JECRC Foundation

JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTRE

Class: -	III Semester / II Year
Subject: -	Engineering Geology
Code: -	**3CE4-08**
Unit:-5	Applied Geology
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Jaipur Engineering College and Research Centre

Jaipur

VISION

- To become a role model in the field of Civil Engineering for the sustainable development of the society.

MISSION

1) To provide outcome base education.

2) To create a learning environment conducive for achieving academic excellence.

3)To prepare civil engineers for the society with high ethical values.

<u>Course Outcomes</u>

CO1:-To understand about weathering, physical properties of minerals and geological action of river and wind.

CO2:-To understand the different types of rocks and their properties.

CO 3:-To understand the folds, faults, joints and unconformity.

CO4:-To understand the geophysical methods and application of remote sensing and GIS.

Programme Outcomes (PO)

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. **Problem analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations

.

6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of 9the engineering practice.

9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

UNIT-5

Applied Geology: Introduction to applied geology and its use in civil engineering, properties of rocks, selection of sites for roads, bridges, dams, reservoirs and tunnels. Prevention of engineering structures from seismic shocks, stability of hill sides, water bearing strata, artesian wells, Use of remote-sensing techniques in selection of abovesites.

Applied Geology

The application of various fields of geology to economic, engineering, water-supply, or environmental problems; geology related to the human activity.

Use of Applied geology in civil engineering

Civil engineering projects involve some excavation of soils and rocks, or involve loading the Earth by building on it. In some cases, the excavated rocks may be used as constructional material, and in others, rocks may form a major part of the finished product, such as a motorway cutting of the site or a reservoir. The feasibility, the planning and design, the construction and costing, and the safety of a project may depend critically on the geological conditions where the construction will take place.

Properties of rocks

Density, unit weight, specific gravity and water content Density of the rock is the mass of rock per unit volume whereas unit weight of the rock is the weight per unit volume. Highly porous rocks and relatively poor arrangement of grains (less packing) usually have relatively less densities and vice versa. The bulk unit weight considers the bulk (total) volume of rocks whereas the solid unit weight considers volume excluding the pores, fissures. Obviously, for porous rocks the unit weight of solid would be relatively higher than the bulk unit weight as the value in the denominator is relatively lower due to exclusion of pores and micro fractures. Bulk unit weight depends on the type of rock, its

REMOTE SENSING

Remote sensing (RS), also called earth observation, refers to obtaining information about objects or areas at the Earth's surface without being in direct contact with the object or area. Humans accomplish this task with aid of eyes or by the sense of smell or hearing; so, remote sensing is day-today business for people. Reading the newspaper, watching cars driving in front of you are all remote sensing activities. Most sensing devices record information about an object by measuring an object's transmission of electromagnetic energy from reflecting and radiating surfaces.

Basic principle of Remote Sensing

Detection and discrimination of objects or surface features means detecting and recording of radiant energy reflected or emitted by objects or surface material (Fig. 1). Different objects return different amount of energy in different bands of the electromagnetic spectrum, incident upon it. This depends on the property of material (structural, chemical, and

physical), surface roughness, angle of incidence, intensity, and wavelength of radiantenergy.

The Remote Sensing is basically a multi-disciplinary science which includes a combination of various disciplines such as optics, spectroscopy, photography, computer, electronics and telecommunication, satellite launching etc. All these technologies are integrated to act as one complete system in itself, known as Remote Sensing System. There are a number of stages in a Remote Sensing process, and each of them is important for successful operation.

Stages in Remote Sensing

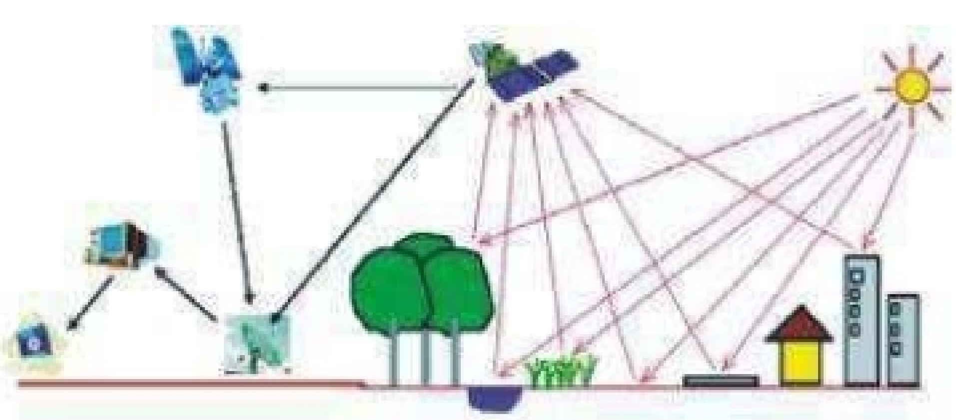
- Emission of electromagnetic radiation, or EMR (sun/self-emission)
- Transmissionofenergyfromthesourcetothesurfaceoftheearth,aswellasabsorption

and scattering

- InteractionofEM ̒ withtheearth’ssurface:reflectionand emission
- Transmission of energy from the surface to the remotesensor
- “ensor dataoutput
- Data transmission, processing andanalysis

All objects radiate electromagnetic energy by virtue of their atomic and molecular oscillations. The total amount of emitted radiation increases with the body’s absolute temperature and peaks at progressively shorter wavelengths. The sun, being a major source of energy, radiation and illumination, allows capturing reflected light with conventional (and some not-so-conventional) cameras andfilms.

The basic strategy for sensing electromagnetic radiation is clear. Everything in nature has its own unique distribution of reflected, emitted and absorbed radiation. These spectral characteristics, if ingeniously exploited, can be used to distinguish one thing from another or to obtain information



about shape, size and other physical and chemical properties.

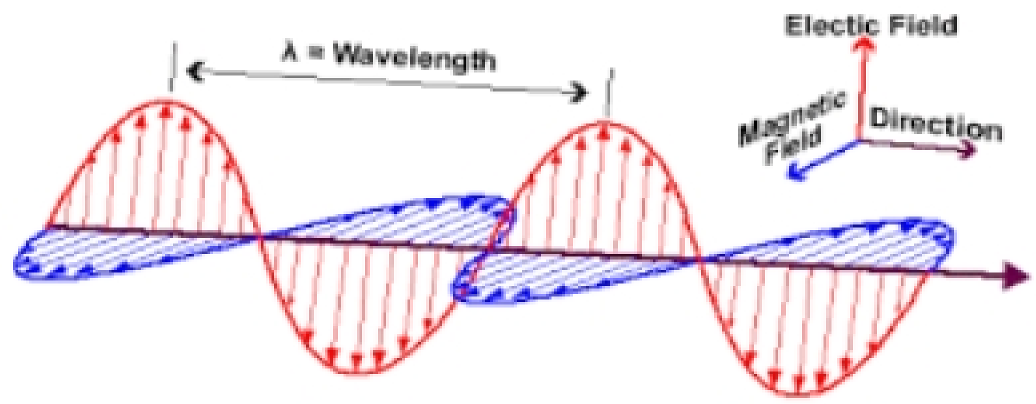
Basic principle of remote sensing

ELECTROMAGNETIC RADIATION AND THE ELECTROMAGNETIC SPECTRUM

EMR is a dynamic form of energy that propagates as wave motion at a velocity of c = 3 x 1010 cm/sec. The parameters that characterize a wave motion are wavelength (λ), frequency (ν) and velocity (c)

(Fig. 2). The relationship between the above is c

= λ ν



Electromagnetic Waves

Electromagnetic energy radiates in accordance with the basic wave theory. This theory describes the EM energy as travelling in a harmonic sinusoidal fashion at the velocity of light. Although many characteristics of EM energy are easily described by wave theory, another theory known as particle theory offers insight into how electromagnetic energy interacts with matter. It suggests that EMR is composed of many discrete units called photons/quanta. The energy of photon is

$Q = hc/\lambda = h\nu$

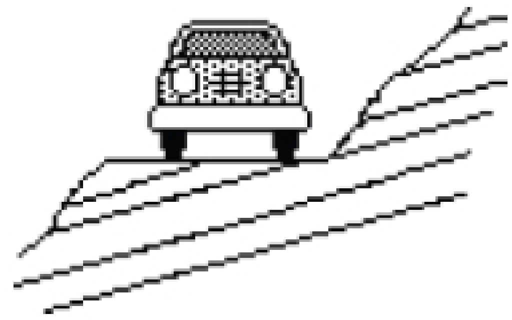
Where

Q is the energy of quantum,

h = Planck's constant

The geology of an area dictates the location and nature of any civil engineering structures. Roads and Railways Problems for a road or railway project may be caused by any of the following geologicalfeatures:

- Faults
- Junctions between hard and softformations
- Boundaries between porous and impermeableformations
- "pring-lines
- Fracturedgranites
- weatheredschists2
- Landslipareas
- Areas where beds dip towards the road or railway, as shown in the adjacentdiagram.



