N.B.K.R. INSTITUTE OF SCIENCE & TECHNOLOGY:: VIDYANAGAR

(AUTONOMOUS)

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Lecture on: Unit-V –GEOLOGICAL HAZARDS

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UNIT V –GEOLOGICAL HAZARDS

Rock instability and slope movement

- ✓ Concept of sliding blocks
- ✓ Different controlling factors
- ✓ Instability in vertical rock structures and
- ✓ Measures to prevent collapse
- ✓ Types of landslide and their prevention.

Ground water:

- ✓ Factors controlling water bearing capacity of rock
- ✓ Pervious and impervious rocks and
- ✓ Lowering of water table.

Earthquake: Magnitude and intensity of an earthquake.

Seismic zones in India and their importance in civil engineering.

Concept of sliding rock blocks:

The term sliding refers to a variety of mass wasting events ,that include slumps, slides, falls, and flows.

The two major types of slides are rotational slides and translational slides.

Rockslides are a type of translational event since the rock mass moves along a roughly planar surface with little rotation or backward tilting.

Rock slides are the most dangerous because they incorporate a sudden, incredibly fast-paced release of bedrock along a uniform plane of weakness.

These uniform weaknesses are key to identifying rock slides because unlike slumps, flows, or falls, the failed material moves in a fairly uniform direction over a layer of solid, pre-existing rock.

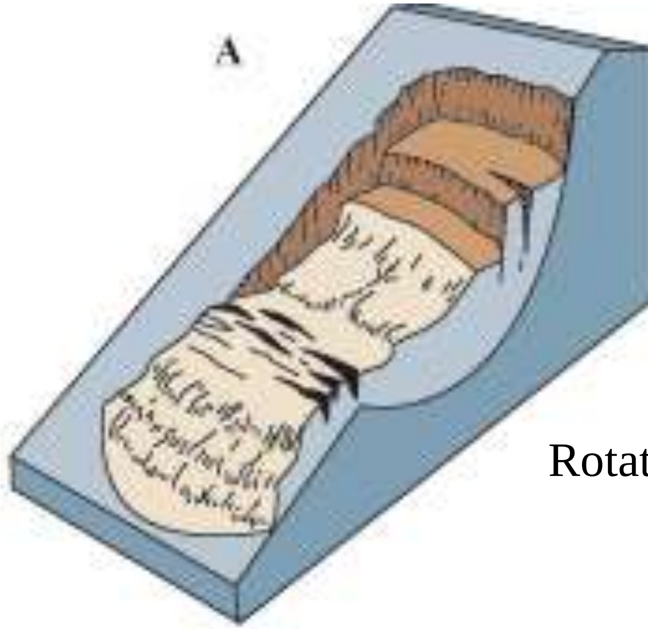
Rock may break down while falling during rockslides.

The sudden, rapid release of material found in rock slides events potential to have devastating effects on human life and infrastructure.

Rock slides are very common in the over steepened canyons.

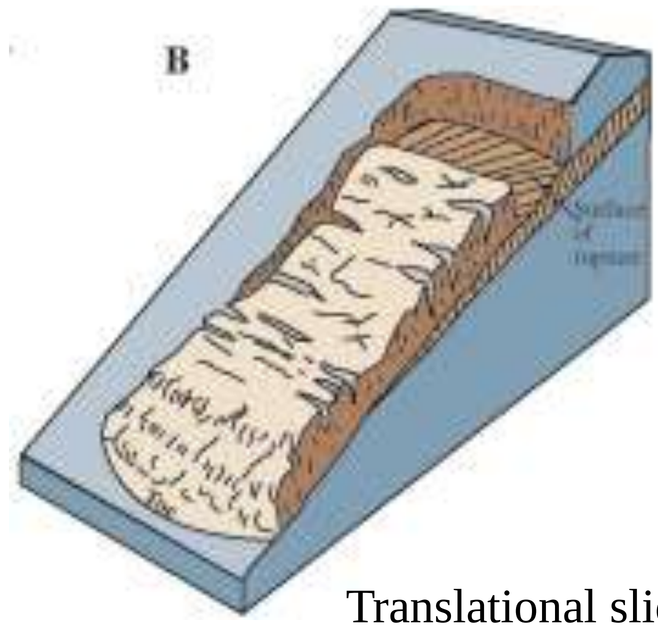
Types of Slides

- Rotational Slide
- Translational slide
- Block slide
- Rock fall
- Topple
- Creeping



Rotational Slide

Block slide



Translational slide

Rock fall

Topple

Causes of mass wasting and sliding:

- ✓ The gravitational force on the rock.
- ✓ An earthquake can cause large rockslides to happen.
- ✓ Erosion influences.
- ✓ A majority of slides occur due to a combination of gravitational pressure and erosion influences.
- ✓ Weight is added to the rock by filling of water in pores, which tends to push apart individual grains, decreasing the resistance of the material to movement.
- ✓ Steepness of failing slope is determined the speed and potential devastation of rock slide.

Factors controlling rock sliding

- ✓Slope
- ✓Water saturation(moisture content)
- ✓Pore pressure
- ✓Shear stress
- ✓Strength of rock
- ✓Joints volume
- ✓Faults

Land slides

A landslide is defined as the movement of a mass of rock, debris, or earth down a slope.

