Catalog

UNIT V

APPLICATION OF GEOLOGICAL INVESTIGATIONS

SYLLABUS

Remote sensing for civil engineering applications; Geological conditions necessary for design and construction of Dams, Reservoirs, Tunnels, and Road cuttings – Hydrogeological investigations and mining - Coastal protection structures - Investigation of Landslides, causes and mitigation.

5.1 REMOTE SENSING FOR CIVIL ENGINEERING

Every object on earth emits its own internal energy according to its molecular and atomic structure, in addition to reflecting sun light during the day time. This radiations can be registered by sensors in several wavelengths, including those in the infrared and microwave regions of the spectrum. When such sensors are installed on aircrafts or on satellites they can record the earth's objects from for off distances. Such distant (Remote) acquisition of information about the objects on the earth's surface is known as remote sensing.

Aerial Photography & Imageries:

The photographs of the earth taken from aircrafts are called the aerial photographs, while the pictures taken from the satellites are called the imageries.

Aerial Photographs:

Aerial photographs of the region are taken by cameras placed in the aircrafts. Aerial photos give three dimension of the photographed area. These photos contain a detailed record of the ground at the time exposure.

Satellite Imageries:

The satellite imageries can either be read manually like aerial photographs, or with the help of computers.

Geographic Information System;

The modern computers can process maps and data with suitable computer programmer. The process of integrating and analyzing various types of data with the help of computer is known as geographic information system.

Applications of Remote Sensing:

The applications of remote sensing are general geological mapping, mineral prospecting, petroleum exploration, groundwater exploration, and engineering, uses of site rocks, disaster studies and also coastal geological studies.

Geological Considerations Involved In the Construction of Buildings

Basic requirements of a building foundation, building foundation on soils, building foundation carried to the deep hard rocks, building founded on surface bed rocks, types of settlement in buildings.

Air Photos:

Air photos have shape and size, flight and photo data, scale.

Kinds of Air Photos:

Vertical air photos, oblique air photos, anusaics, photo strips, and stereo rain.

Stereo Meter:

The instrument is used under a mirror stereoscope for measuring heights and areas of objects from air photos.

Components of remote sensing

There are seven basic components of remote sensing. They are:

A – Energy source or illumination

B – Radiation and the atmosphere

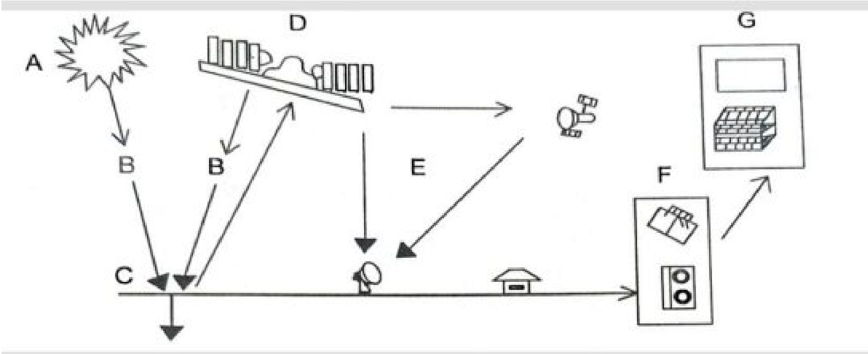
C – Interaction with the target

D – Recording of energy by the sensor

E – Transmission, reception and processing

F – Interpretation and analysis

G - Application



REMOTE SENSING TECHNIQUES

Remote sensing is the science, art and technology of obtaining information about the object, through the analysis of data acquired by a device this is not in contact with the object under the investigation. Various objects are identified with the help of variation in the reflected electromagnetic radiation reflected by different earth's objects. A remote sensing system, therefore, must be sensitive enough to capture the changes in the reflected electromagnetic energy. An ideal remote sensing may have the following components. Source of electromagnetic energy Medium which interacts with this energy Ground objects Sensor to detect and record the changes in electro-magnetic energy Electromagnetic radiation: Sun is the source of light. It radiates the heat and light energy in the form of electromagnetic radiation, the EMR comprises various rays such as, X- rays UV,

Visible, Infrared, thermal inferred, microwave and radio wave. , X- rays and UV are observed and reflected by upper layer of atmosphere, which is most useful for remote sensing hence it is known as atmosphere window.

The part of the electromagnetic radiation from visible to microwave is called electromagnetic spectrum (EMS).

- Various components of an electromagnetic spectrum with their wavelength and frequency are shown in the above figure.

Principle:

- All objective on the earth reflective absorb or radiate energy in the form of electromagnetic waves coming directly from the sun.
- The electromagnetic radiation (EMR) reflected from the objective is transmitted through the atmosphere. The remotely placed sensors can pick up the transmitted energy, record and form an image.
- This image data is sent to the earth recording stations, where all the data is recorded on high density digital tapes.
- Information about an object depends upon its spectral characteristic, which itself depends upon the nature of the object and its environment.
- The electromagnetic radiation travelling through the atmosphere gets modified by absorption and or scattering.

Remote sensing plate form:

- Plate form is defined as a stage of sensor or camera. They play vital role in remote sensing data acquistation.
- They are necessary to correctly position the sensors that collect data from the objects of interest.
- The platforms may be air-borne, or space-borne, depending upon the objects under study on earth surface and also on the sensor employed. Balloons, Aircraft, and Satellites are the common remote sensing platform.

Balloons: These are designed and used for specific projects. Through the use of balloon is commonly restricted by meteorological factors, there application in resource mapping has been significant useful. Balloons are usually of two types, a) Free balloons and b) Threaded balloons.

Aircraft: aircraft are commonly used as remote sensing plate forms for obtaining aerial photographs.

They considered useful for regional converge and large scale mapping.

Space born plate form:

- Satellite has provided to be vital use in natural resource mapping, meteorological and communication application applications.

- Satellites are free- flying orbiting vehicles, whose motion is governed by the gravity, and atmosphere based on well-known Kepler's laws.
- Broadly, satellites can be grouped under two categories depending upon the types of orbits in which they move.

Geostationary satellite

Altitude - 35,000km

Orbital Movement - Parallel to Earth Rotation

Uses - Communication

Example - GOBS, GMS, INSAT etc

Sun-Synchronous or Polar orbiting satellite

Altitude - 800-900km

Orbital Movement - Pole to Pole

Uses - Earth Observation

Example - LANDSAT, SPOT, IRS, IKNAS, QUAKE BIRD etc

Sensor system:

- In remote sensing, the acquisition of data is dependent upon the sensor system used. Various remote sensing platforms are equipped with different sensor systems.
- It is a device that receives electromagnetic radiation, converts it into a signal and presents it in a form suitable for obtaining information about the land or earth resource as used by an information gathering system. Sensor can be grouped, either on the basis of energy source or on the basis of wave bonds employed. Based on the energy source, sensors are classifies as follows.