Roads On Inclinal Beds

1 - A passage for surplus water from a dam.

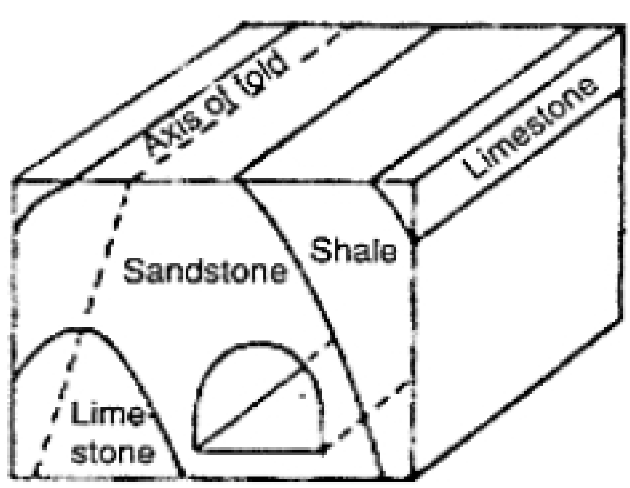
2 - A coarse-grained metamorphic rock that consists of layers of different minerals and can be split into thin irregular plates.

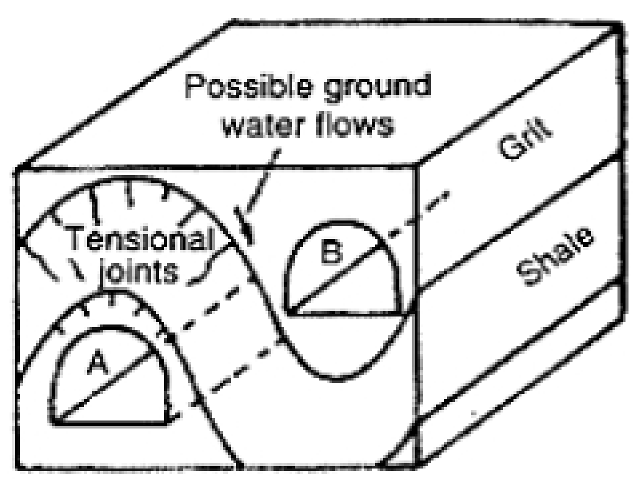
If the terrain and proposed route are such that these features cannot be avoided, construction of suitable safety features is required. Earthwork construction must include an embankment to stabilize areas of landslip. Lightweight material on a concrete raft may be needed where the road traverses deep, compressibledeposits.

Drainage holes can be drilled into rock to ensure that water is drained from potential slip surfaces, such as bedding planes. Unless water is properly drained from a rock embankment, pressures will build-up within and behind the rock, eventually causing it to fracture and collapse.

Effects of geological structures in tunneling Case of Folds

For tunneling purposes, folded rocks are in general unsuitable because the affected rocks are under great strain and the subsurface removal of material, i.e., creation of tunnels in such rocks may cause the release of the contained strain which may appear as collapse of the roof, or as caving or bulging of sides, or floor etc. If the tunneling work is taken up along the thick beds of limbs, parallel to the axis of the fold, because the disadvantages associated with crests and troughs do not occur. This is because, along the crests of folds, the beds contain numerous tensions and other factures and if the tunnel is made through them, frequent falling of rocks from the roof mayoccur.



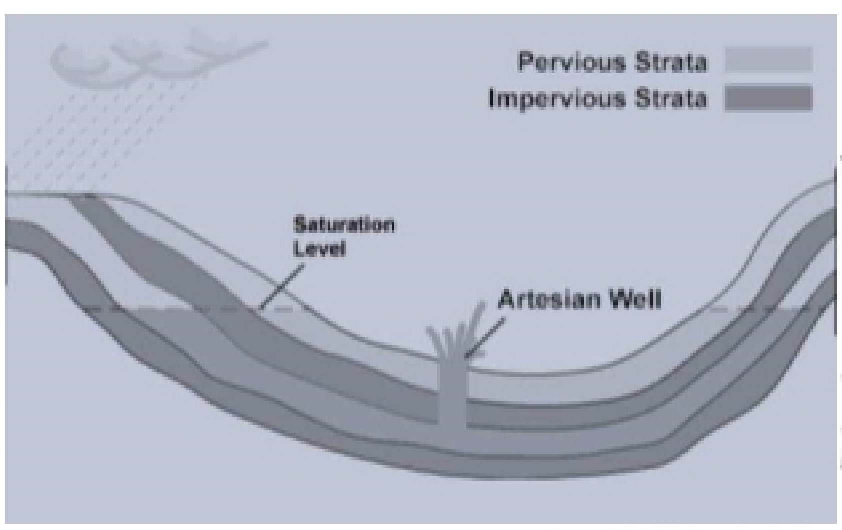


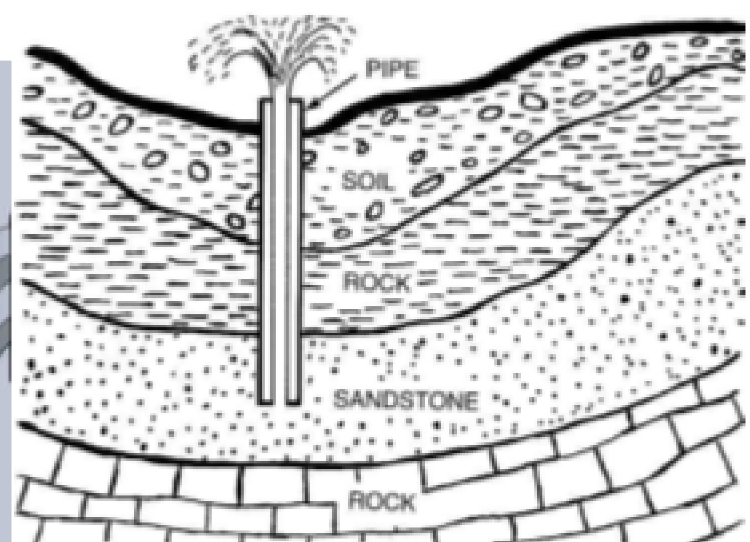
Tunneling Anticlinalfold

At certain situations, where folds occur with wedge-shaped rocks tapering downwards may provide a desirable situation for tunneling. This is because the wedge-shaped shapes will lie perpendicular to the curved bedding and prevent rocks from falling as they act as key rocks in arches. In spite of this, as the fractured rock is not cohesive, it cannot be strong and competent. Its competence becomes lesser when its openings get saturated with water. Hence, tunneling by excavation in such ground is unsafe and unstable. Over break also occurs there considerably which means lining work will becostlier.

Along the troughs, rocks will be highly compressed. Therefore they will be tough and offer greater resistance for excavation. This means tunneling work will be difficult and progress less. Further, by virtue of dip of limbs, water will be percolated along the bedding planes and accumulate along troughs. If the accumulation of water is of artesian1 type then tunneling along troughs may encounter sever ground water problems and shall be disastrous also.

