Importance of Geological Structures:

The physical properties of rocks, mineral and other materials of civil engineering, like textures, grain size are very important for a civil engineer. Similarly the secondary structures formed after the formation of rocks, like folds, faults and joints may be more suitable or unsuitable for a given civil engineering purpose. This is truer in the case of site rocks where foundations of constructions, such as dams, bridges, reservoir basins, tunnels, roads and railway lines, are planned.

Effects of Folding and their importance in civil engineering:

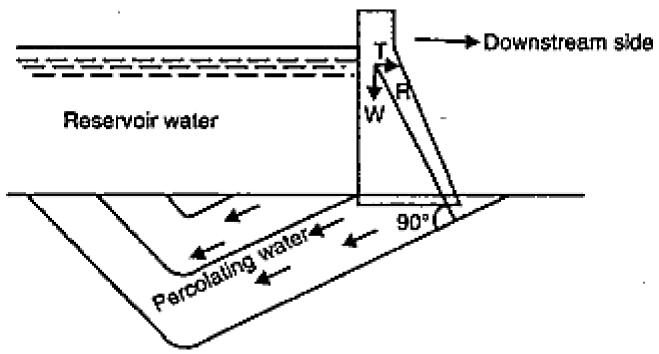
The deformities like folds can be of much important from civil engineering point of view. Their importance can be listed as followed.

Folding importance in location of Dams:

The site chosen for dam construction if contains folds, the inclination of limbs in the dam site may produce a geological setting which may be either more favourable or unfavourable at the dam site.

The situations of fold occurred at dam site can be listed as:

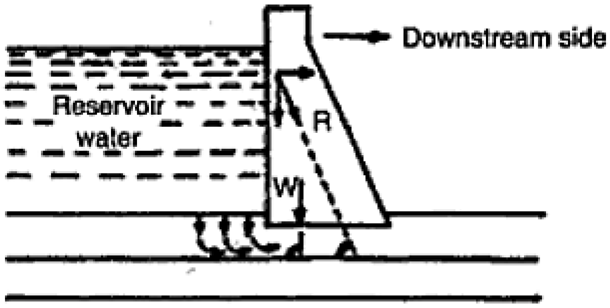
Situation 1: If the beds of limb of the fold dip gently in the upstream direction, it is more favourable and advantageous. This is because at the dam site, the weight of the dam (W) (as in the fig.) acts vertically downwards, and in addition, there also exists a great lateral thrust (T) due to reservoir water. The resultant force (R) of these two will be always inclined in the downstream direction. Depending on the quantum of reservoir water, the inclination (R) may vary from 10^o to 30^o from the vertical. This means the beds which have a gentle upstream dip will be perpendicular to the resultant force and hence can offer their best competence to withstand the stresses or loads acting in the area.



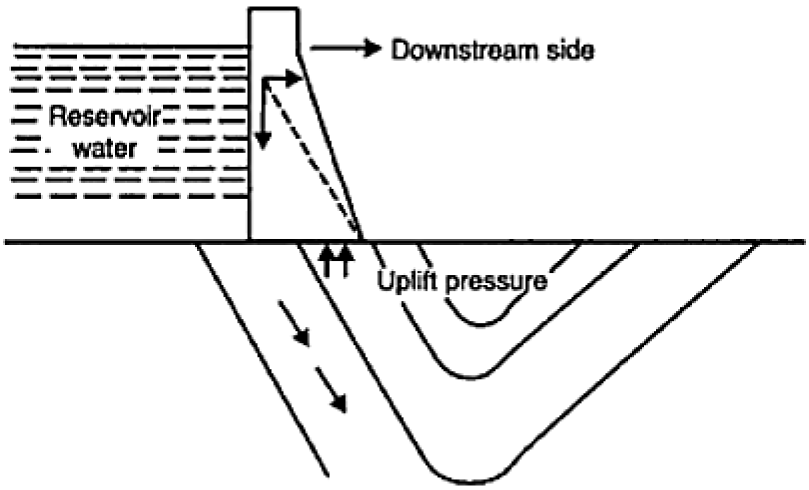
Normally sedimentary rocks will have the greatest load-bearing capacity when forces act perpendicular to the bedding planes yet the same rocks have the least competence when the forces act parallel to the bedding planes, this point is very important in considering the dam site.