Sensor Classification

Based on the energy source Sensor May be classifies in to the followings:

- Active Sensors (Sensor which produce the EMR by its own i.e RADAR)
- Passive Sensors (Sensor depends the suns EMR i.e., MSS, TM, XS, LISS, PAN, WiPS etc)
- Passive Sensor further divided into number of following types based on function of sensor in EMR>

- Photographic Camera (Operated in single band from 0.4-0.7mm)
- Return Beam Vidcon (Operated in Green, Red, NIR)- RBV in Landsat and TV in Bhaskara
- Thermal Sensor (Operated in Thermal Infrared Region)
- Optical and Mechanical Sensors (Operated in 0.5-1.1 mm) MSS and XS Radar and Microwave Sensor (Operated in Microwave Region) SLAR, SAR
- Advanced Remote Sensor (Operated in GBR and IR) LISS-II, LISS-III, LISS-IV, WiPS, PAN,

TM Parameter of sensor:

- **Spatial Resolution**: The minimum detectable area on the ground by a detector placed on a sensor
- **Spectral Resolution:** The small amount of spectral changes is detected by the sensor.
- **Radiometric Resolution**: The presence of grey level
- **Temporal Resolution**: Smaller period of repetitive coverage
- **Remote Sensing Satellite**: Remote sensing, as conceived today for natural resource mapping was started with the launching of the first earth resource.
- Technology's satellite (ERTS) now known as LANDSAT-1, by USA in 1972 since then, with the advancement in sensor technology, a number of remote sensing earth resource satellite have been launched. The important milestones crossed so far in achieving end-to-end capability are LANDSAT Series, 1, 2, 3, 4, 5, 6 and 7; Frances satellite 1, 2,and 3, Indian polar satellite Bhaskara 1&2, IRS 1A/ IRS 1B/IRS 1C/IRS 1D/IRS P2/IRS P3/IRS P4/IRSP5/IRS P6& Indian meteorological satellite INSAT 1A/1B/1C/1D and 2A/2B/2C/2D/2E etc.,

5.2 GEOLOGICAL CONSIDERATIONS FOR DESIGN AND CONSTRUCTION OF DAM AND RESERVOIR

Dam:

A dam is a hydraulic structure constructed across a river to store water in the upstream side for various purposes like domestic water supply schemes, irrigation, hydro-power generation, etc.

Geological considerations for site selection:

1. Topography
2. Water tight reservoir basin with adequate capacity, in which the rate accumulation of silt is not likely to exceed the admissible limits.
3. A narrow river channel.
4. Safe foundation.
5. Provision for disposal of surplus water through a suitable spillway and
6. Availability of the required materials for construction in the neighbour good area.

1. Topography:

Topography refers the naturally available land features, such as mountains, valleys, rivers, plains, plateau, etc.

The topography of an area suggests the first choice of the type of the dam.

Eg

i. A narrow V shaped river valley suggests the selection of an arch dam.

ii. A narrow U shaped river valley suggests the selection of a concrete gravity over flow dam.

2. Water tight reservoir basin:

The reservoir may fail due to:

i. Excessive leakage of water

ii. Rapid accumulation of silt in it.

The rate of leakage of water from any reservoir is dependent on the initial position of the water table underneath the basin and nature of the rocks forming the country.

In many river valleys regional water table lies near the earth's surface and as a result the river or stream is partially fed from the groundwater. Those streams are called effluent streams.

Streams which feed groundwater are known as influent streams. Therefore, reservoirs lying along the course of effluent rivers are not likely to lose much water through seepage.

3. Narrow river channel:

This is a natural characteristic, purely contributing towards the size of the dam and hence the economy of the dam project. If the river channel is narrow, relatively smaller dam can be built with low cost and vice versa.

4. Safe foundation & abutments of dams:

The failure of a dam, due to the prevalence of adverse geological conditions along its foundation and abutment may lead to devastating flood in the downstream area.

So, in selecting a dam site, immense responsibility is involved, which includes geological and geophysical studies to find out the depth to the bed rocks on which the dam has to stand. The thickness of the overburden, i.e., unconsolidated deposits of clay, silt, sand, gravel, etc., can be found out by geophysical investigations.

Granite, syenite, diorite, gabbros, gneiss, schist, quartzites and other varieties of massive igneous and metamorphic rocks are capable of supporting enormous load and are impervious to desired extent, provided they do not contain much of joints and other planes of weakness.

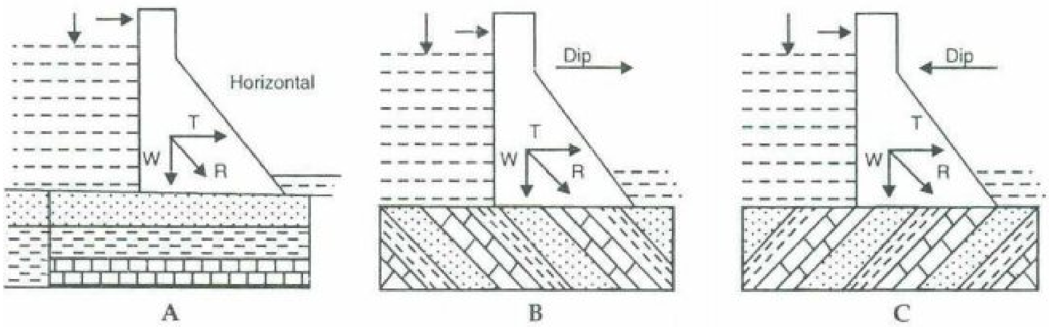
Volcanic rocks like basalts are generally vesicular and jointed and these opening allow excessive percolation. So, they are unsuitable for the supporting the load of the dam. Carbonate rocks like limestones, dolomites, marbles and other soluble rocks often contain enough joints and solution cavities which allow percolation of enough water through them. So, the extent of leakage has to be studied carefully.

Dams on various Geological Strata:

The strength of sound, unfractured stratified rock is always greater when the stresses are acting normal to the bedding planes than if applied in other directions.

This being so, horizontal beds should offer best support for the weight of the dam.