1-An artesian aquifer is a confined aquifer containing groundwater under positive pressure. This causes the water level in a well to rise to a point where hydrostatic equilibrium has been reached. This type of well is called an artesian well. Water may even reach the ground surface if the natural pressure is high enough, in which case the well is called a flowing artesian well.



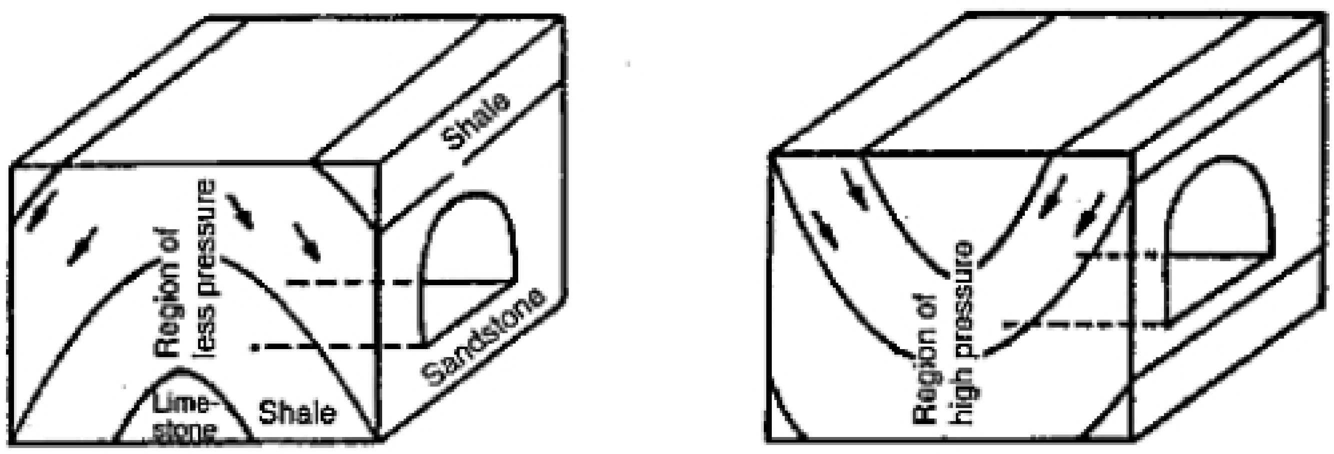


Artesian wells

Artesian wells

When the tunnel alignment is perpendicular to the axis of the fold, this situation is also undesirable because, under such a condition, different rock formation are encountered from place to place along the length of the tunnel and also the tunnel has to pass through a series ofanticlinesandsynclines.Thesetwofactorsbringheterogeneityinthephysicalpropertiesof

rocks and also in physical conditions in anticlinal parts. In synclinal folds, the conditions are exactly reversed



Tunneling synclinal fold

Effect of faults at Tunnel site:

Normally faults are harmful and undesirable as they create a variety of problems. The problems with faults occurring at tunnel site can be described as followed.

1. Active fault zone: These are the places where there is scope for further recurrence of faulting which will be accompanied by the physical displacement of lithological units. Such faults will lead to dislocation and discontinuity in the tunnel alignment. So occurrence of any active fault in tunnels is veryundesirable.

2. Inactive fault zone: These are the places where there is no scope of further occurrence of faulting, yet these prone to intense fractures due to earlier faults. This means that these zones are of great physical weakness. So if such zones occur along the course of a tunnel, it is necessary to providelining.

3. Highly permeable zones (with or without faulting): Zones that are highly porous, permeable and decomposed may occur at tunnel sites these also require heavy concrete lining.

Effect of Joints on Tunneling:

Joints interfere with tunneling work as follows:

1. They cause serious ground water problems, unless the water table position is reasonably below the level of the tunnelfloor.

2. If the joints re too many, they may severely hamper the competence even inherently strong rocks and render them unsuitable fortunneling.

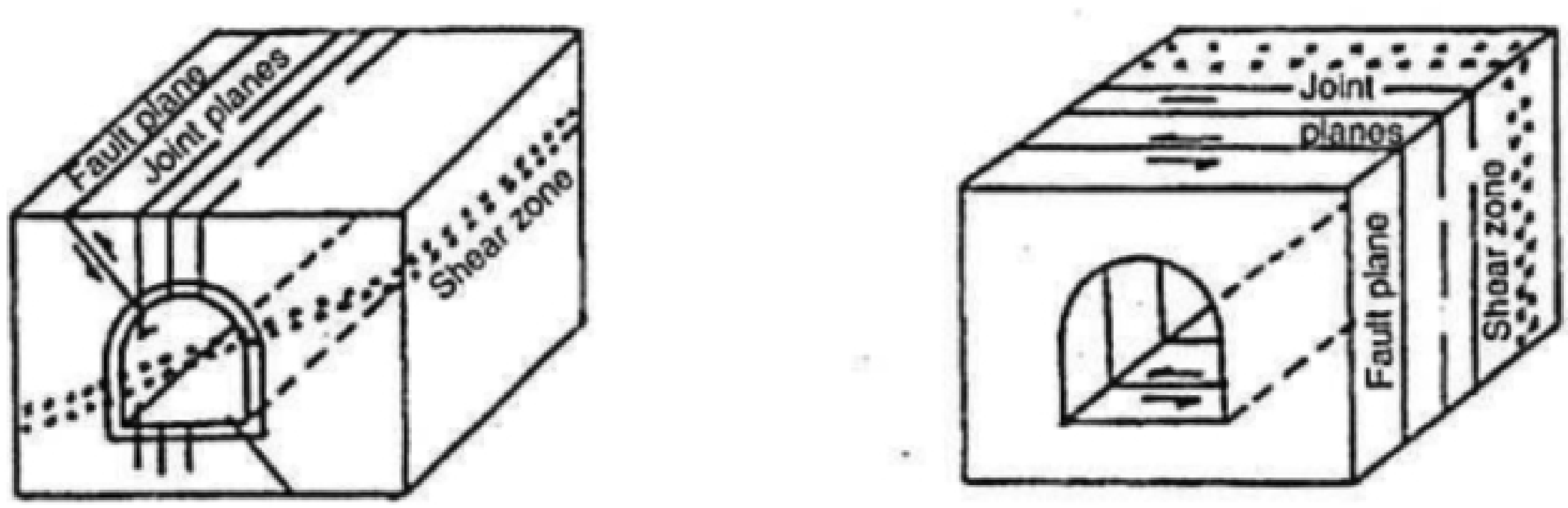
3. The openings of joint planes enable the ground to be saturated with water and thereby decrease the strength of the rocks considerably. So, joints become responsible indirectly also for reduction in strength of rocks at the tunnelsite.

4. If joints occur unfavorably, they may cause fall of rocks from the roof of the tunnel. This means tunneling will be unsafe and needslining.

5. Joints may act as sites for the development of solution cavities and solution channels in lime stone terrain. This is due to the action of percolating carbon dioxide-bearingwaters.

Joints, being oriented cracks, their attitude with reference to the tunnel alignment are also very important. Such of these joints which strike parallel to the tunnel axis naturally persist

for long distances and hence are undesirable for tunneling. On the other hand, joints which strikeobliqueorperpendiculartothetunnelaxis will obviouslyhavealimitedeffectonthem.



Tunneling in jointed beds

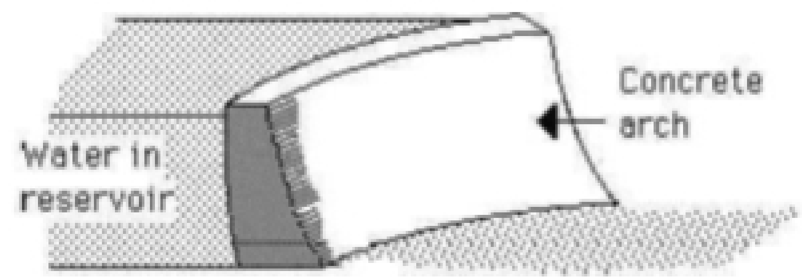
In sedimentary rocks, the occurrence of joints is undesirable because these rocks, which are originally weak and incompetent, and become weaker.

