean floors. the oceanic crust is made up of heavier and darker rocks called basalts compared to light-coloured and light-density, granitic rocks of continental crust. When considered as a part of the total structure of the earth, crust makes only an insignificant part represented by a thin layer, similar to the skin of an apple. as regards the chemical composition of the crust, analysis made by Clarke and Gold Schmith, using rocks from different geographic regions of the crust have all shown that when expressed in terms of oxides, the **crust has silica as the most dominant component, its value lying above 50% by volume in the oceanic crust and above 62% in the continental crust.** alumina is the next important oxide, varying between 13-16% followed by iron oxides (8%), lime (6%), sodium (4%), magnesium (4%), potassium (2.5%) and titanium (2%). the crust itself shows a complicated structure both in make-up and compositional variations.

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Mantle:-At the base of the crust materials of the earth become greatly different in many properties from those overlying them in the crust. These materials appear to form an early homogeneous zone till a depth of **2900 km is reached. This zone of materials lying between crust and a depth of 2900 km is known a MANTLE. It is made up of extremely basic materials, called ultra basic rocks, which are believed to be very rich in iron and Magnesium but quite poor in silica.** Such rock names as a periodotites, dunite. this one is characterized with a high density, increasing steadily with depth further; the mantle material is believed to be highly plastic in nature. Many of the most important geological process such as earthquakes and formation of mountains are believed to have their origin in this zone

The Core:-It is the third and the inner most structure shell of the earth, which is clearly marked by the seismic evidence. It **starts at a depth of 2900 km below the surface and extends right up to the center of the earth at 6370 km.** the material making the core is found to be from seismic studies only strikingly different from that making the other 2 shells in one major aspect, in elastic properties.

The material has no shear resistance which makes it nearer to liquid than to a solid body. It has a very high density, above 10 gms/cubic centimeter, at the mantle–core boundary. Nothing can be said about the composition of the core. According to one, widely favored view, the core is **made up of Iron and Nickel alloy material**

Natural Disasters

A natural disaster is a major event caused by natural processes of the Earth; examples floods, hurricanes, tornadoes, volcanic eruptions, earthquakes, tsunamis, and other geologic processes. A natural disaster causes loss of life or property damage, and leaves some economic damage after it has been completed.

The Most Common Occurring Disasters of Nature:

- 1. Hurricane:** Hurricanes, tropical cyclones, and typhoons are different names for the same phenomenon: a cyclonic storm system that forms over the oceans. It is caused by evaporated water that comes off of the ocean and becomes a storm. The Coriolis Effect causes the storms to spin, and a hurricane is declared when this spinning mass of storms attains a wind speed greater than 74 mph. Hurricane is used for these phenomena in the Atlantic and eastern Pacific Oceans, tropical cyclone in the Indian, and typhoon in the western Pacific.
- 2. Earthquake:** An earthquake is the result of a sudden release of energy in the Earth's crust that creates seismic waves. Earthquakes are recorded with a seismometer, also known as a seismograph. The magnitude of an earthquake is conventionally reported on the Richter scale, with magnitude 3 or lower earthquakes being mostly imperceptible and magnitude 7 causing serious damage over large areas. Intensity of shaking is measured on the modified Mercalli scale. At the Earth's surface, earthquakes manifest themselves by shaking and sometimes displacement of the ground.
- 3. Tsunami:** A tsunami is a series of waves created when a body of water, such as an ocean, is rapidly displaced. Earthquakes, mass movements above or below water, volcanic eruptions and other underwater explosions, landslides, large meteorite impacts comet impacts and testing with nuclear weapons at sea all have the potential to generate a tsunami. A tsunami is not the same thing as a tidal wave, which will generally have a far less damaging effect than a Tsunami.
- 4. Flood:** A flood is an overflow of an expanse of water that submerges land, a deluge. It is usually due to the volume of water within a body of water, such as a river or lake, exceeding the total capacity of the body, and as a result some of the water flows or sits outside of the normal perimeter of the body. It can also occur in rivers, when the strength of the river is so high it flows right out of the river channel , usually at corners or meanders.
- 5. Drought:** A drought is an extended period of months or years when a region suffers a severe deficiency in its water supply. Generally, this occurs when a region receives consistently below average rainfall. It can have a substantial impact on the ecosystem and agriculture of the affected region. Although droughts can persist for several years, even a short, intense drought can cause significant damage and harm the local economy.