Landslides are a type of down-slope movement of soil and rock under the direct influence of gravity.

Causes of landslide

I. Geological causes

a. Weak or sensitive materials
b. Weathered materials
c. Sheared, jointed, or fissured materials
d. Adversely oriented discontinuity (bedding, schistosity, fault, unconformity, contact, and so forth)
e. Contrast in permeability and/or stiffness of materials

II. Morphological causes

a. Tectonic or volcanic uplift
b. Glacial rebound
c. Fluvial, wave, or glacial erosion of slope toe or lateral margins
d. Subterranean erosion (solution, piping)
e. Deposition loading slope or its crest
f. Vegetation removal (by fire, drought)
g. Thawing
h. Freeze-and-thaw weathering
i. Shrink-and-swell weathering

3. **Human causes**

a. Excavation of slope or its toe
b. Loading of slope or its crest
c. Drawdown (of reservoirs)
d. Deforestation
e. Irrigation
f. Mining
g. Artificial vibration
h. Water leakage from utilities

Other causes

Rainfall, snowmelt, changes in water level, stream erosion, changes in ground water, earthquakes, volcanic activity, disturbance by human activities, or any combination of these factors.

Types of landslides

The landslides occur in various types as

- Falls
- Topples
- Slides
- Spreads and
- flows.

These are further subdivided by the type of geologic material (bedrock, debris, or earth).
Debris flows (commonly referred to as mudflows or mudslides) and rock falls are examples of common landslide types.

FALLS:

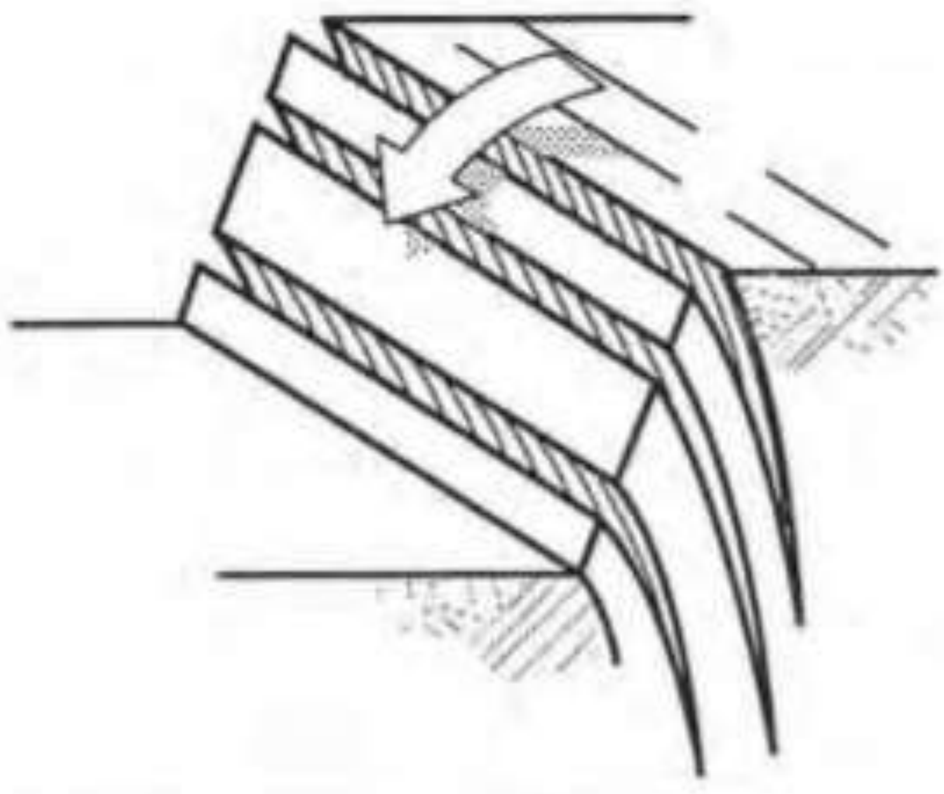
✓Falls are abrupt movements of masses of geologic materials, such as rocks and boulders, that become detached from steep slopes or cliffs.

✓Separation occurs along discontinuities such as fractures, joints, and bedding planes.

✓Movement occurs by free-fall, bouncing, and rolling. Falls are strongly influenced by gravity, mechanical weathering, and the presence of interstitial water.

TOPPLES

Toppling failures are distinguished by the forward rotation of a unit or units about some pivotal point, below or low in the unit, under the actions of gravity and forces exerted by adjacent units or by fluids in cracks.



FLOWS:

Form of rapid mass movement in which a combination of loose soil, rock, organic matter, air, and water mobilize as a slurry that flows down slope is defined as flows.

There are five basic categories of flows that differ from one another in fundamental ways.

a. Debris flow
b. Debris avalanche
c. Earth flow
d. Mudflow
e. Creep

Prevention of landslides

Vulnerability to landslide hazards is a function of location, type of human activity, use, and frequency of landslide events.

The effects of landslides on people and structures can be lessened 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.