In metamorphic rocks also, joints are not characteristic, but are frequently present. Granite genisses and quartzites, being very competent, can remain suitable for tunnelling even if some joints occur in them. But schist and slates with joints will become very incompetent and necessarily require lining.

Dams:

Geological investigations of a site proposed for construction of a dam must be complete and detailed. Features such as rock-types, geological structures, weathering, fractures and fissures must all be considered. The main considerations are that the material on which the dam rests must be able to carry the weight of the structure without failing. The geology upon which the dam is built must also be impervious1 to water. The abutments2, (the rock faces to which the dam wall is attached) must also be impervious and strong enough to support the dam wall, especially in the case of an arch dam (where more force is transmitted to the abutments).

Left: Cross-section through an arch dam.



Cross section of Arc

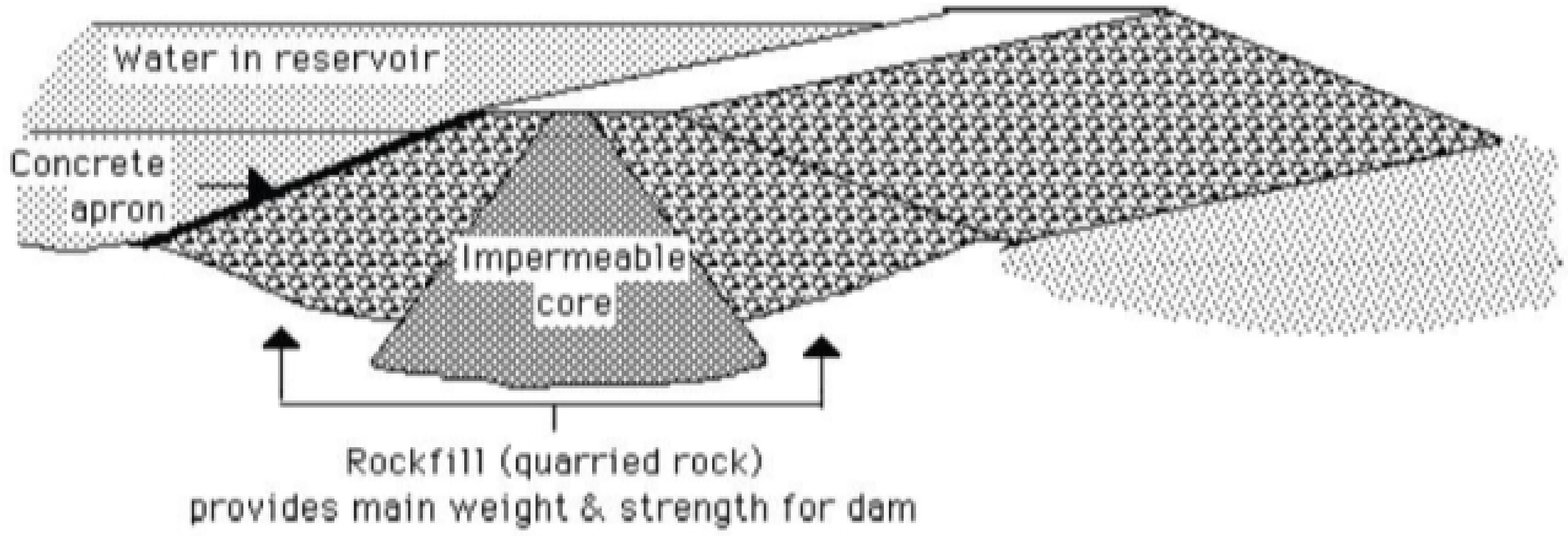
Dam Failure of a dam can be due to many factors including:

- Earthquakes
- A sudden drop in waterlevel
- Inadequate protection of the reservoir side of the dam from waveaction
- Insufficientspillwaycapacity,sothatwaterflowsoverthewholeofthedamsurface,with consequent erosion

1 - Not allowing something to pass through; not penetrable. 2 - A structure built to support the lateral pressure of an arch or span, e.g., at the ends of a bridge.

The type of dam selected depends largely on the nature of the surrounding rocks. If they are strong and stable, an arch dam, such as the one shown below can be constructed. This type of dam requires a minimum of construction materials, but the concrete must be of high quality. The Barossa Reservoir Dam (the Whispering Wall), The Roosevelt Dam are examples of an arch dams.

An earth and rock fill embankment dam, as shown in the diagram below must be constructed where the surrounding rocks are not strong enough to support an arch dam. This type of dam is more expensive to build, requiring much more material. The main weight and strength of the dam is provided by compacted quarried rock. The core is made of impermeable material, such as clay, bitumen1 or concrete.



Cross-section through an embankment dam.

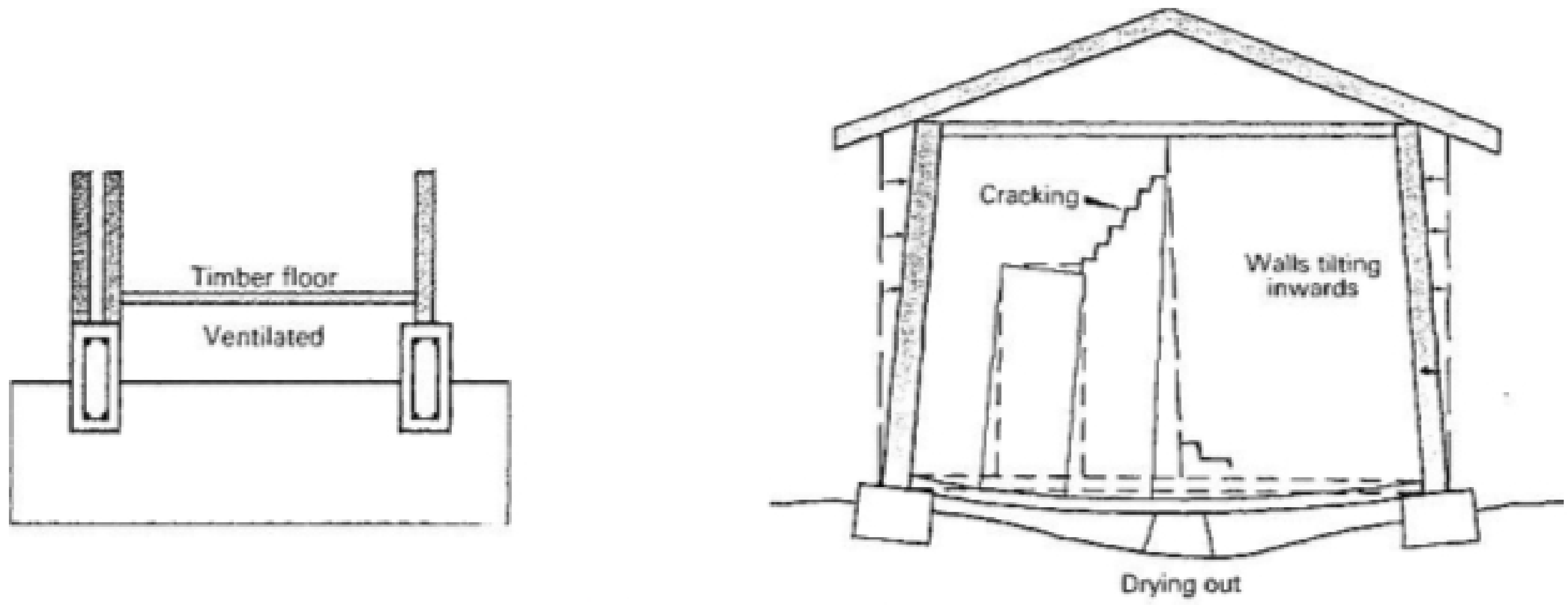
Rock and soil tests are taken before homes are built. For larger buildings, deep holes may be drilled to test the strength and stability of the rocks under the proposed building. The type and strength of foundations required are determined from the results of these tests. People who build houses in areas of clay soil are likely to find that windows and doors stick and that cracks appear in brick walls. Piers under the house move and concrete slabs may crack. This is because clays swell when wet and shrink after drying. Adelaide's 'Bay of Biscay' soils, which underlie some of the north-eastern suburbs, contain a type of clay called montmorillonite which swells to almost twice its dry volume when wet. This is responsible for many cracks in older buildings. These soils are said to be expansive.