But as is shown in a latter section, the resultant force is always inclined downstream.



The most unfavourable strike direction is the one in which the beds strike parallel to the axis of the dam and the dip is downstream

It must be avoided as far as possible.

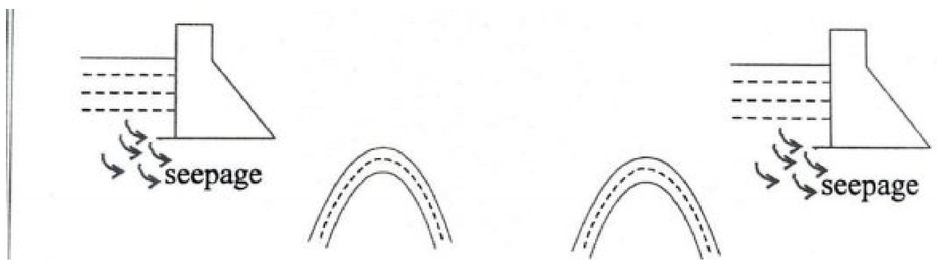
Therefore, other conditions being same, beds with upstream dips are quite favorable sites for dam foundations.

Dam in Anticlinal upstream and downstream sides

Fold – Favourable situations for civil engineering projects:

1. **Dam along upstream side of anticline:**

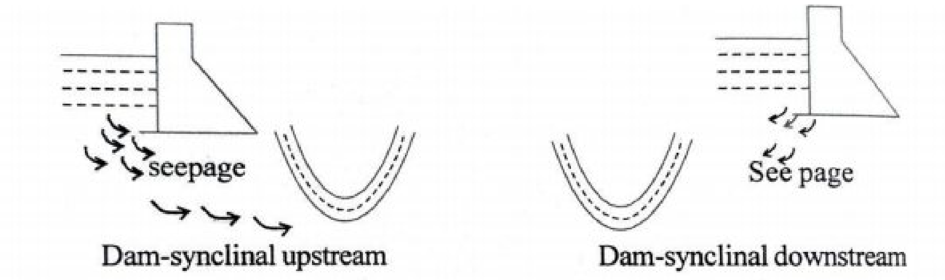
   The upstream side of the anticline will be a favourable site for dam, because, seepage from reservoir, if any, will be along the upstream side of the anticline, i.e., within the reservoir side itself.



2. **Dam along downstream side of syncline:**

The downstream side of the syncline will be a favourable site for dam, because, seepage from reservoir, if any, will be along the downstream side of the syncline, i.e., within the reservoir side itself.

Folded strata are found favourable for accumulation of oil and natural gas.



Fold – Unfavourable situations for civil engineering projects:

1. **The downstream side of anticline:**

   Unfavourable for dam project, because, there will be loss of water to reservoir, due to seepage towards the downstream side of the dam.

2. **The upstream side of syncline:**

   Unfavourable for dam project, because, there will be loss of water to reservoir, due to seepage towards the downstream side of the syncline as well as dam.

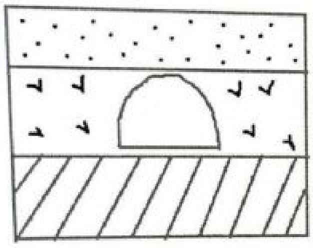
5.3 GEOLOGICAL CONSIDERATIONS FOR DESIGN AND CONSTRUCTION OF TUNNELS

Tunnels: Tunnels are the underground passages or routes through hills, mountains or earth crust used for different purposes. These passages are made by excavating rocks below the surface or through the hills, mountains.

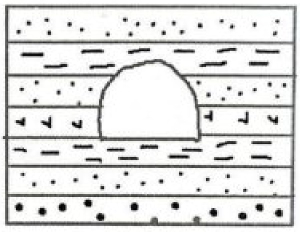
Types of tunnels: Tunnels are basically made to serve some specific purposes.

For instance:

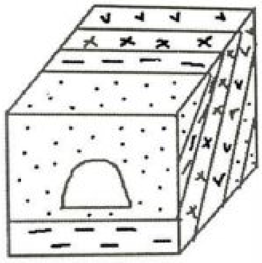
1. Transportation tunnels: tunnels made across hills or high lands to lay roads or railway tracks for regular traffic and transportation purpose.
2. Traffic tunnels: Tunnels lay to reduce the distance between places of interest across natural obstacles like hills, to save time and provide convenience is called traffic tunnels. These have the advantage of leaving the ground surface undisturbed so that it can be used as desired.
3. Diversion tunnels: The tunnels laid for diverting normal flow of river water to keep the dam site dry are called diversion tunnels.
4. Pressure tunnels: these are also called as hydropower tunnels. These are used to allow water to pass through them under force, used for power generation.
5. Discharge tunnels: These are meant for conveying water from one point to another under gravity force, like across hill.
6. Public utility tunnels: These are the tunnels laid for public supplies like drinking water supply, cables laying, sewage discharge or oil supply etc.



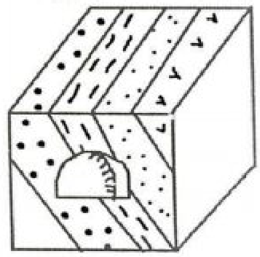
Safe Tunnel



Unsafe Tunnel

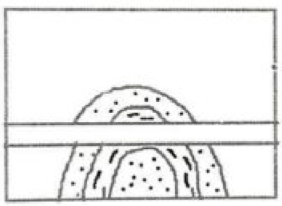


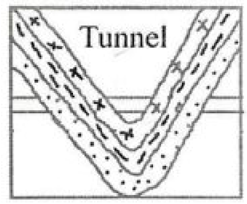
Tunnel parallel to dip direction - safe



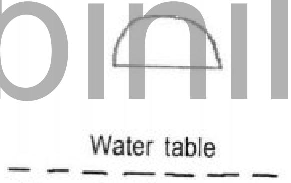
Tunnel parallel to strike - unsafe

Tunnel





Tunnel in syncline - unsafe



Tunnel - Deep water table area (suitable)

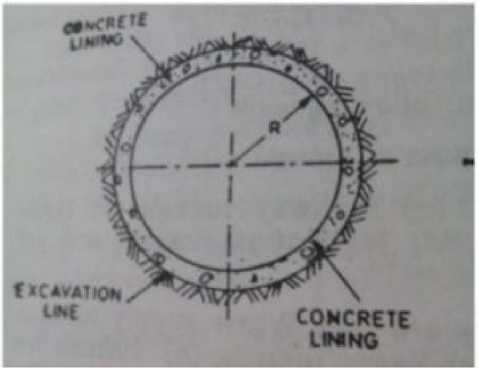
Tunnel - Shallow water table area (not advisable)

Effect of tunnelling on the ground:

- Deterioration of the physical conditions of the ground is the common effect of tunnelling.
- This happens because due to heavy and repeated blasting during excavating, the rocks get shattered to a great extent and develop numerous cracks and fractures.
- This reduces the cohesiveness and compactness of rocks.
- At normal conditions the earth crust or underground rocks are under great pressure (overburden) or they will be in association with some geological structures like folding will be at equilibrium stress holding the prevailing strain intact.