Various Prevention methods of landslides

I. Avoidance methods

II. Excavation

III. Drainage

IV. Retaining structures

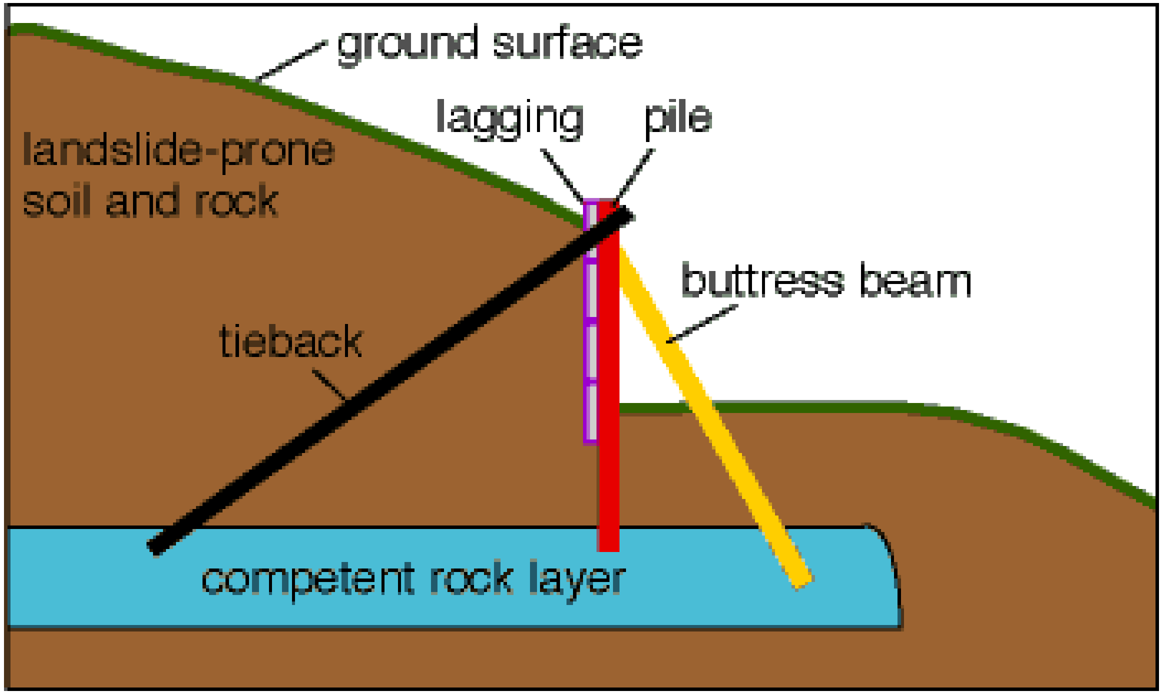
V. Miscellaneous methods

Effect on **Stability of landslide**	**Method of treatment**
Not effected	I. Avoidance methods A.Relocation B.Bridging
Reduces shearing stresses	II Excavation A. Removal of head B. Flattening of slopes C. Benching of slopes D. Removal of all unstable material

Effect on Stability of landslide	Method of treatment
Reduces shearing stresses and increases shearing resistance.	III. Drainage A. Surface 1.Surface ditches 2.Slope treatment 3.Regrading surface 4.Sealing cracks 5.Sealing joint planes and fissures B. Subdrainage 1.Horizontal drains 2.Drainage trenches 3.Tunnels 4.Vertical drain wells 5.Continuous siphon

Effect on Stability of landslide	**Method of treatment**
Increasing shearing resistance	IV. Retaining structures A. Buttresses at foot 1.Rock fill 2.Earth fill B. Cribs or retaining walls C. Piling 1.Fixed at slip surface 2.Not fixed at slip surface D. Dowels in rocks E. Tie-rodding slopes

Effect on Stability of landslide	**Method of treatment**
Primarily increases shearing resistance	V. Miscellaneous methods A. Hardening of slide mass 1.Cementation or chemical treatment a. At foot b. Entire slide mass B. Blasting C. Partial removal of slide at toe


ground surface
lagging
pile
landslide-prone
soil and rock
buttress beam
tieback
competent rock layer

GROUNDWATER

The water present beneath the earth's surface in rock and soil pore spaces and in the discontinuities like fractures, joints and fault planes etc. of rock formations is defined as groundwater.

Aquifer

If the unit of rock or unconsolidated deposits yields usable quantity of water is called an aquifer.

Water table

The depth at which soil or rock pore spaces completely saturated with water is termed as water table.

Groundwater is recharged by rainfall or precipitation and it is discharged naturally as seep,springs,oases and wetlands.

Groundwater is also often pumped for irrigation, municipal and industrial etc. use.

The study of groundwater movement and distribution is called hydrogeology or groundwater hydrology.

Zones of Groundwater

Unsaturated zone or Vadose zone

The zone of from the surface of the earth to groundwater table with unsaturation of water is called as vadose zone or unsaturated zone.

Capillary zone

The zone of Groundwater formed by seeps or by capillary action from the groundwater . Normally capillary zone is fond above the groundwater table.

Saturated zone

The part of the rock or soil below the groundwater table saturated with water is called as saturation zone.