- 6. Avalanche:** An avalanche is a geophysical hazard involving a slide of a large snow or rock mass down a mountainside, caused when a buildup of material is released down a slope, it is one of the major dangers faced in the mountains in winter. As avalanches move down the slope they may entrain snow from the snowpack and grow in size. The snow may also mix with the air and form a powder cloud. An avalanche with a powder cloud is known as a powder snow avalanche. The powder cloud is a turbulent suspension of snow particles that flows as a gravity current
- 7. Landslide:** A landslide is a disaster involving elements of the ground, including rocks, trees, parts of houses, and anything else which may happen to be swept up. Landslides can be caused by an earthquake, volcanic eruptions, or general instability in the surrounding land. Mudslides or mudflows, are a special case of landslides, in which heavy rainfall causes loose soil on steep terrain to collapse and slide downwards.
- 8. Wildfire:** Wildfires, or forest fires, are uncontrolled fires burning in wild land areas. Common causes include lightning, human carelessness, arson, volcano eruption, and pyroclastic cloud from active volcano. They can be a threat to those in rural areas and also to wildlife. Wild fires can also produce ember attacks, where floating embers set fire to buildings at a distance from the fire itself.
- 9. Volcanic eruption:** A volcanic eruption is the point in which a volcano is active and releases lava and poisonous gasses into the air. They range from daily small eruptions to extremely infrequent super volcano eruptions (where the volcano expels at least 1,000 cubic kilometres of material.) Some eruptions form pyroclastic flows, which are high-temperature clouds of ash and steam that can travel down mountainsides at speeds exceeding that of an airliner.

Mitigation for Natural Disasters

Mitigation is a actions taken to prevent or reduce the risk to life, property, social and economic activities, and natural resources from natural hazards. Awareness, education, preparedness, and prediction and warning systems can reduce the disruptive impacts of a natural disaster on communities. Mitigation measures such as adoption of zoning, land-use practices, and building codes are needed, however, to prevent or reduce actual damage from hazards. Avoiding development in landslide- and flood-prone areas through planning and zoning ordinances, for example, may save money in construction and reduce the loss of life and damage to property and natural resources.

To achieve this goal, it is necessary to take the following steps

1. Incorporate both structural and non structural mitigation measures in new development,
2. Examine ways to reduce the vulnerability of existing structures,

3. Take steps to reduce the vulnerability of natural resources, and undertake mitigation training with support from state and federal governments

A program for enhancing the nation's hazard mitigation capabilities should include:

- 1. Protection of schools and hospitals:** All new schools and hospitals should be located and constructed to ensure that high-hazard areas are avoided and that special provisions are made to reduce the potential for damage by natural hazards. In addition, existing school and hospital buildings should be surveyed to determine their levels of resistance to relevant hazards. Efforts should be made to strengthen facilities that would fail in a disaster. In some instances, legislation may be required to ensure that mitigation actions are taken.
- 2. Adoption of non-structural:** measures. Businesses and homes should incorporate non-structural mitigation measures to minimize injuries and property damage from natural disasters. Furniture and equipment, for example, can be easily secured to reduce injuries and damage from earthquakes. Other non-structural measures are management of vegetation to reduce damage from wildfires and location of structures away from high-hazard areas
- 3. Incorporation of mitigation into new development:.** Local jurisdictions should ensure that new development is located, designed, and constructed to withstand natural hazards. They should use information from hazard and risk assessments, land-use plans, and zoning regulations to limit development of hazard-prone areas. Compatible uses of floodplains and other hazardous areas should be incorporated into local planning and zoning so that losses are reduced. Such areas could have a high value for recreation, fish and wildlife reserves, open space, or other community use.
- 4. Protection of natural resources:** Particularly valuable natural resources such as endangered species of wildlife, fish, and plants should be identified in mitigation plans and protection measures included in disaster response plans. Such natural resources are found not only in the wild, but in zoos and parks as well.
- 5. Government leadership of mitigation implementation:** Government at all levels should set an example by requiring that new facilities that it funds, regulates, or leases be designed, built, and located in accordance with modern building codes .
- 6. Mitigation trainin:.** Training programs that focus on contemporary challenges associated with implementing mitigation should be developed and offered. A national training program, supported by the federal government and fully integrated with the preparedness training proposed here, should be developed for this purpose. Its curriculum would include land-use planning, zoning, building codes and regulations.