- When the tunnel is created, such rocks which are at equilibrium gets disturbed resulting in the collapse of the roof. Frequent bursts may also occur.
- This phenomenon of fall of rocks in brittle and hard rock is called Popping. Due to tunnelling, the overlying Rocks deprive of support from the bottom and may become unstable.
- Such unstable conditions become still more precarious if the tunnelled beds are incompetent or loose or unconsolidated or saturated with ground water

Lining of tunnels:



- When tunnels are made through weak or loose or unconsolidated formations, they are provided with suitable lining for safety and stability. Lining refers to the support provided to tunnel.
- Lining may be in the form of steel structures or concrete. The main purposes of lining are to resist the pressures from the surroundings and to protect the shape of tunnel. It takes care of the weaknesses of the ground.
- It also helps in checking leakage of ground water into tunnel. The thickness of concrete lining depends on the extent of protection required, and the degree of weakness of the ground. It also depends on the over break phenomenon. Lining is provided to support weak parts of the tunnel. Lining is also provided in such places where the seepage of water into the tunnel occurs and creating problems.
- In the case of very weak rocks with unfavourable geological structures, lining may be necessary throughout the length of the tunnel.
- The zones of faulting or shearing also need suitable lining to impart strength to them.

Over break: During tunnelling the excavations normally involve the removal of extra rocks or matter around the tunnel. The quantity of rock broken and removed, in excess of what is required by the perimeter of the proposed tunnel, is known as over break.

Factors governing the amount of over break: The nature of the rocks. Orientation and spacing of joints or weak zones in them.

In the case of sedimentary rocks, the orientation of the bedding planes

- Thickness of the beds with respect to the alignment of the tunnel.
- Geological factors influencing the over break: Massive and soft rocks of a homogenous nature cause less over break than harder rocks with well-developed joints or weak zones. In sedimentary rocks, thin formations and those with alternating hard and soft strata produce more over break. This is because, during excavation, softer rocks yield more than the hard rocks.

5.4 GEOLOGICAL CONSIDERATION FOR THE DESIGN AND CONSTRUCTION OF ROAD CUTTINGS

Geological investigation plays a vital role in the design and economical construction of road.

1. Topography
2. Lithology
3. Structural characteristics of rocks.
4. Weathering conditions and
5. Ground water conditions.

1. Topography:

Topography refers land features or landforms, such as valley, hilly terrain, plains, plateaus, etc.

2. Lithology:

Lithology gives the details of rocks, such as, their composition, texture, origin, etc.

The terrain is broadly classified into two types, namely.

i. **Hard rock terrain** : made up of consolidated, massive and hard bed rock.

ii. **Soft rock terrain** : made up of soft and unconsolidated strata.

3. Structural characteristics of rocks.

The foundation of any civil engineering structure should be rested upon sound and solid bed rock.

The structure will fail, if constructed upon rocks having structurally weaker planes.

The following are the structural factors to be considered in road alignment.

i. Dip and strike

ii. Joint

iii. Faults

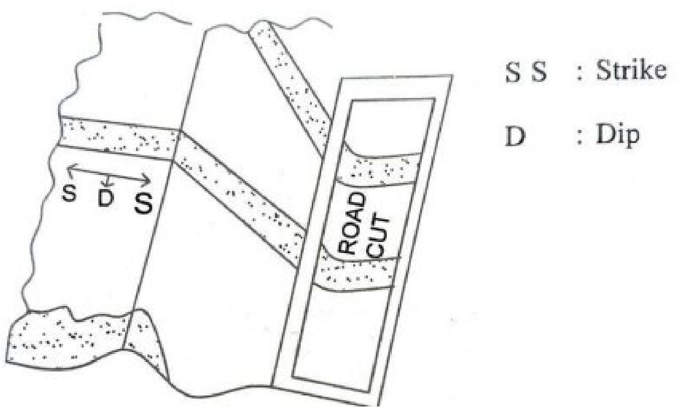
i. Dip and strike:

Three cases are considered under this factor.

a. Road cut parallel to dip direction:

In this case, the strata will offer a uniform behaviour on either side of road cut and hence the risk of failure is minimal in this case.

ROAD CUT PARALLEL TO DIP DIRECTION

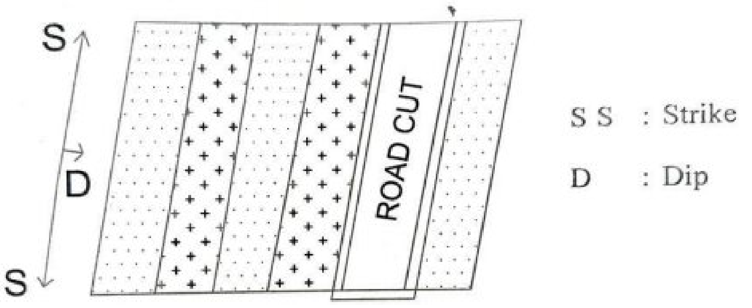


b. Road cut parallel to the strike:

1. Strata / layer plunge or dip inside the road cut:

In this case, when rocks are lubricated with rain water or ground water movement, there is likely to have slip or fall of materials.

ROAD CUT PARALLEL TO STRIKE



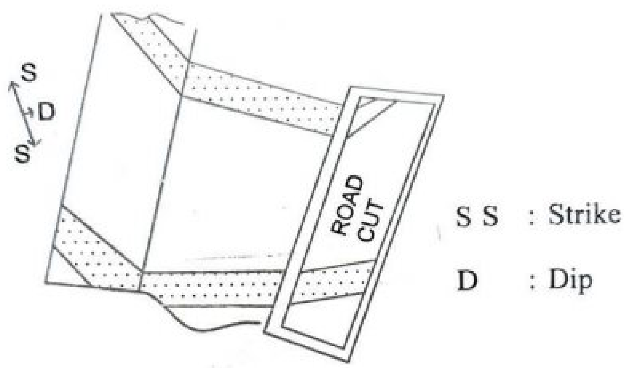
2. Strata dipping into the hill:

In this case, the slope of road cut will be unequal on both sides. This situation would result in similar difficulties as raised in cuts parallel to strike.

c. Road cut inclined to dip and strike:

In this case, the slope of road cut will be unequal on both sides. This situation would result in similar difficulties, as raised in cuts parallel to strike.