Factors controlling water bearing capacity of rock

Porosity

The ration of voids volume to the total volume of rock is defined as porosity. It an be calculated as in percentage.

n=Vv/Vt

n=Vv/Vt*100

Type of Rocks	Porosity%
Granite	0.1 – 0.5
Basalt	0.1 – 1
Sedimentary Rocks	
Sandstone	5 – 25
Limestone	5-20
Metamorphic Rocks	
Marble	0.5 - 2
Quartzite	0.1 – 0.5

Porosity of various rocks.

Permeability

If rocks have good connections between pores or fractures and water can move freely through them, then that rock shows good permeable nature.

If the pores or fractures of rock are not connected, the rock material cannot allow the movement of water and it is said to be impermeable.

For water to move through underground rock, pores or fractures in the rock must be connected.

Permeability measured in Darcy(d) or millidarcy (md)

Pore geometry

Permeability is controlled in sandstone by

- ✓Grain size,
- ✓Grain orientation,
- ✓Packing arrangement,
- ✓Cementation,
- ✓Clay content,
- ✓Bedding,
- ✓Grain size distribution and
- ✓Sorting.

In carbonates, permeability controlled by

- ✓degree of mineral alteration
- ✓porosity development and
- ✓fractures.

Bedding

Permeability perpendicular to bedding planes (vertical permeability) is typically lower than horizontal permeability (parallel to the bedding planes).

Confining pressure

Permeability decreases with increasing confining pressure. Unconsolidated or poorly lithified rock undergoes much greater permeability reduction under confining pressure than well-consolidated rock.

Lowering of water table

Drawdown of water from the well, which causes rapid decrease of water level in certain well is defined as lowering of water table.

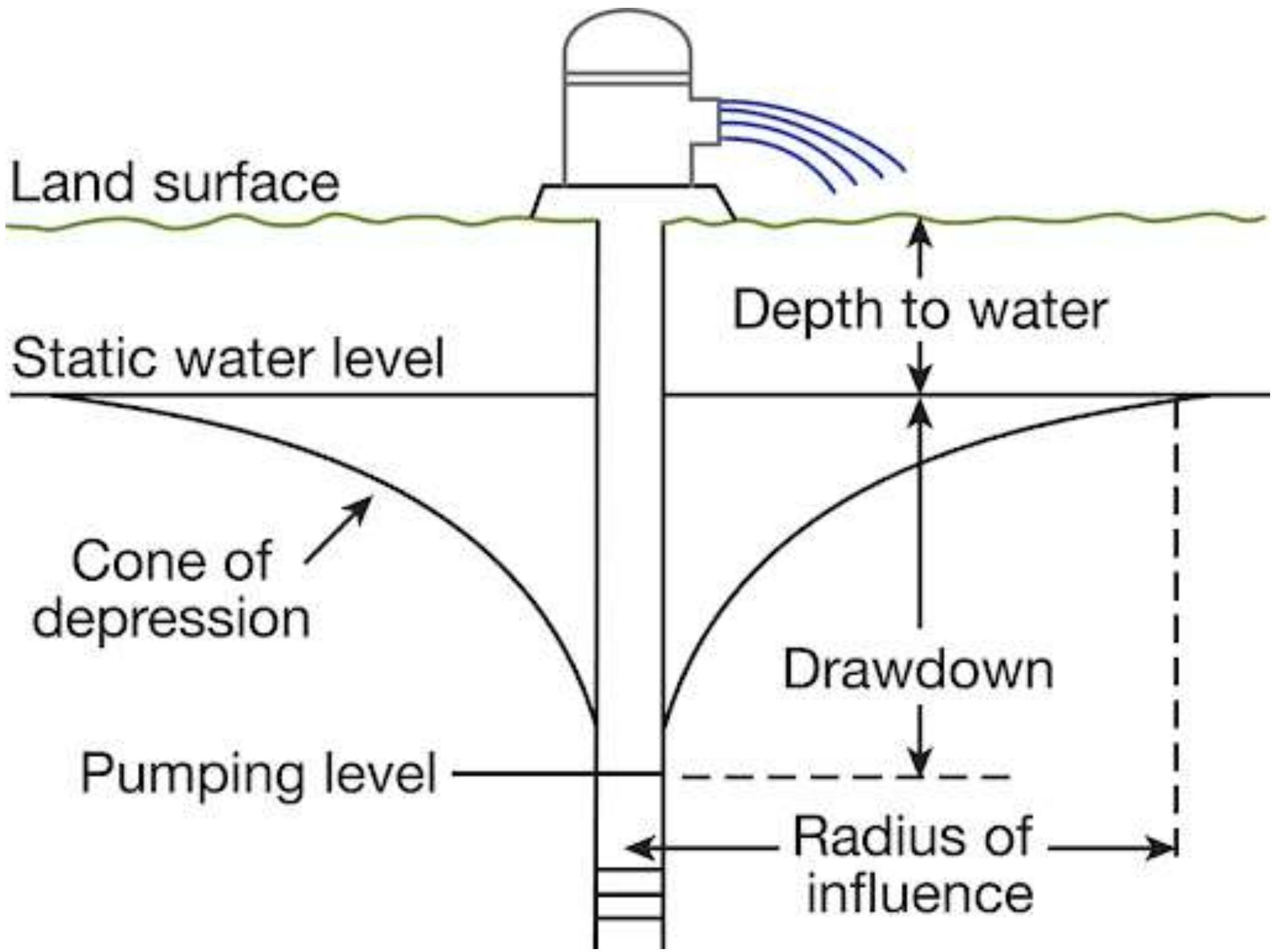
When the discharge is high than recharge in the well leads to water level drop, such water level decrease phenomenon is called lowering of water table.