- 7. Hazard-specific research:.** Recent disasters have demonstrated the benefits of mitigation efforts while pointing out the need for research to improve mitigation practice

PLATE TECTONICS

Tectonic Plate Theory

Plate tectonics is the movement of 7 major plates of earth crust. Movement of these plates is due to the **generation of convective current inside the earth**. Generation of this convective current is due to **huge temperature differences between core and crust**. Due to this movement, displacement will take place in the rocks of earth crust, due to displacement work has been done and work will be stored in the form of energy called as strain energy.

Due to this displacement, a **slip will take place in the faults of rock**. Length of faults may vary from 1 m to many km. due to slip stored strained energy will be released which will induce violent shaking of earth called earthquake.

99% of EQ's taken place on the boundaries of plate (the countries like Japan, California and san Francisco lie on the border of the plates) such EQ are called as interplate EQ, 1% of EQ takes place within the plates called intraplate EQ's

Tectonic plates

- 1) North American Plate 2) South American Plate 3) Eurasian Plate 4) African Plate
- 1) Indo-Australian Plate 6) Pacific Plate 7) Antarctic Plate

Elastic Rebound Theory: - After divesting EQ in San Francisco in 1906 a fault trace was discovered that could be followed along the ground in more or less straight line for 270 miles. it was found that the earth on 1 side of the fault had slipped compared to the earth on thru other side of the fault upto 21 feet and this fault drawn the attention of many scientists, but no 1 was able to explain what happening within the earth to cause EQ.

Prof. of geology H F Reid (1911) introduced the concept of possible mode of origin of tectonics EQ and is known as Elastic Rebound Theory. according to this theory materials of the earth being elastic and can withstand a certain amount of stress without deforming permanently, but if the stress is continued for long time or if the magnitude is increased, the rocks will first take permanent deformation . A fault is a fracture in the materials of the earth along which there has been displacement. when the rupture occurs, rock on either side of the fault tends to return to their original shape because of their elasticity and elastic rebound occurs. This rebound sets up seismic waves, thus the energy storied in the system through decade is released instantaneously causing underground dislocation of rock and setting up vibration.

ISO-Seismic Line

- Definition. An isoseismal (line) is a contour or line on a map connecting points of equal intensity relating to a specific earthquake and confining the area within which the intensity is the same
- An Iso-seismal (line) is a line on a map bounding points of equal intensity for a particular earth-quake.
- Whenever an earthquake takes place, the intensity which is maximum at the epi-centre, decreases outwards
- The decrease in the earthquake is inversely proportional to the square of the distance from the center of disturbance-
- In an earthquake hit area, places of same intensity can be marked.
- **A line joining points of same intensity is called Iso-seismal line.**
- The area enclosed by the Iso-seismal line is **circular** if the forms of the earthquake is a point and **elliptical** if it is an elongate zone or line.

- In seismology, an isoseismal map is used to show lines of equally felt seismic intensity, generally measured on the Modified Mercalli scale.
- Such maps help to identify earthquake epicenters, particularly where no instrumental records exist, such as for historical earthquakes.
- They also contain important information on ground conditions at particular locations, the underlying [geology](#), radiation pattern of the [seismic waves](#), and the response of different types of buildings. They form an important part of the macroseismic approach, i.e. that part of seismology dealing with noninstrumental data. The shape and size of the isoseismal regions can be used to help determine the [magnitude](#), [focal](#) depth, and [focal mechanism](#) of an earthquake

Seismic Zonation Map

- Seismic zonation is a process of estimation of the seismic hazard in terms of parameters of ground motion for a certain area.
- Assessment results in seismic zonation map compilation, which reflects territorial distribution of the seismic hazard

EARTHQUAKE

An earthquake (or quakes) is shaking of the surface of earth, caused by sudden movement in the Earth's crust. They can be extremely violent. they are the result of a sudden release of energy in the Earth's crust. This creates seismic waves, which are waves of energy that travel through the Earth. The study of earthquakes is called seismology.