1 - A metamorphic rock with a banded or foliated structure, typically coarse-grained and consisting mainly of feldspar, quartz, and mica.

Two other types of problem soils are collapsing soils, which settle rapidly on wetting, and compressible soils that consolidate and settle slowly over several years.

The footing is that part of a house that is in direct contact with the soil or rock forming the foundation. Strip footings were the earliest type used. These consisted of concrete strips beneath the walls of the house.

Strip footings proved to be unsuitable in areas of expansive soil, as the soil under the house dried out and shrank (shrink), causing the problems shown in the diagram below.



Cross-section through strip footings

SLOPE FAILURE

The term slope failure covers a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. The photograph below shows the Thredbo landslide (30 July 1997) where 18 people died.

Causes of Slope Failure

Gravity

Although gravity acting on an over-steepened slope is the primary cause of a landslide, other contributing factors include:

- Earthquakes that create stresses causing weak slopes tofail.
- Volcanic eruptions that produce loose ash deposits and debrisflows.
- Vibrations from machinery, traffic, blasting, and even atmospheric thunder that may trigger failure of very weak slopes.
- Excessweightfromaccumulationofrain,snow,thestockpilingofrockorore,orfrombuilt structures that may stress weak slopes to failure.

Relief

Slope failure occurs in hilly or mountainous regions all over the world — essentially wherever there is any significant topographic relief. In Australia, significant landslides coincide with mountainous areas.

Water

Rock and soil slopes are weakened through saturation by melting snow or heavy rain. Water filling the pores of permeable materials allows the grains to slide past each other with little friction. Water acts as a lubricant increasing the ease of movement of rock and soil particles (and therefore slope failure). Slope material that becomes saturated with water may develop a debris flow or mudflow. The resulting slurry of rock and mud can pick up trees, houses, and cars, causing the blocking of bridges and tributaries and increasing the likelihood of flooding.

Undercutting

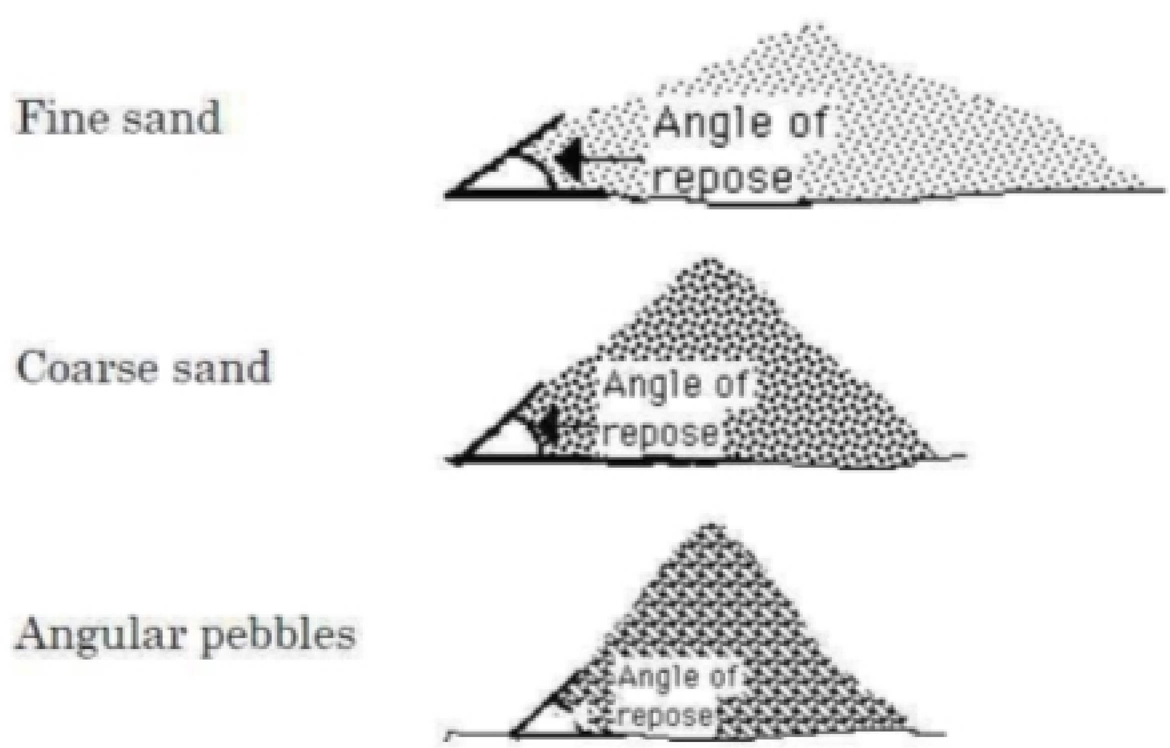
Undercutting is erosion of material at the foot of a cliff or steep bank — e.g. on the outside of a meander. Ultimately the overhang collapses and the process is repeated. Undercutting caused by rivers, glaciers, or ocean waves creates over-steepened slopes, which are prone to failure. Human activities, such as quarrying and road construction also result in undercutting.

Rock Types

In unconsolidated material, that is material not held together by cement or by a strong interlocking crystal structure, landslides start after a significant part of the whole rock mass is saturated with water and therefore lubricated. A single shock or vibration can trigger the down-slope movement of an entire unstable hillside. Any area of very weak or fractured materials resting on a steep slope will be likely to experience landslides.

Slope Angle

A pile of sand always assumes the same angle of slope, whether it is a few centimetres high, or a huge sand dune. The angle that the sand makes with the horizontal is called the angle of repose. It is about 37° for fine sand, and steeper for coarse sand and angular pebbles, as shown in the diagrams below.

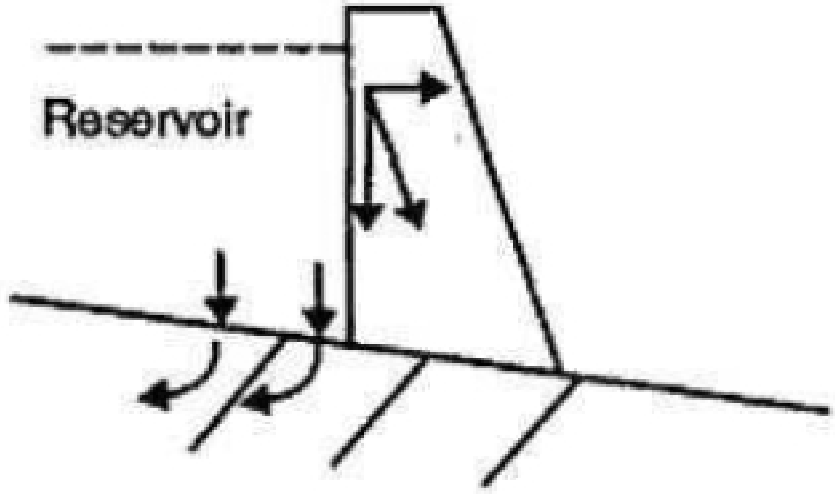


If a slope is steepened beyond this natural angle, for example for a road cutting, it then becomes unstable and the slightest vibration may lead to slope failure. The angle of repose is reduced if the sand or unconsolidated rock material becomes water-saturated. Moreover, the angle of repose is significantly reduced underwater.