Normally lowering of water table expressed in cone of depression.

Causes of lowering water table

- ✓Over pumping
- ✓Reduction of water in streams and lakes
- ✓Deforestation
- ✓Low or no required rainfall to recharge

Cone of depression



As pumping continues, the rate of local drawdown decreases and eventually stabilizes as the withdrawal is compensated for by inflow of groundwater from the surrounding area.

The pattern of water table distortion is called the cone of depression, and the area over which the depression can be detected is called the zone of influence of the well.

This zone of influence can easily have dimensions of a mile or more, depending on the characteristics of the aquifer.

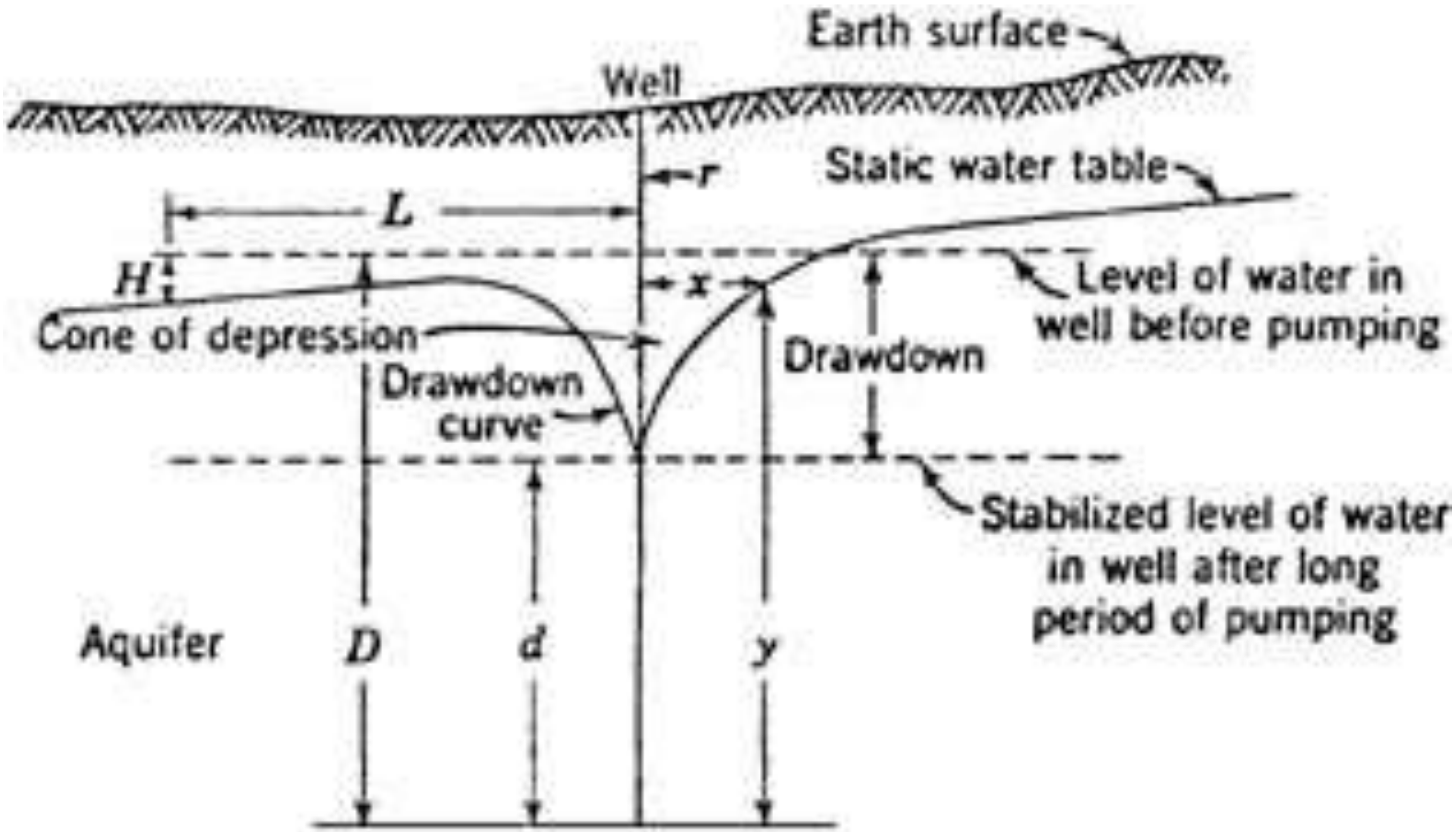
Effects of lowering water table

- ✓Deepening of well for water
- ✓Drying of well
- ✓The yield rate of water from the well decline
- ✓Ground settlement
- ✓Reduced flow to springs
- ✓Surface subsidence or land subsidence

Control of lowering of water table

- Avoiding of unnecessary pumping from well.
- Aforestation
- Water table management system
  - Controlled drainage
  - Subirrigation
  - Water table control structures

(i) a resource worth protecting and managing or (ii) a problem requiring a solution during below-ground works.