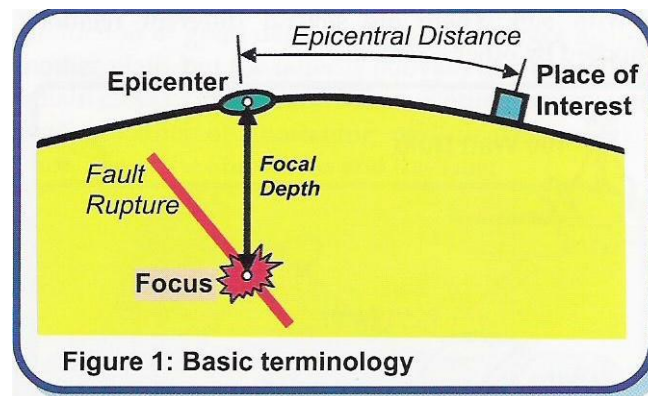


Fig: Basic Terminologies in an Earthquake

Focus: The focus is also called the hypocenter of an earthquake. The vibrating waves travel away from the focus of the earthquake in all directions.

Epicentre: Directly above the focus on the Earth's surface is the earthquake epicenter. Earthquake waves start at the focus and travel outward in all directions. Earthquake waves do not originate at the epicentre.

Focal depth : depth below the Earth's surface of the hypocentre of an earthquake.

Epicentral Distance : The distance between epicentre and point of interest.

Causes of an Earthquake

causes of earthquake can be classified into 2 categories,

1. Natural Earthquake
2. Man made Earthquake

1. **Natural Earthquake** :- The occurrence of natural earthquakes is a complex process, they are caused in many ways and are classified accordingly

a. **collapse EQ** :- EQ caused by gravitational energy due to land slips and slides, in mountain and valley slopes, steep and subsidence and collapse of roof of ground caves.

b. **Volcanic EQ:** - When a volcano become active with gas explosions, fissuring and up or collapse of the volcanic tremors soon take the form of rapid seismic waves. Quakes usually are of shallow origin and restricted to small areas but dangerous for the cities in the vicinity of volcanoes.

c. **Tectonic EQ:** Earthquakes are caused by tectonic movements in the Earth's crust.

The main cause is that when tectonic plates , one rides over the other, causing orogeny collide (mountain building)

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Continental Drift Theory:- Continental Drift was a revolutionary scientific theory developed in the years 1908-1912 by Alfred Wegener, a German meteorologist, climatologist, and geophysicist, that put forth the hypothesis that the continents had all originally been a part of one enormous landmass or supercontinent about 240 million years ago before breaking apart and drifting to their current locations. Based

on the work of previous scientists who had theorized about horizontal movement of the continents over the earth's surface during different periods of geologic time, and based on his own observations drawing from different fields of science, Wegener postulated that about 200 million years ago this supercontinent that he called "Pangaea," (which means "all lands" in Greek) began to break up.

Over millions of years the pieces separated, first into two smaller supercontinents during the Jurassic period, called Laurasia and Gondwanaland, and then by the end of the Cretaceous period, into the continents we know today.

Effects of an EQ

1. Direct effect
2. Indirect effect

1. Direct effect- Direct effect causes damages directly, including ground motion and faulting.

- i) Seismic waves, especially surface waves result in ground motion, such motion can damage and sometimes completely destroy buildings
- ii) EQ vibration may cause landslides and mud slides in the region consisting of hills and steep slopes which can damage building and lead to loss of life
- iii) Soil vibration can either shake a building off its foundation or cause its foundation disintegration
- iv) In areas with very wet ground infilled land, near the coast or in location that have high water table, ground shaking may lead to a problem of liquefaction.
- v) Strong surface waves make the ground heavy and damage the structure.

2. Indirect Effect :- indirect effect cause damages indirectly as a result of the EQ

- i) Following violent movement in the sea floor causes series of waves with extremely long periods which are called Tsunamis.
- ii) Seiches, similar to small Tsunamis occur as a result of the sloshing of enclosed water in reservoirs, lake and harbour shaken by EQ.
- iii) EQ can damage or rupture dams causing floods, resulting in damage of structure and considerable loss of life.
- iv) EQ can cause fire by damaging gas lines and snapping electric wires.

Seismic Waves

Seismic waves are the waves of energy caused by the sudden breaking of rock within the earth or an explosion. They are the energy that travels through the earth and is recorded on seismographs.