ROAD CUT INCLINED TO DIP AND STRIKE



When there is no alternative in the above two undesirable cases, slope stability measures, such as perfect retaining wall, efficient drainage system etc, have to be taken before initiating the project.

4. **Weathering conditions:**

When the strata under the road cut is composed of layers of heterogeneous nature with varying hardness, then weathering will lead to erode softer layers faster than harder ones, giving rise to undermining of the face. This will lead to rock fall or debris fall.

5. **Groundwater conditions:**

Groundwater due to its movement or other factors, lubricate the rock strata and reduce their bearing capacity.

Hence, the water table depth be should studied thoroughly in the proposed road site.

5.5 HYDROGEOLOGICAL INVESTIGATIONS

- ✓ Hydrogeological investigation refers to Hydrogeological surveying techniques, relating to groundwater studies of an area under investigation.
- ✓ Hydrogeological investigation plays a key role in any water supply projects to be implemented.
- ✓ It includes the following works to collect information about groundwater details of any area under study.
  1. Reconnaissance Survey
  2. Groundwater Investigation by Geophysical surveying.
  3. Yield test of Wells to know the aquifer characteristics.
  4. Water level monitoring, etc.

1. Reconnaissance Survey

It is a preliminary survey required for any detailed groundwater study of an area under investigation.

The following works are done in the reconnaissance survey.

i. **Well inventory:** Collecting details about all the existing wells available in and around the project site, such as size & depth of the wells, HP used (pump), hours of pumping, water table depth, etc.

ii. **Groundwater Investigation:** this is carried out by a universal method called, ‘Electrical Resistivity Method’, which is based on the principle of ohm’s law (i.e, V=IR).

Electrical Resistivity Method:

In this method, the electrical resistivity of various soil and rock strata present below the earth’s surface is found out, applying Vertical Electrical Sounding (VES) techniques with Wenner or Schlumberger electrode array.

2. Groundwater Investigation by Geophysical surveying

All the materials (whether soil or rock) will conduct or resist current. If they conduct current, it will be in various proportions, based on their composition and moisture content present. The conductivity of any rock / soil is the reciprocal of its resistivity. Knowing the resistivity values, different rock strata present in earth's crust is inferred and their aquifer characteristics are studied. Ohm's law is the basis for the principle of this method.

Equipment used:

1. Resistivity meter
2. Two current electrodes & two potential electrodes
3. Power pack
4. Cables, hammers, etc.

Types / Methods of Resistivity Survey:

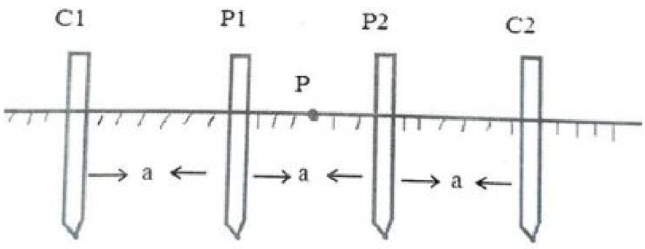
1. Wenner electrode array
2. Schlumberger array

Procedure:

In both the methods, all the four electrodes are erected firmly into the ground and a known current (I) is sent into the ground through the two current electrodes (C1& C2) and the potential difference (V) between the two potential electrodes (P1 & P2) is measured.

In the case of Wenner configuration of electrodes, all the four electrodes are equally spaced where as in case of Schlumberger configuration, the potential electrodes are closely spaced and current electrodes are placed further apart.

Wenner Array:



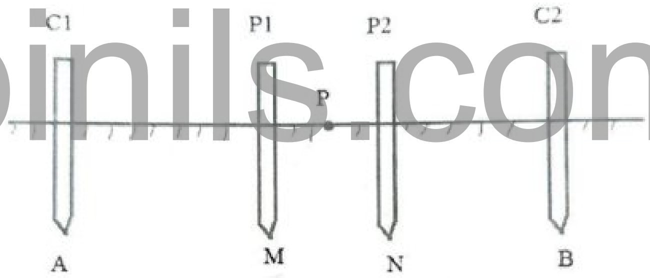
a = Electrode spacing

C1, C2 = Current electrodes

P1, P2 = potential electrodes

P = Point of exploration

Schlumberger Array:



Formula applied:

Wenner array:

$\ell_a = 2\pi a (V / I)$ ohm m

Where ℓ_a = apparent resistivity in ohm m

a = electrode spacing

V = potential difference between 2 potential electrodes in millivolts / volts

I = current sent in Ampere / milli amps

Schlumberger array:

$$\ell_a = \frac{[(\frac{AB}{2})^2 - (\frac{MN}{2})^2]}{MN} \times (\frac{V}{I})\ ohm\ m$$

Where AB = spacing between current electrodes

MN = spacing between potential electrodes

All the four electrodes are moved laterally at a uniform spacing / span (in case of Wenner) and only the two current electrodes are shifted laterally (in case of Schlumberger), in order to increase the depth of exploration and at every shifting of electrodes, current is sent and potential difference between electrodes is measured. This process is repeated till the total depth of exploration is reached.

In case of Schlumberger, after reaching certain depth of exploration (say 50m), the potential electrodes are shifted to 1/5th distance of current electrodes (say 10m) and the procedure is repeated.

The linear expansion of electrodes denotes the depth of exploration at the point of investigation. Then applying the relevant formula, the apparent resistivity values (ℓ_a) are calculated.

Sedimentary strata	**Resistivity (in ohm m)**	**Hard rock terrain strain**	**Resistivity (in ohm m)**
Sand	8-15	Top soil	> weathered strata
Clay	Less than 5	Weathered strata	25-80
Sandy clay / clayey sand	5-8	Fractured rock	80-150
Kankar	25-40	Jointed rock	150-300
Sea water intrusion	Less than 1	Massive bed rock	> 300

Depending upon the water table conditions of the study area and available favourable rock formations, the investigated location is recommended for open well or bore well or rejected, if unfavourable.