Earthquake
Shaking of the surface of the by sudden release of energy in the lithosphere as seismic waves.
The focus
Point inside Earth's crust where an earthquake originates.

Epicenter
The point on the Earth's surface directly above the focus is the epicenter.

When energy is released at the focus, seismic waves travel outward from that point in all directions.

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.

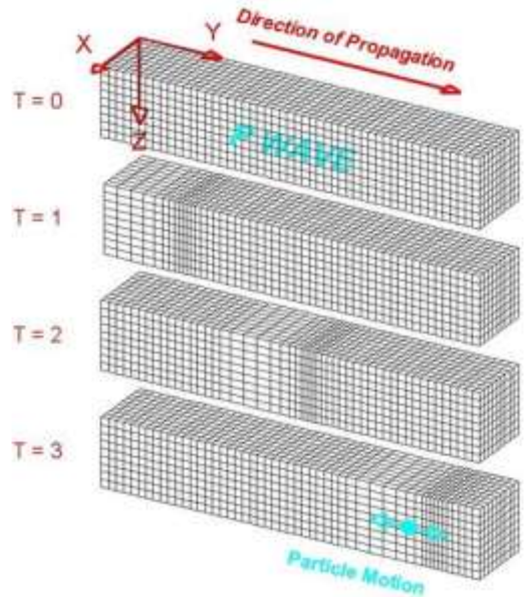
Types of Seismic Waves

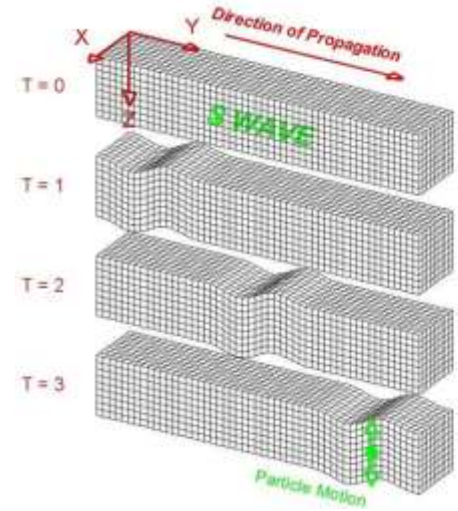
Body waves

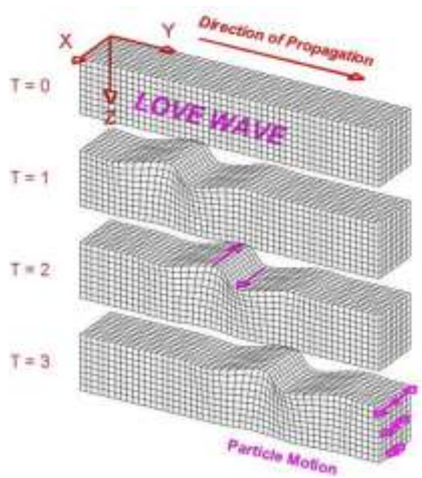
- P waves
- S waves

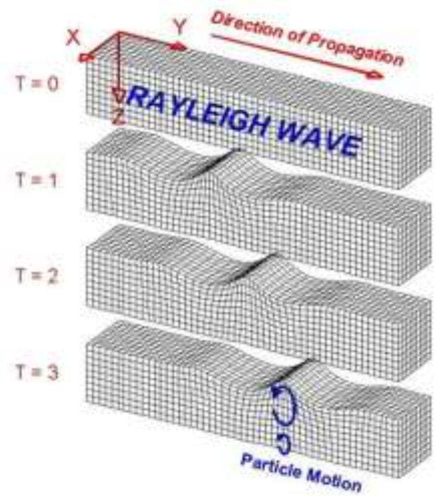
Surface waves

- Love waves
- Reyleigh waves









The Richter Magnitude Scale

The Richter magnitude scale(M), assigns a number to measure the amount of seismic energy released by an earthquake. It is a base-10 logarithmic scale.

Richter magnitudes	Description	Earthquake effects
< 2.0	Micro	Micro earthquakes, not felt.
2.0-2.9	Minor	Generally not felt, but recorded.
3.0-3.9	Minor	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. At most slight damage to well-designed buildings.
6.0-6.9	Strong	Can be destructive in areas up to about 160 kilometers (100 mi) across in populated areas.
7.0-7.9	Major	Can cause serious damage over larger areas.
8.0-8.9	Great	Can cause serious damage in areas several hundred kilometers across.
9.0-9.9	Great	Devastating in areas several thousand miles across.
10.0+	Epic	Never recorded

Earth quake Intensity scale

Measurement of shaking caused by an earthquake at a particular location is known to be earthquake intensity scale.

Different intensities can be measured by Modified Mercalli Scale in the area of epicenter.

So the intensity of an earthquake will vary in the earthquake area.