Types of Seismic Waves

1. Body Waves
2. Surface Waves

1. Body Waves:- Travelling through the interior of the earth, body waves arrive before

the surface waves emitted by an earthquake. These waves are of a higher frequency than surface waves

- a) **P wave or primary wave**:-The first kind of body wave is the P wave or primary wave. This is the fastest kind of seismic wave and consequently, the first to 'arrive' at a seismic station. The P wave can move through solid rock and fluids, like water or the liquid layers of the earth. It pushes and pulls the rock it moves through just like sound waves push and pull the air. Sometimes animals can hear the P waves of an earthquake. P waves are also known as **compressional waves**, because of the pushing and pulling they do. Subjected to a P wave, particles move in the same direction that the wave is moving in, which is the direction that the energy is traveling in, and is sometimes called the 'direction of wave propagation'. Velocity of this wave is 4.8 km/s.
- b) **S wave or secondary wave**:-The second type of body wave is the S wave or secondary wave, which is the second wave you feel in an earthquake. An S wave is slower than a P wave and can only move through solid rock, not through any liquid medium. S waves move rock particles up and down, or side-to-side--perpendicular to the direction that the wave is travelling in (the direction of wave propagation). Velocity of this waves is 3 km/s
2. **Surface Waves**: Travelling only through the crust, surface waves are of a lower frequency than body waves though they arrive after body waves, it is surface waves that are almost entirely responsible for the damage and destruction associated with earthquakes. This damage and the strength of the surface waves are reduced in deeper earthquakes.
- a) **Love wave**; - The first kind of surface wave is called a Love wave, named after A.E.H. Love. It's the fastest surface wave and moves the ground from side-to-side. Confined to the surface of the crust, Love waves produce entirely horizontal motion.
- b) **Rayleigh wave**: - The other kind of surface wave is the Rayleigh wave, named for, Lord Rayleigh. A Rayleigh wave rolls along the ground just like a wave rolls across a lake or an ocean. Because it rolls, it moves the ground up and down and side-to-side in the same direction that the wave is moving. Most of the shaking felt from an earthquake is due to the Rayleigh wave, which can be much larger than the other waves.

Magnitude of an EQ: - Magnitude of an earthquake is a value that tells a reader the amount of seismic energy released by it. It is a single value and is not dependent upon distance from the epicenter of the earthquake. It is calculated by measuring the amplitude of the seismic waves (through a seismometer). The scale which is used to measure magnitude of an earthquake is called Richter magnitude scale. This is a

logarithmic scale and assigns values from 1-10 to the magnitude of any earthquake. So it is obvious that the devastation power of an earthquake is directly proportional to the value assigned on the Richter scale. As it is logarithmic, an earthquake of value 5.0 has shaking amplitude ten times greater than an earthquake measuring 4.0 on the scale. Richter magnitude scale has today given way to moment magnitude scale that yields similar but more accurate results than Richter scale.

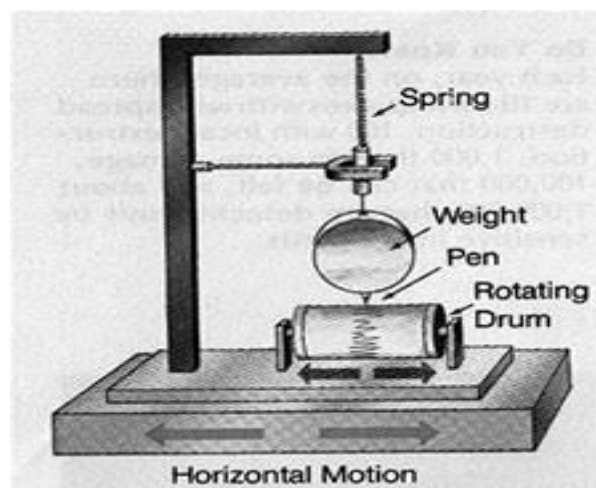
Intensity of an EQ: - Intensity is a qualitative measure of the actual shaking at a location during an earthquake, and is assigned in Roman Capital Numerals. There are many intensity scales. Two commonly used ones are the Modified Mercalli Intensity (MMI) Scale and the MSK Scale. Both scales are quite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

Table: Modified Mercalli Scale Intensities

Intensity	Shaking	Description/ Damage
I	Not felt	Not felt except by a very few under especially favourable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very Strong	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.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.

IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	Extreme	Few, if any, structures remain standing, bridges destroyed, underground pipelines completely out of service, earth slumps and slips in soft ground, rails bend greatly.
XII	Extreme	Total damage, waves seen on ground, line of sight & level distorted, Objects thrown upward in the air

Seismograph



A **seismograph** is a device for measuring the movement of the earth, and consists of a ground- motion detection sensor, called a seismometer

A simple seismometer that is sensitive to up-down motions of the earth, the spring and weight are suspended from a frame that moves along with the earth's surface. As the earth moves, the relative motion between the weight and the earth provides a measure of the vertical ground motion. If a recording system is installed, such as a rotating drum attached to the frame, and a pen attached to the mass, this relative motion between the weight and earth can be recorded to produce a history of ground motion, called a seismogram. Any movement of the ground moves the frame. The mass tends not to move because of its inertia, and by measuring the movement between the frame and the mass, the motion of the ground can be determined.