5.6 MINING

Mining or quarrying is the method of the exploitation of mineral deposits / rock formations, exposed upon the earth's surface or present underground, applying manual or mechanical methods.

Exploitation:

Exploitation is defined as the act of using natural resources like mineral deposits, oil & gas, groundwater, etc., applying various mining and extraction techniques.

Quarrying is the term used for minor minerals like granites.

Mining is the term used for major minerals like limestone.

Methods of mining:

Mining is broadly classified into 2 types.

1. Open cast mining
2. Underground mining

1. Open cast mining:

If the mining is done from the surface of the earth, then it is termed as open cast mining. I.e. Mining is done by disturbing the surface of the earth. Eg lime stone mining.

2. Underground mining:

Without disturbing the surface of the earth, if mining is carried out through shafts and underground tunnels to exploit mineral deposits occurring at greater depths, it is called underground mining. Eg Kolar gold mining

Components of mining:

1. Mine plane approval
2. Explosive license
3. Environmental clearance from competent authorities.
4. Mining lease.

5. Drilling
6. Blasting
7. Hauling

- **Mine plan approval** is granted by Indian Bureau of Mines, Bangalore.
- Explosive license is issued by competent authority of Explosives, Nagpur.
- **Environmental clearance** should be obtained from State Government Authorities or Ministry of Environment & Forests, depending upon the real extent of mining area. If it exceeds 50 hectares, clearance & mining lease should be obtained from Union Government.
- **Mining lease:**

It should be obtained from State Government Authorities, if minor minerals have to be exploited with an extent of mining restricted to be less than 50 hectares. Mining lease is required from Union Government.

- **Drilling and Blasting** are mining operations to explore mineral deposits.
- **Hauling** refers transportation of mined mineral deposits from the mining area to the required place. It requires **'Transport Permit'** which will be issued by respective District Mining Authorities. Transport Permit will be issued on payment of **'Royalty'** to Government per tonne of production of mineral deposits.

5.7 COASTAL PROTECTION STRUCTURES

Coastal erosion is a ceaseless operation by sea waves and tides. India has a coastal boundary of about 7000km long, which has to be protected from the attack of sea waves and tides, since areas close to the sea shore are always subject to continual action of sea waves.

Protection of the coast and the shore against the erosive forces of waves, currents and storm surge can be performed in many ways, and protection of coast areas against flooding too.

Coastal protection works are under taken for

i) Stabilization of existing beach
ii) Restoring eroded beach
iii) Creation of artificial beaches and for their stabilization
iv) Protecting the shore line.

Generally two types of coastal protection measures are undertaken. They are studied under the following headings.

1. Structural
2. Non structural

Structural measures:

The following structures fall under this category

i. Sea walls & Bull heads
ii. Groynes
iii. Break waters

i) Sea walls & Bulk heads

Sea walls

- A seawall is defined as a structure separating land and water.

➢ It is designed to prevent coastal damage due to wave action and storm surge, such as flooding.

➢ Sea walls are normally very massive structures because they are designed to resist the full force of wave and storm surge.

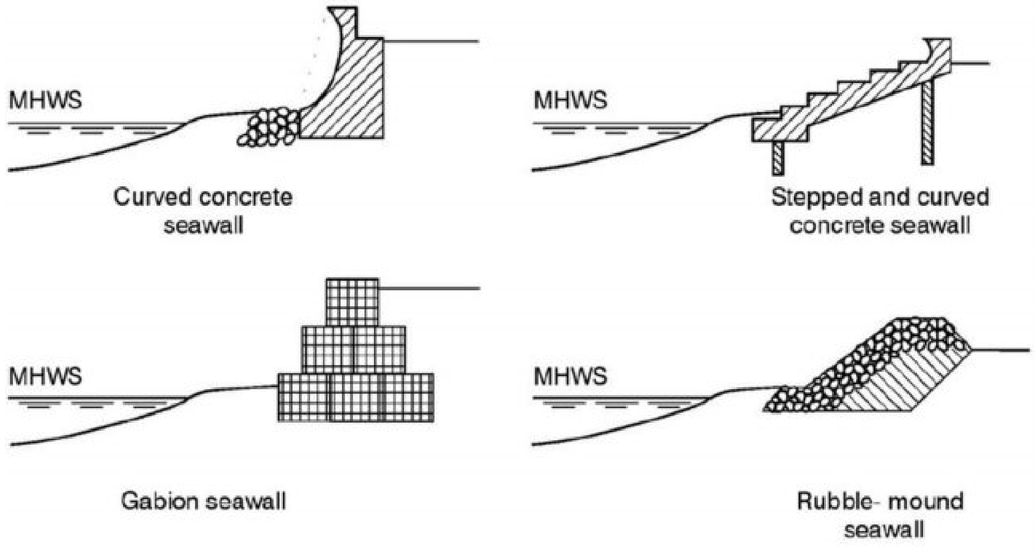


Figure Examples of seawall structures.

➢ A sea wall protects the coast against erosion and flooding.

➢ Seawalls are often used at location of exposed city fronts, where good protection was needed.

Figure Seawall/revetment in front of Corniche in Alexandria.

Figure Rubble mound seawall protecting the coastal road at Madampagama, SW coast of Sri Lanka.

Bulk heads

➢ A bulk head is a structure or partition used to retain or prevent sliding of the land.

➢ A secondary purpose is to protect the coast against damage from wave action

➢ Bulkhead area normally smaller than seawalls, as their primary function is to retain fill at locations with only limited wave action and not to resist coastal erosion.

Bulkhead structure constructed by
Gabion mesh boxes

➢ These are used along natural shorelines and along filled area, where a well defined separation between land and sea is required.

➢ These can be used against sea level rise if adjusted in height and if the area is still protected against wave despite the sea level rise.

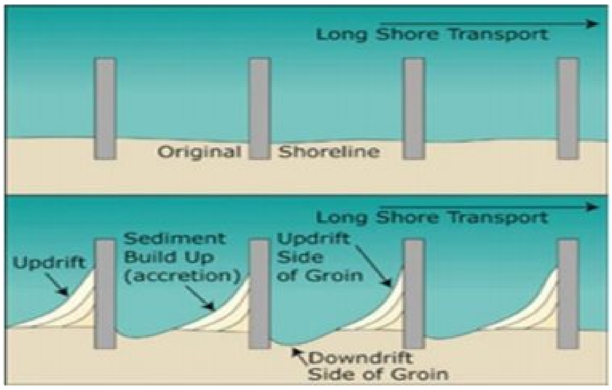
➢ These are not used to protect against erosion.

ii) Groynes:

➢ These are normally straight structures perpendicular (could be slightly oblique) to the shoreline.