Category of Intensity	Definition
MM 1: Imperceptible	Sensed only by a very few people.
MM 2: Scarcely felt	Felt only by a few people at rest in houses or on upper floors.
MM 3: Weak	Felt indoors as a light vibration. Hanging objects may swing slightly.
MM 4: Largely observed	▪Moderate vibration or jolt. ▪Light sleepers may be awakened. ▪Walls may creak, and glassware, crockery, doors or windows rattle.

Category Of Intensity	**Definition**
MM 5: Strong	Generally felt outside and by almost everyone indoors. •Most sleepers are awakened and a few people alarmed. •Small objects are shifted or overturned, and pictures knock against the wall. •Some glassware and crockery may break, and loosely secured doors may swing open and shut.
MM 6: Slightly damaging	Felt by all. •People and animals are alarmed, and many run outside. •Walking steadily is difficult. •Furniture and appliances may move on smooth surfaces, and objects fall from walls and shelves. •Glassware and crockery break. •Slight non-structural damage to buildings may occur.
MM 7: Damaging	General alarm. •People experience difficulty standing. •Furniture and appliances are shifted. •Substantial damage to fragile or unsecured objects. • A few weak buildings are damaged.

Category of Intensity	Definition
MM 8: Heavily damaging	Alarm may approach panic. •A few buildings are damaged and some weak buildings are destroyed.
MM 9: Destructive	Some buildings are damaged and many weak buildings are destroyed.
MM 10: Very destructive	Many buildings are damaged and most weak buildings are destroyed.
MM 11: Devastating	Most buildings are damaged and many buildings are destroyed.
MM 12: Completely devastating	All buildings are damaged and most buildings are destroyed.

Seismic zones of India

Geographical statistics of India show that almost 54% of the land is vulnerable to earthquakes.

Based on the past seismic history, Bureau of Indian Standards grouped the India into four seismic zones namely

Zone-II,

Zone-III,

Zone-IV and

Zone-V.

From these four zones,

Zone-V is the highest level seismicity region .

Zone-II is the lowest level seismicity region.

Seismic zoning map of India helps in identifying the lowest, moderate as well as the highest hazardous or earthquake-prone areas in India.

These maps are used before the construction of high rise building to check the level of seismology in that particular area.

In the long run, this helps in saving lives.

Regions that fall under the Earthquake (seismic) Zones in India

Zone-V

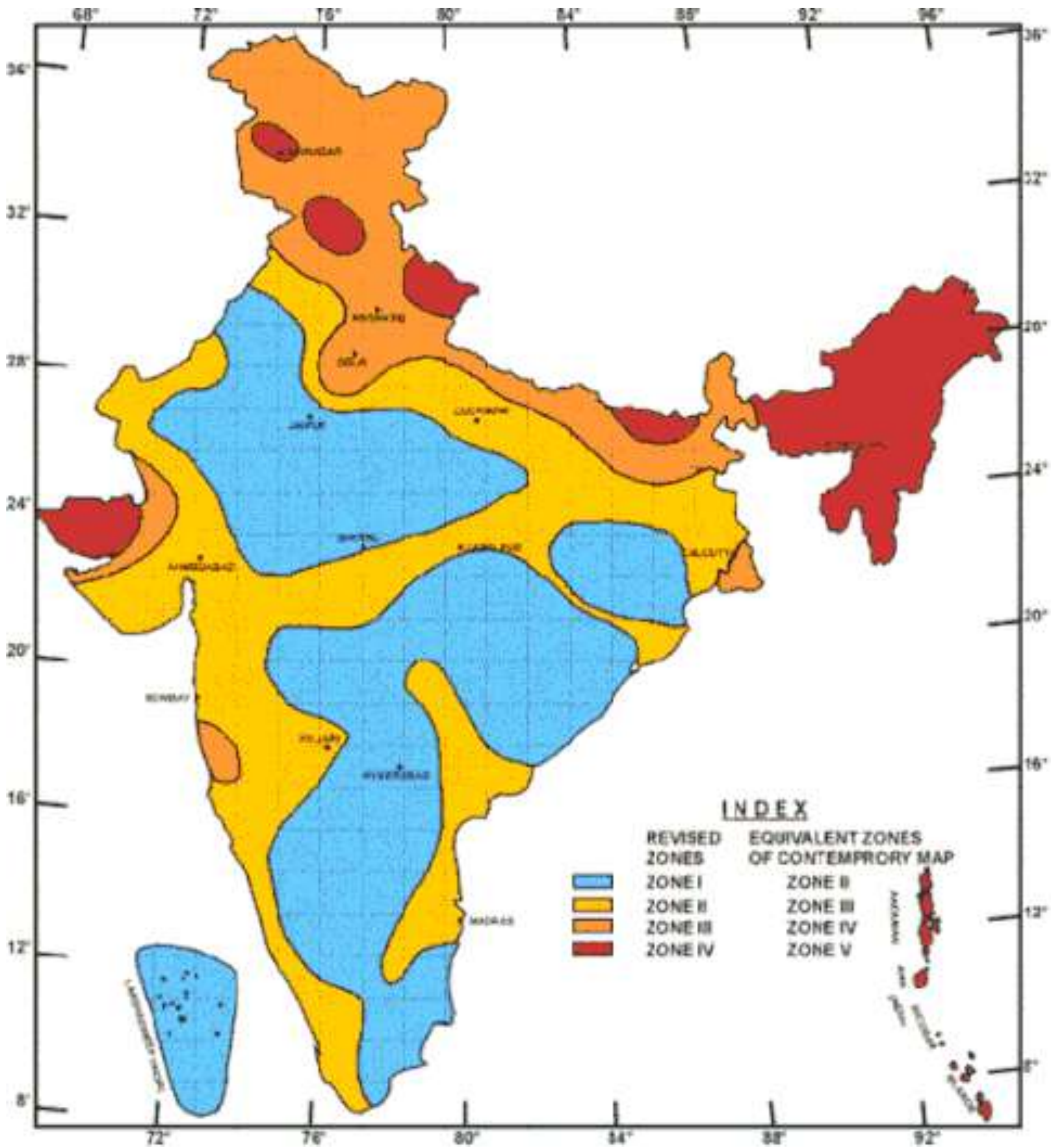
covers entire northeastern India, some parts of Jammu and Kashmir, some parts of Ladakh, Himachal Pradesh, Uttarakhand, Rann of Kutch in Gujarat, some parts of North Bihar and Andaman & Nicobar Islands.