Seismic Zones of India

The varying geology at different locations in the country implies that the likelihood of damaging earthquakes taking place at different locations is different. Thus, a seismic zone map is required to identify these regions. Based on the levels of intensities

sustained during damaging past earthquakes, the 1970 version of the zone map subdivided India into five

zones - I, II, III, IV and V. The maximum Modified Mercalli (MM) intensity of seismic shaking expected in these zones were **V or less, VI, VII, VIII, and IX and higher**, respectively. Parts of Himalayan boundary in the north and northeast, and the Kachchh area in the west were classified as zone V.

The seismic zone maps are revised from time to time as more understanding is gained on the geology, the seismo-tectonics and the seismic activity in the country. The Indian Standards provided the first seismic zone map in 1962, which was later revised in 1967 and again in 1970. The map has been revised again in 2002, and it now has only four seismic zones - II, III, IV and V. The areas falling in seismic zone I in the 1970 version of the map are merged with those of seismic zone II. Also, the seismic zone map in the peninsular region has been modified. Madras now comes in seismic zone III as against in zone II in the 1970 version of the map. This 2002 seismic zone map is not the final word on the seismic hazard of the country, and hence there can be no sense of complacency in this regard.

Tsunami

in Japanese "Tsu" means Harbour and "nami" means wave, also known as a seismic sea wave, is a series of waves in a water body caused by the displacement of a large volume of water, generally in an ocean.

A tsunami is a series of fast moving waves in the ocean caused by volcanic eruptions or powerful earthquakes. A tsunami has a very long wavelength; it can be hundreds of kilometers long. Usually, a tsunami starts suddenly. The waves travel at a great speed across an ocean with little energy loss. They can remove sand from beaches, destroy trees, toss and drag vehicles, houses and even destroy whole towns. Tsunamis can even be caused by meteorite strikes, though it is very rare. Tsunamis are often called tidal waves because they usually rise and fall more slowly than ordinary ocean surface waves.

A tsunami may travel hundreds of kilometers across the deep ocean, reaching speeds of about 725 to 800 km/hr. height of waves may vary from few centimeter to meters.

Tsunamis can cause very destructive effects, These effects are :

1. The effects of a tsunami on a coastline can range from unnoticeable to devastating
2. Tsunami flooding cause damage for several weeks.
3. The effects of a tsunami is destruction and damage, death, injury, millions of dollars in financial loss, and long lasting psychological problems for the inhabitants of the region.
4. A tsunami's tidal waves batter the shoreline and can destroy anything in their path. This includes boats, buildings, houses, hotels, cars, trees, telephone lines - and just about anything else in their way.
5. The buildings infrastructure in these poorer nations are not well built and cannot withstand the impact of the tsunami.
6. Flooding and contamination of drinking water can cause disease to spread in the tsunami hit areas
7. Tsunami causes loss of life's and property.

Reservoir Induced Seismicity

The load on the rocks below the valley surface is increased due to weight of the water in the reservoir. Pressure of the water within the rock area is also increased, which lubricates the existing faults making it easier for them to slip. For deep reservoirs, this can lead to the rupture of faults in the rock and triggering EQ as large as magnitude 6. This EQ are related to filling and emptying of the reservoir and hence called Reservoir Induced Seismicity.

Konya dam is 103 m high gravity dam made of concrete, as the reservoir was being filled no of EQ were felt in the area at first they were small, then they increased in size and in December 10th 1967, an EQ of magnitude 6.5 occurred. This EQ

severely damaged the dam with cracks appearing on its upstream and downstream faces and also 200 peoples were died.

Land Slides

A landslide, sometimes known as landslip, slope failure or slump, is an uncontrollable downhill flow of rock, earth, debris or the combination of the three. Landslides stem from the failure of materials making up the hill slopes and are beefed up by the force of gravity. When the ground becomes saturated, it can become unstable, losing its equilibrium in the long run. That's when a landslide breaks loose. When people are living down these hills or mountains, it's usually just a matter of time before disaster happens.