Effect of Geological Structures on location of Reservoirs:

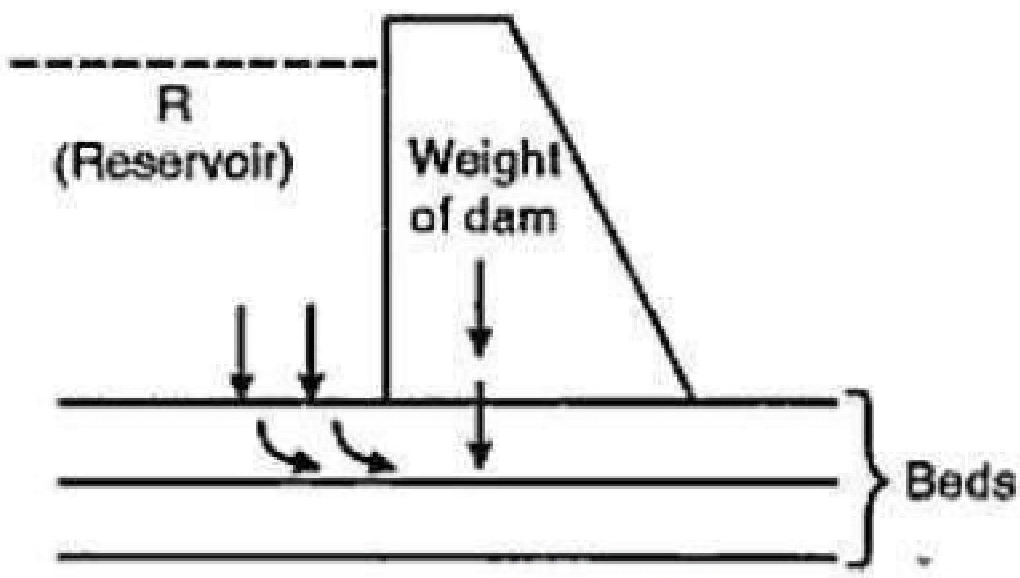
If any of the following geological settings occur at the reservoir site, there will be significant difference in terms of leakage of reservoir water.

1. The case wherein beds of the limb dip in the upstream direction, there will not be any effective leakage of water from the reservoir. This is so because all percolated water will be directed in the upstream direction only, along the beddingplanes.



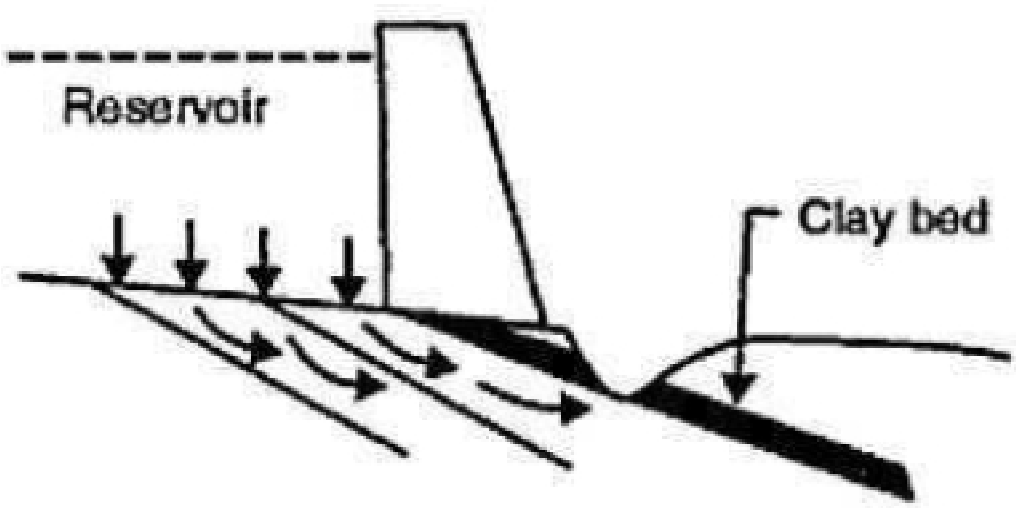
Reservoir Along Incline Beds

2. The case wherein if strata at the reservoir site are horizontal, there may baa little seepage of water of the reservoir in the downstream side along the horizontal beddingplanes.



Reservoir Along horizontal Beds

3. The case wherein strata dip in the downstream direction, there shall be considerable leakage of reservoir water along the bedding planes which are dipping in the downstream direction.



Reservoir on clay bed (inclined strata)

4. In the case of strata containing faults, the faults which dip in the downstream direction are more harmful. This is so because they not only cause effective and significant loss of water butalsoendangerthesafetyofthedambycreating,upliftpressureoverit.However,ifthe water table occurs at or near the surface of the reservoir site, faults do not contribute to loss of water. If server fault or shear zone occurs as outcrops along the upstream course of the river,theygeterodedquicklyandcontributeheavilytothe loadoftheriver.Thismeanssever silting problems in the concernedreservoirs.

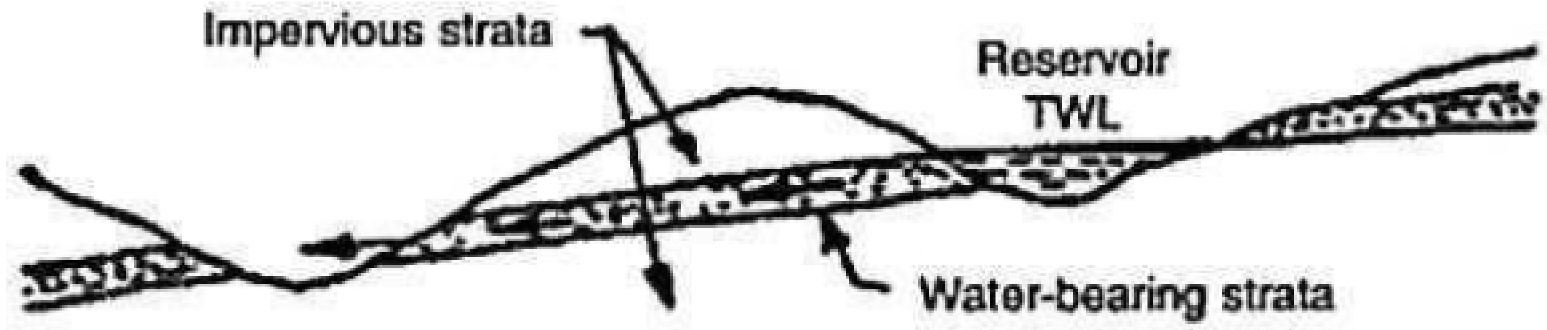
5. In the case of joints present in the reservoir site or basin, they act as avenues for serious leakage of water. The prevailing water table position will affect the influence ofleakage.

a. If the ground water is contributing to the surface water (effluent conditions), the resultant effect will nullify the effect of presence of joints and cause no leakage. If the ground water is fed by surface water (influent conditions), this will permit the joints to play their role in leakage of water as expected. But a matter of consolation is that even if joints are contributing to the leakage of water, in course of time, this adverse effect partly disappears slowly, because the fine silt and clay settle in the openings of joints and seal themoff.

b. The other adverse effect of joints is similar to faulting when it occurs in the upstream side. If jointing has occurred in the valley in the upstream side, such disintegrated rocks under quick erosion and contribute to the river load heavily. This means that rate of silting will be very heavy in the reservoir. This, in turn, reduces the life of the reservoir. So, as a precaution, such places have to be grouted or coveredsuitably.