Zone-IV covers remaining parts of Jammu & Kashmir, Ladakh and Himachal Pradesh, Union Territory of Delhi, Sikkim, northern parts of Uttar Pradesh, Bihar and West Bengal, parts of Gujarat and small portions of Maharashtra near the west coast and Rajasthan.

Zone-III comprises of Kerala, Goa, Lakshadweep islands, remaining parts of Uttar Pradesh, Gujarat and West Bengal, parts of Punjab, Rajasthan, Madhya Pradesh, Bihar, Jharkhand, Chhattisgarh, Maharashtra, Odisha, Andhra Pradesh, Tamil Nadu and Karnataka.

Zone-II covers remaining parts of the country.

Seismic Zone
Zone-II (Low-Intensity Zone)
Zone-III (Moderate Intensity Zone)
Zone-IV (Severe Intensity Zone)
Zone-V (Very Severe Intensity Zone)



Earthquake (seismic) Zones in India

Seismic Zone	**Intensity on M.M Scale**
Zone-II (Low-Intensity Zone)	6 (or less)
Zone-III (Moderate Intensity Zone)	7
Zone-IV (Severe Intensity Zone)	8
Zone-V (Very Severe Intensity Zone)	9 (and above)

Date	Event	Time	Magnitude	Max. Intensity	Deaths
16 June 1819	Cutch	11:00	8.3	VIII	1,500
12 June 1897	Assam	17:11	8.7	XII	1,500
8 Feb. 1900	Coimbatore	03:11	6.0	X	Nil
4 Apr. 1905	Kangra	06:20	8.6	X	19,000
15 Jan. 1934	Bihar-Nepal	14:13	8.4	X	11,000
31 May 1935	Quetta	03:03	7.6	X	30,000
15 Aug. 1950	Assam	19:31	8.5	X	1,530
21 Jul. 1956	Anjar	21:02	7.0	IX	115
10 Dec. 1967	Koyna	04:30	6.5	VIII	200
23 Mar. 1970	Bharuch	20:56	5.4	VII	30
21 Aug. 1988	Bihar-Nepal	04:39	6.6	IX	1,004
20 Oct. 1991	Uttarkashi	02:53	6.6	IX	768
30 Sep. 1993	Killari (Latur)	03:53	6.4	IX	7,928
22 May 1997	Jabalpur	04:22	6.0	VIII	38
29 Mar. 1999	Chamoli	12:35	6.6	VIII	63
26 Jan. 2001	Bhuj	08:46	7.7	X	13,805
26 Dec. 2004	Sumatra	06:28	9.3	VII	10,749

Earthquake can cause cracks, settlement and dislocation of plumbing and electrical lines in the structures.

To resist these forces, seismic code (IS 1893:2002) has to be followed to improve the stability and durability of structure so that they may withstand earthquakes.

Therefore structures need to be designed to withstand these forces and deformations.

A seismic code guides engineers to construct structures which can resist seismic waves.

The failure of structures due to earthquake which causes loss of life on large scale.

During construction of buildings, structure engineer should take into account the seismic factors which are provided according to the zones ranging from 0.1-0.36. (0.1-Z-II,0.16-Z III, 0.24-Z IV, 0.36-Z V)
It is the ration of accelaration due to earthquake and acceleration due to gravity (SF=a/g).
Therefore seismic factor is an important in considering dead and live loads on structures.

These maps also can be used to determine

(a) The relative probability of earthquake or ground motion from one part of the country to another.

(b) Te relative demand on structures from one part of the country to another, at a given probability level.

(c) Building codes use one or more of these maps to refine standards.

(d) Helps in protection of buildings against earthquake ground motion at different levels of probability.

- ➢Seismic evaluation helps in design and repair of buildings or other structures under seismic forces.
- ➢Therefore, for important projects, such as a major dam or a nuclear power plant, the seismic hazard is evaluated specifically for that site by performing a seismic hazard study.