Parts of Typical Slide

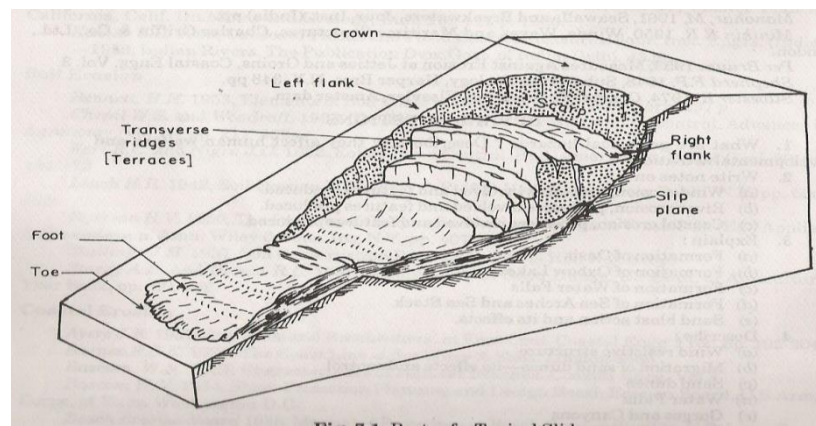


Fig: A Typical Slide Section

Crown:- The upper portion still in place from which solid rock and soil materials are torn away from the rest of the slope.

Scarp:-The steep wall of the undisturbed material below crown around the periphery of the slide material

Head: - The upper part of the slide material

Slip plane:-The shear surface, the surface of movement downhill of the slide material

Flanks: - Sides of a slide, left flank and Right Flank

Transverse ridges: - Terrace or step like pressure or compression ridges

TOE: - The lower portion in which the rock or soil material is heaped up

Length: - Horizontal distance from crown to toe.

Width: - Horizontal distance from flank to flank

Height: - Vertical distance, crown to toe

Depth: - Thickness of the slide mass between crown and foot.

Foot : the line of intersection of the lower part of the slip plane and the original ground surface.

Causes of Land Slides

a) Natural causes

1. Climate: Long-term climatic changes can significantly impact soil stability. A general reduction in precipitation leads to lowering of water table and reduction in

overall weight of soil mass, reduced solution of materials and less powerful freeze-thaw activity. A significant upsurge in precipitation or ground saturation would dramatically increase the level of ground water. When sloped areas are completely saturated with water, landslides can occur. If there is absence of mechanical root support, the soils start to run off

- 2. Earthquakes:** Seismic activities have, for a long time, contributed to landslides across the globe. Any moment tectonic plates move, the soil covering them also moves along. When earthquakes strike areas with steep slopes, on numerous occasion, the soil slips leading to landslides. In addition, ashen debris flows instigated by earthquakes could also cause mass soil movement.
- 3. Weathering:** Weathering is the natural procedure of rock deterioration that leads to weak, landslide-susceptive materials. Weathering is brought about by the chemical action of water, air, plants and bacteria. When the rocks are weak enough, they slip away causing landslides.
- 4. Erosion:** Erosion caused by sporadic running water such as streams, rivers, wind, currents, ice and waves wipes out latent and lateral slope support enabling landslides to occur easily.
- 5. Volcanoes:** Volcanic eruptions can trigger landslides. If an eruption occurs in a wet condition, the soil will start to move downhill instigating a landslide. Strato volcano is a typical example of volcano responsible for most landslides across the globe.
- 6. Forest fires:** Forest fires instigate soil erosion and bring about floods, which might lead to landslides.

Human Cause

- 1. Mining :** Mining activities that utilize blasting techniques contribute mightily to landslides. Vibrations emanating from the blasts can weaken soils in other areas susceptible to landslides. The weakening of soil means a landslide can occur anytime.
- 2. Clear cutting :** Clear cutting is a technique of timber harvesting that eliminates all old trees from the area. This technique is dangerous since it decimates the existing mechanical root structure of the area.

Types of Land Slides

- 1. Falls :** Falls are sudden movements of loads of soil, debris, and rock that break away from slopes and cliffs. Falls landslides occur as a result of mechanical weathering, earthquakes, and force of gravity.
- 2. Slides :** This is a kind of mass movement whereby the sliding material breakaways from underlying stable material. The kinds of slides experienced during this type of landslide include rotational and transitional. Rotational slides are sometimes known

as slumps since they move with rotation.