➢ They are build a rubble mound structures but they can be constructed in other materials such as concrete, timber, geo-tube etc.

➢ These are generally applicable against chronic erosion as groynes are active when there is a net long shore transport. Groynes are not applicable against acute erosion.



iii) Break waters

- It is structure parallel or close to parallel, to the coast, build inside or outside the surf-zone.
- Breakwater are able to protect sections of shoreline in a less harmful way than groynes
- The applicability of breakwater to different types of needs to be studied before choosing a particular design.

Non structural measures:

The following methods are adopted under non structural category to reduce sea erosion.

i. Grass dykes
ii. Beach nourishment
iii. Sand dune rebuilt
iv. Planting vegetation

i) Grass dykes

- Grass dykes of sufficient width and height are orderly arranged along the shore line to withstand the wave action.
- They are densely placed so as to stay with standing for a month time or so.

ii) Beach nourishment

- Eroded beaches are filled with beach materials with suitable dimensions to protect the uplands.
- It is a low cost beach nourishment method by providing natural sand supply periodically to ensure shore protection.

iii) Sand dune rebuilt

- The demolished sand dunes are reconstructed, by bringing beach materials from other unaffected areas, to safe guard the coast line from sea waves and tidal action.

iv) Planting vegetation

- Plantation development, like growing 'mangrove' trees will effectively protect the shore line from the sea erosion.
- Further, sand dunes will be stabilized by this vegetation.

5.8 INVESTIGATION OF LANDSLIDES, CAUSES AND MITIGATION

Land sliding:

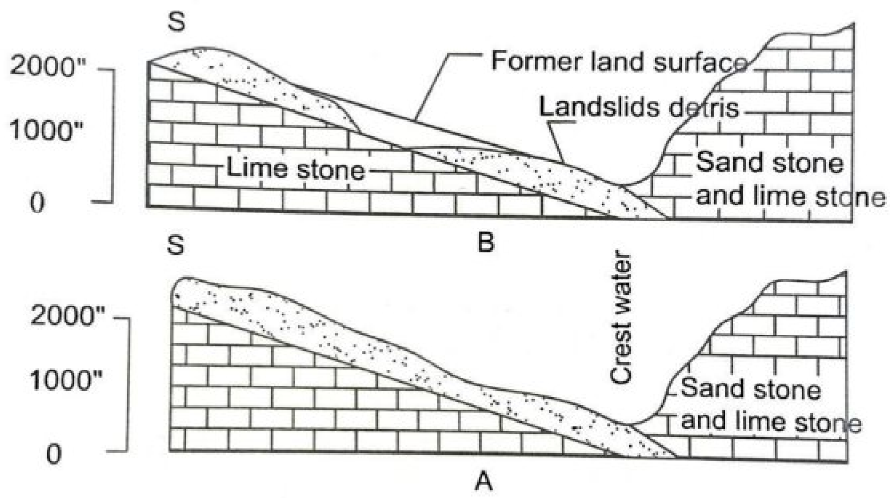
The downward movement of the superficial land masses, due to slope failure is called Land sliding or Mass movement.

Causes of Land slide:

The following are the important causes of land sliding.

- Slope failure
- Movement of the tectonic plates.
- Earthquakes.
- Heavy rainfall.
- Geological factors such as soil conditions.
- Drainages conditions
- Deforestation
    - Other artificial causes such as, Mining activities, Heavy traffic loads, etc.

LANDSLIDING



Classification of Land sliding:

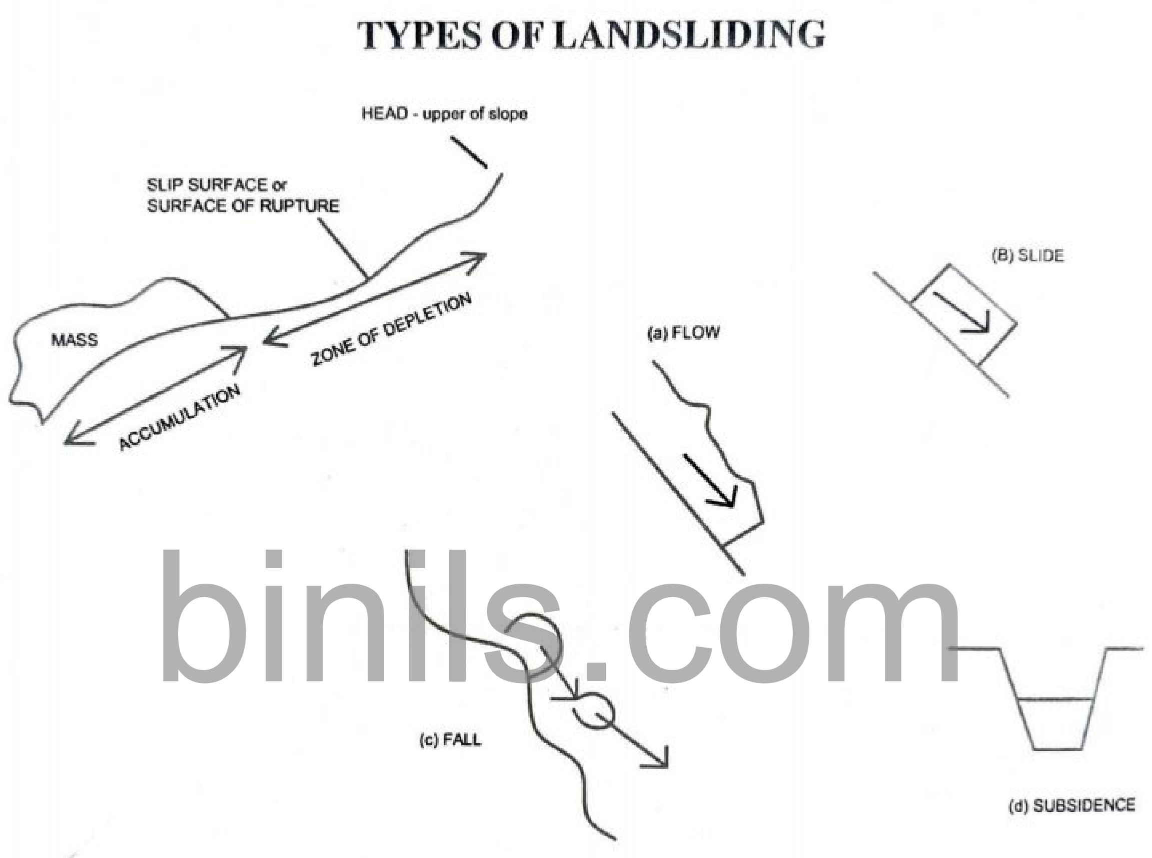
The land sliding is broadly classified into three categories.