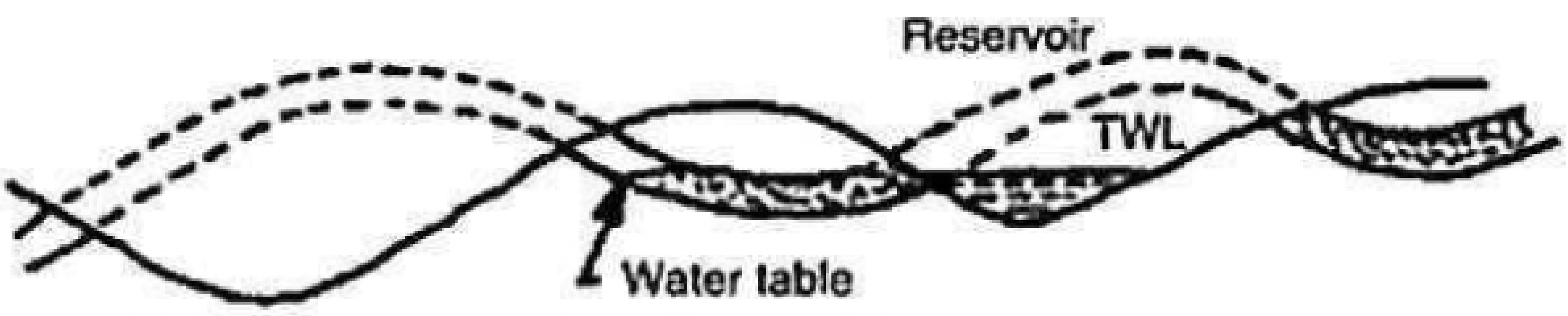
In the case where beds strike parallel to the length of the valley, topography and the position of occurrence of different beds at the reservoir site are taken granted for the same as, topographically, another parallel valley occurs at the lower level and adjacent to the valley containing the reservoir. In this situation, lithological, a permeable bed (say, sandstone or cavernous lime stone) occurs in between the impermeable beds (like shales). When all the beds are conformable and striking parallel to the length of the valley, with respect to the relative position of the beds, the permeable bed occurs at the rim of the reservoir and all beds are dipping towards the same side. Under theseconditions,

c.When tilted permeable bed is exposed in the adjacent valley, there will be leakage of the reservoir water into the adjacent valley lying at the lowerlevel.



Impervious strata

b.



If the folding occurs in such an area, the leakage won't occur

c. If a fault occurs in the reservoir area, and if the permeable bed through which reservoir water percolates gets terminated against an impermeable bed along the fault plane, the leakage is prevented.

EARTHQUAKE RESISTANT CONSTRUCTION

Earthquake is a natural phenomenon occurring with all uncertainties. Engineering design aims to link economics, social, environmental and safety factor to produce the best solution. India is a large country. Nearly two thirds of its area is earthquake prone. A large part of rural and urban buildings are low-rise buildings of one two three stroyes. Many of them may not be adequately designed from engineers trained in earthquake engineering. Most loss of life and property due to earthquakes occur due to collapse of buildings. The number of dwelling units and other related small-scale constructions might double in the next two decades in India and other developing countries of the world. This amplifies the need for a simple engineering approach to make such buildings earthquake resistant at a reasonably lowcost.

The behaviour of a building during earthquakes depend critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. Hence, at the planning stage itself, architects and structural engineers must work together to ensure that the unfavorable features are avoided and a good building configuration is chosen. The main objective of seismic resistant construction is that the structure does not collapse during mild earthquakes. This also helps in preventing catastrophic failure of the structure giving sufficient warning during severe earthquakes thereby saving preciouslives.

In this presentation emphasis will be given to the performance of unengineered buildings during earthquake and some methods to reduce the damages during earthquake.

EARTHQUAKE RESISTANT CONSTRUCTION

Earthquake is a natural phenomenon occurring with all uncertainties. Among all the natural calamities, the most devastating one is earthquake. During the earthquake, ground motions occur in a random fashion, both horizontally and vertically, in all directions radiating from epicenter. These ground motions cause structures to vibrate and induce inertia forces on them. Hence structures in such locations need to be suitably designed and detailed to ensure stability, strength and serviceability with acceptable levels of safety under seismic effects.

The interest of an engineer in earthquakes is mainly from design point of view. He studies them so that the structure he builds can safely withstand the earthquake shocks and the associated erratic ground motion.

At present, the principle of earthquake-resistant design of building has two aims:

1. The building shall withstand with almost no damage to moderate earthquake which have probability of occurring several times during life of abuilding.

2. The building shall not collapse or harm human lives during severe earthquake motions which have a probability of occurring less than once during the life of thebuilding.

In the former case deformation of the structures remain within the elastic range.

In the latter case, they may exceed the elastic limit and the building should be designed with sufficient ductility to survive collapse.

In order to satisfy these aims, building design should conform following rules:

(a) The configuration of the building (Plan and elevation) should be as simple aspossible.

(b) The formation should generally be based on hard and uniformground.

(c) The members resisting horizontal forces should be arranged so that torsional deformation is notproduced.

(d) The structure of the building should be dynamically simple anddefinite.

(e) The frame of the building structure should have adequate ductility in addition to requiredstrength.

(f) Deformations produced in a building should be held to values, which will not provide obstacles to safety use ofbuilding.

2.0 Classification

Intensity of an earthquake is measured by an instrument called Richter Scale.

Classifications of earthquakes are as follows:

Slight: Magnitude up to 4.9 on the Richter scale

Moderate: Magnitude 5.0 to 6.9

Great: Magnitude 7.0 to 7.9 Very

Great: Magnitude 8.0 andabove

- Anearthquakeofmagnitudebelow2.0onthe ˂ ichter"caleusually can' tbefelt.
- An earthquakeofmagnitudebelow4.0onthe ˂ ichter"caledon' tcauseanydamage.
- An earthquake of magnitude over 5.0 on the Richter Scale usually can cause minor damage.
- An earthquake of magnitude 6.0 and above is considered strong andcause Substantialdamage.
- An earthquake of magnitude 7.0 and above is a major earthquake and renders worst possibledamage.

Seismic Design Philosophy for Buildings:

Severity of ground shaking at a given location during an earthquake can be minor, moderate and strong. Relatively speaking, minor shaking occurs frequently, moderate shaking occurs occasionally and strong shaking rarely. For instance, on average annually about 800 earthquakes of magnitude 5.0-5.9 occur in the world, while the number is only about 18 for magnitude range 7.0-7.9, and the rare earthquake may occur only once in 500 years or once in 2000 years. As we know that the life of the building itself may be only 50 or 100 years, a conflict arises: whether to design the building to be "earthquake proof" where in there is no damage during the strong but rare earthquake shaking or should we do away with the design to building. Clearly, the former approach is too expensive and the second approach can lead to a major disaster. Hence, the design philosophy should lie somewhere in between these twoextremes.

Seismic Risk to Buildings in India:

The construction may generally be classified into two types:

1. Non-Engineered BuildingConstruction
2. Engineered Construction including building andinfrastructure

Non-Engineered buildings are those which are spontaneously and informally constructed in various countries in the traditional manner without any or little intervention.

by qualified architects and engineers in their design. Such buildings involve field stone, fired brick, concrete blocks, adobe or rammed earth, a combination of wood with these traditional locally available materials in their construction. Cement and lime are sometimes used as mortar. Reinforced concrete lintels, floor, roof slabs and beams are also being increasingly used. In some cases, use of reinforced columns and beams is also made particularly for shopping centers and school buildings, but here also a post beam type simple concept is frequently adopted in a non-engineered manner without taking into consideration the stability of the system under horizontal seismic forces. Masonry buildings of all types, except those constructed with earthquake resisting elements, are at the greatest risk of heavy damage in seismic zoneIII and of destruction to collapse in zones IV and V.

Classification of Seismic Zones in India:

The earthquake resisting features specified to be incorporated while constructing any new building depend on the seismic intensity, zone in which the building is located, the base soil and the functional use of the building, whether considered important or ordinary. The extra cost of these resisting features will vary accordingly.

India is divided into 5 seismic zones in ascending order of magnitude of earthquake. The map was taken up for further revision after the Lathur earthquake of 1993. the resulting revised map published in IS:1893-2002(part I) where in the number of zones has been reduced to 4

i.e. II to V only, zone I being merged in zone II , and zone III now further expanded in the peninsular area.

The seismic zone map shows that of the total land area of the country, seismic zone V covers 12%, zone IV 18% and zone III about 27%, thus 57% could be subjected to damaging e

Earthquake intensity, masonry building inparticular.

Seismic Effects onStructures:

Inertia forces in structures:

Earthquake causes shaking of the ground. So the building resting on it will experience motion at its base. From Newton's I Law of Motion, even though the base of the building moves with the ground, the roof has a tendency to stay in its original position. But since the walls and columns are connected to it, they drag the roof along with them. This tendency of the roof to continue to remain its previous position is known as inertia. In the building, since the walls or columns are flexible, the motion of the roof is different from that of the ground.