Transitional slides consist of a planer or 2 dimensional surface of rupture. They involve landslide mass movement following a roughly planar surface with reduced rotation or backward slanting. Slides occur when the toe of the slope is undercut. They move moderately, and the consistency of material is maintained.

3. **Topples:** Topples occur when the topple fails. Topple failure encompasses the forward spinning and movement of huge masses of rock, debris, and earth from a slope. This type of slope failure takes place around an axis near or at the bottom of the block of rock. A topple landslide mostly lead to formation of a debris cone below the slope. This pile of debris is known as a Talus cone.
4. **Spreads :** They are commonly known as lateral spreads and takes place on gentle terrains via lateral extension followed by tensile fractures.
5. **Flows :** This type of landslide is categorized into five; earth flows, debris avalanche, debris flow, mudflows, and creep, which include seasonal, continuous and progressive. Flows are further subcategorized depending upon the geological material, for example, earth, debris, and bed rock.

Effects of Land Slide

1. **Lead to Economic Decline:** Landslides have been verified to result in destruction of property. If the landslide is significant, it could drain the economy of the region or country. After a landslide, the area affected normally undergoes rehabilitation.
2. **Decimation of Infrastructure:** The force flow of mud, debris, and rocks as a result of a landslide can cause serious damage to property. Infrastructure such as roads, railways, leisure destinations, buildings and communication systems can be decimated by a single landslide
3. **Loss of Life:** Communities living at the foot of hills and mountains are at a greater risk of death by landslides. A substantial landslide carries along huge rocks, heavy debris and heavy soil with it. This kind of landslide has the capacity to kills lots of people on impact.
4. **Affects Beauty of Landscapes:** The erosion left behind by landslides leaves behind rugged landscapes that are unsightly. The pile of soil, rock and debris downhill can cover land utilized by the community for agricultural or social purposes.
5. **Impacts River Eco Systems:** The soil, debris, and rock sliding downhill can find way into rivers and block their natural flow. Many river habitats like fish can die due to interference of natural flow of water. Communities depending on the river water for household activities and irrigation will suffer if flow of water is blocked.

Preventative Measures Of Land Slides

Landslide hazards are a function of location, type of human activity, use, and frequency of landslide events. The effects of landslides on people and structures can be reduced by total avoidance of landslide hazard areas or by restricting, prohibiting, or imposing conditions on hazard-zone activity. Local governments can reduce landslide effects through land-use policies and regulations. Individuals can reduce their exposure to hazards by educating themselves on the past hazard history of a site and by making inquiries to planning and engineering departments of local governments. They can also obtain the professional services of an engineering geologist, a geotechnical engineer, or a civil engineer, who can properly evaluate the hazard potential of a site, built or unbuilt.

The hazard from landslides can be reduced by avoiding construction on steep slopes and existing landslides, or by stabilizing the slopes. Stability increases when ground water is prevented from rising in the landslide mass by (1) covering the landslide with an impermeable membrane, (2) directing surface water away from the landslide, (3) draining ground water away from the landslide, and (4) minimizing surface irrigation. Slope stability is also increased when a retaining structure and/or the weight of a soil/rock berm are placed at the toe of the landslide or when mass is removed from the top of the slope.

VOLCANIC ERUPTION

- Cyclones are centred on areas of low atmospheric pressure, usually over warm ocean waters near the equator.
- The warm moist air over the ocean rises from the surface in the upward direction, resulting in the formation of the low-pressure zone over the surface.
- Air from the surrounding region, with higher pressure, pushes into the low-pressure area.
- The cool air becomes warm and moist and rises again, thus the cycle continues.
- As the warm air rises, the moisture in the air cools thus leading to the formation of cloud.
- The whole system grows gradually and becomes fast with time.
- As a result of this, an eye is created in the centre, as shown in the figure, which is the low-pressure centre into which the high-pressure air flows from above, thus creating a cyclone.

CYCLONE

- A volcano is an opening or rupture in the earth's surface that allows magma (hot liquid and semi-liquid rock), volcanic ash and gases to escape.
- They are generally found where tectonic plates come together or separate but they can also occur in the middle of plates due to volcanic hotspots.

- A volcanic eruption is when lava and gas are released from a volcano—sometimes explosively.

QUESTION BANK

1. Explain Earth Internal Dynamics
2. Explain Landslide and its effects
3. Write a short notes on plate tectonics
4. Explain Cyclone
5. Briefly explain location of epi-centre