1. Flowage

2. Sliding
3. Subsidence

I. Flowage:

Flowage is defined as the down grade irregular movement of superficial land mass, along no definite surface of failure.



In flowage, the movement is distributed throughout the mass.

Types of flowage:

Flowage is divided into two types.

1. Slow flowage
2. Rapid flowage

1. Slow flowage:

Movement is very slow, not visible, only few centimeters a year or less.

It is further classified into:

i. Soil creep

ii. Talus creep

iii. Solifluction

i. Soil creep:

- Soil creep is a surface phenomenon.
- Only the top one meter of the soil is involved in failure, without much water content.
- The movement may be 1mm to few centimeters a year.

ii. Talus creep:

- The materials involved in failure are weathered rock debris & fragments (talus) along sloping terrain.
- The movement may be 10cm a year or more.

iii. Solifluction:

- Solifluction refers movement of soil mass in water saturated condition.
- It s characteristic phenomenon in extremely cold climatic regions.
- Porous and unconsolidated solids are involved in failure.

2. Rapid flowage:

Movement is visible, few meters or more a day.

It is further classified into:

i. Earth flows

ii. Mud flows

iii. Glacier flow

i. Earth flows and Mud flows:

- Un consolidated materials are involved in failure
- Both refer same types of failure, but with different water content.
- In mud flows, the quantity of water per unit volume of the soil mass is very high, compared to earth flows.

ii. Glacier flow:

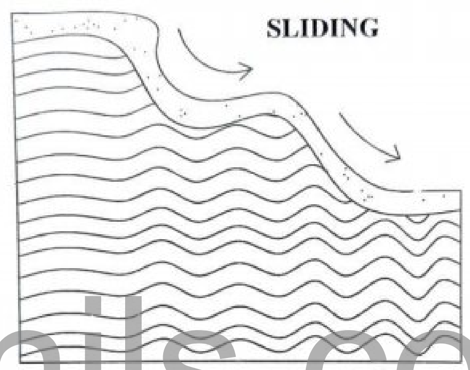
- Glacier flow occurs in permo frost region.
- In India, Himalayan ranges are evidenced with glacier flows.
- Glaciers bring broken rock debris and stones along with their flow.

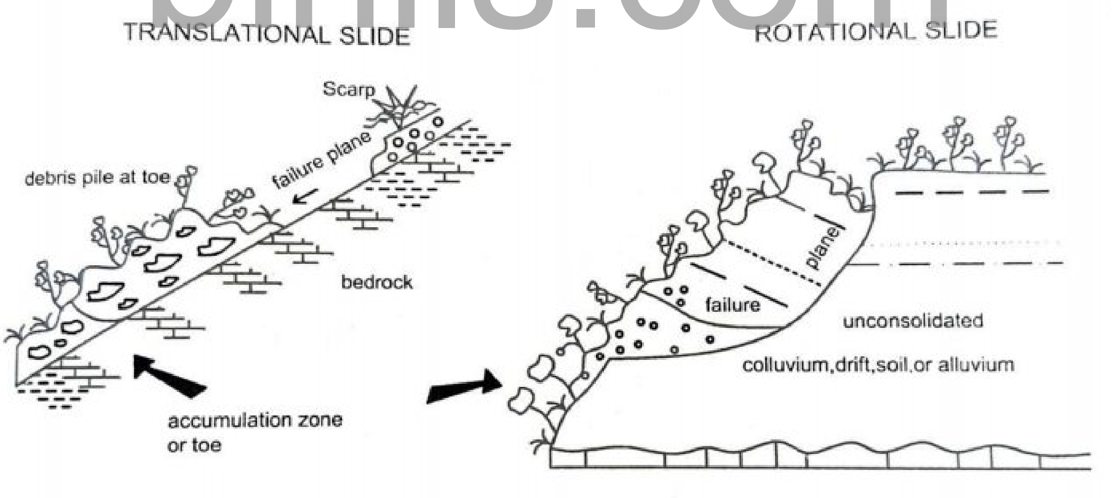
II. Sliding:

- This term refers the ‘real or true’ land sliding.
- Land sliding occurs along definite surface of failure.

  Sliding occurs along planar surface of failure or curved surface of failure.

If sliding occurs along planar surface of failure, then it is called translational slide.





- In rotational slide, the surface of failure is curved.
- Rock slide refers sliding of rock blocks.
- Debris slide refers sliding of unconsolidated fragments.
- Rock fall refers sudden falling of rock blocks.
- Debris fall refers sudden falling of unconsolidated debris.
- In sliding, Velocity of movement will be less than that of rock fall.

- Single rotational slide refers sliding of either rock block or debris.
- Multiple slides refer sliding of the combination of rock blocks and debris.
- **Avalanche:**

The downward movement of the huge solid rock blocks, weighing thousands of tons with terrific speed is called an Avalanche.

III. Subsidence:

- The failure of ground in a vertically downward movement is called as subsidence.
- Subsidence is due to natural or artificial causes.

Natural causes:

- Presence of the structurally weak rock strata.
- Heavy rainfall.
- Solution of subsurface rocks.
- Vertical movement of the tectonic plates.
- Earth quakes etc.,

Artificial causes:

- Removal of the supporting materials.
- Mining.
- Over exploitation of oil and gas, ground water, etc.,

MITIGATION AND PREVENTION CONTROL MEASURES OF LANDSLIDING:

Prevention Control Measures:

1. Providing proper drainage.
2. Constructing retaining walls.
3. Providing rock blots and rock anchors as reinforcement in slopes.
4. Providing slope treatment:

i. Slope terracing.

ii. Planting vegetation along slopes

5. Controlling traffic load, along slopes.
6. Promoting afforestation.

7. Preventing deforestation, etc.,

Mitigation Measures

Landslide mitigation refers to lessening the effect of landslides by constructing various man made projects at slopes vulnerable to; in addition to shallow erosion or reduction of sheer strength caused by seasonal rainfall, causes triggered by anthropic activities such as adding excessive weight above the slope, digging at mid slope or at the foot of the slop, can also be included.