Horizontal and Vertical Shaking:

Earthquake causes shaking of the ground in all three directions- along two horizontal directions (x &y) and the vertical direction (z). During the earthquake, the ground shakes randomly back and forth along each of these directions. All structures are primarily designed to carry the gravity loads in the vertical direction. Hence, most structures tend to be adequate against vertical shaking. However, horizontal shaking along x and y directions remains a concern. Structures designed for gravity loads, in general, may not be able tosafelysustain the effects of horizontal earthquake shaking. Hence it is necessary to ensure adequacy of the structures against horizontal earthquakeeffects.

Causes of Earthquake Damage:

The conventional masonry, particularly in unreinforced and non- engineered structures, being very weak in resisting tensile and shear stresses, leads to disastrous collapse of the entire building/ structure, causing heavy damage to property and loss of lives.

The main deficiencies in the conventional non- engineered/ un-reinforced masonry construction and other reasons for the extensive damage in such buildings are:

1. Heavy dead weight and very stiff buildings, attracting large seismic inertiaforces.
2. Very low tensile strength, particularly with poormortars.
3. Low shear strength, particularly with poormortars.

4. Brittle behavior in tension as well ascompression.
5. Weak connection between wall andwall.
6. Weak connection between roof andwall.
7. Stress concentration at corners of doors andwindows.
8. Overall unsymmetry in plan and elevation of thebuilding
9. Unsymmetry due to imbalance in the sizes and positions of openings in thewall.
10. Defects in construction, such as use of substandard materials, unfilled joints between bricks.

stock under strong earthquake shaking. Thus, it is very important to improve the seismic behavior of masonry buildings. A number of earthquake-resistant features can be introduced to achieve this objective.

Ground vibrations during earthquakes cause's inertia forces at locations of mass in the building. These forces travel through the roof and walls to the foundation. The main emphasis is on ensuring that these forces reach the ground without causing major damage or collapse. Of the three components of a masonry building (roof, wall and foundation the walls are most vulnerable to damage caused by horizontal forces due to earthquake. A wall topples down easily if pushed horizontally at the top in the direction perpendicular to the plane (termed weak direction), but offers much greater resistance if pushed along its length (termed strong direction, Horizontal inertia forces developed at the roof transfers to the wall acting either in the weak or in the strong direction. If all the walls are not tied together like a box, the walls loaded in their weak direction tend totopple

To ensure good seismic performance, all walls must be joined properly to the adjacent walls. In this way, walls loaded in the weak direction can take advantage of the good lateral resistance offered by walls loaded in strong direction further, walls also need to be tied to the roof and foundation to preserve their overall integrity.

Improving Behavior of Masonry Walls

Masonry walls are slender because of their small thickness compared to their height and length. A simple way of making these walls behave well during earthquake shaking is by making them act together as a box along with the roof at the top and foundation at the bottom. A number of construction aspects are required to ensure this box action.

Firstly, connections between the walls should be good. This can be achieved by

(a) Ensuring good interlocking of the masonry courses at thejunction.

(b) Employing horizontal bands at various levels, particularly at the lintellevel.

Secondly, the size of the doors and window opening need to be kept small. The smaller the opening, larger is the resistance offered by the wall.

Thirdly, the tendency of wall to topple when pushed in the weak direction can be reduced by limiting its length-to-thickness and height-to-thickness ratios. Design codes specify limits to these ratios. A wall that is too tall or too long in comparison to its thickness, is particularly vulnerable to shaking in its weak direction. Importance of Reinforcements in Masonry Building

The walls, if constructed with plain masonry would be incapable of resisting the magnitude of horizontal shear and bending forces imposed on them during earthquakes. For this reason, in the modern reinforced masonry systems, reinforcing steel is incorporated to resist the shear and tensile stresses, so developed. When these walls are subjected to lateral forces acting on them, they behave as flexural members spanning vertically between floors and horizontally between pilasters/ lateral walls. Therefore reinforcement in both vertical and horizontal directions is required to be provided to develop resistance against torsion.

Role of Horizontal Bands

Horizontal bands are the most important earthquake-resistant feature in masonry buildings. The bands are provided to hold a masonry building as a single unit by tying all the walls together. There are four types in a typical masonry building named after their locations in the building. They are:

(a) Plinth band: This should be provided in those cases where the soil is soft or uneven in their properties, as it usually happens in hilly areas. This band is not toocritical.

(b) Lintel band: This is the most important band and covers all door and windowlintel.

(c) Roof band: In buildings with flat reinforced concrete or reinforced brick roofs, the roof band is not required because the roof slab itself plays the role of a band. However, in buildings with flat timber or CGI sheet roof, a roof band needs to be provided. In buildings with pitched or sloped roof, the roof band is veryimportant.

(d) Gable band: It is employed only in buildings with pitched or slopedroofs.

Design of LintelBands

During earthquake shaking, the lintel band undergoes bending and pulling actions. To resist these actions, the construction of lintel band requires special attention. Bands can be made of wood including bamboo strips) or of reinforced concrete (RC) (Fig.8); the RC bands are the best. The straight lengths of the bands must be properly connected at the wall corners. This will allow the band to support walls loaded in their weak directions by the walls loaded in their strong direction. Small lengths of wood spacers (in wooden band) or steel links (in RC bands) are used to make the straight lengths of wood runners or steel bars act together. In wooden bands, proper nailing of straight lengths with spacers is important. Likewise, in RC bands, adequate anchoring of steel links with steel bars isnecessary.

Role of Vertical Reinforcements in Walls:

When the ground shakes, the inertia force causes the small-sized masonry wall piers to disconnect from the masonry above and below. These masonry sub-units rock back and forth, developing contact only at the opposite diagonals (Fig. 10(a)). The rocking of a masonry pier can crush the masonry the corners. Rocking is possible when masonry piers are slender, and when weight of the structure above is small. Otherwise, the piers are more likely to develop diagonal (X-type) shear cracking (Fig. 10(b)); this is the most common failure type in masonry buildings.

lintel band or at the skill level. Sometimes, the building may also slide at the plinth level.

Vertical Reinforcement

Duringstrongearthquakeshaking,thebuildingmayslidejustundertheroof,belowthe

Embedding vertical reinforcement bars in the edges of the wall piers and anchoring themin the foundation at the bottom and in the roof band at the top (Fig 11), forces the slender masonry piers to undergo bending instead of rocking. In wider wall piers, the vertical bars enhance their capability to resist horizontal earthquake forces and delay the X-cracking. Adequate cross-sectional area of these vertical bars prevents the bar from yielding in tension. Further, the vertical bars also help protect the wall from sliding as well as from collapsing in the weak direction.

Protection of Openings in Walls:

The most common damage, observed after an earthquake, is diagonal X-cracking of wall piers, and also inclined cracks at the corners of door and window opening. When a wall with an opening deforms distorts and becomes more like a rhombus. Steel bars provided in the wall masonry all around the openings restrict these cracks at the corners

Structural Design:

Three important aspects to be considered in the design of earthquake resistant structures are given below:

1. The structure should be ductile, like the use of steel in concrete buildings. For these ductile materials to have an effect, they should be placed where they undergo tension and thus are able toyield.

2. Apart from ductility, deformability of structures is also essential. Deformability of structures is also essential. Deformability refers to the ability of a structure to dispel or deform to a significant degree without collapsing. For this to happen, the structure should be well-proportioned, regular and tied together in such a way that there are no area of excessive stress concentration and forces can be transmitted from one section to another despite large deformations. For this to happen, components must be linked to resisting elements

3. Damageability is another aspect to be taken into consideration. This means the ability of a structure to withstand substantial damage without collapsing. To achieve this objective "minimum area which shall be damaged in case a member of the structure is collapsed" is to be kept in view while planning. Columns shall be stronger than beams for that purpose and it is known as strong column and weak beamconcept.

Water bearingstrata

Artesian well

If water reaches the ground surface under the natural pressure of the aquifer, the well is called a flowing artesian well. An aquifer is a geologic layer of porous and permeable material such as sand and gravel, limestone, or sandstone, through which water flows and is stored.

An aquifer is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted using a water well. The study of water flow in aquifers and the characterization of aquifers is calledhydrogeology.