The geological setting of folds can also indirectly contribute to the stability of dam, by completely eliminating the possible uplift pressure. This is because, if any possible leakage (shown by arrows in fig.) of reservoir water is directed to the upstream by virtue of the inclination of beds. Hence there is no scope for the flow of reservoir water beneath of the dam.

The above said advantage is not benefited when the dam is constructed on horizontal strata as shown below. In this situation, the resultant force in the dam will not be perpendicular and will be inclined downstream. This is not at all ideal though not bad. And the reservoir water, which is under great pressure, shall attempt to leak beneath the dam along the horizontal bedding planes, thereby causing uplift pressure, leading to unstable geological setting depending on the location of the dam.

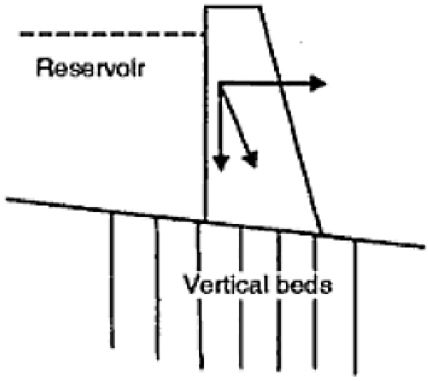


Situation 2:
If the dam is located over the limb of the fold which dips along the downstream direction as shown below. The resultant force of the dam will be parallel or nearly parallel depending on the amount of dip. In this situation the sedimentary beds are less competent, leading to unfavourable geological setting. In this situation there will be leakage of the reservoir water along the bedding planes, resulting further instability of the dam structure.



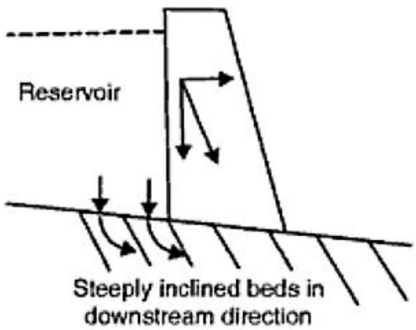
Situation 3:
Dam site with vertical beds. The occurrence of perfectly vertical beds is rather uncommon, as strata will normally have certain inclination. If any such occurrence is observed in the

given place, it will not pose problems of uplift pressure on dam, or leakage below the dam. However, it shall not have any advantage in terms of competence of rocks.



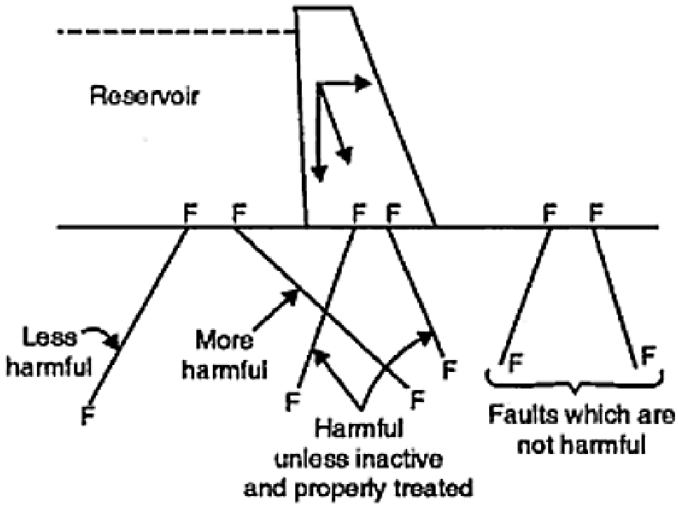
The Escales dam on the Ribagorzana river in northern Spain is an example where the dam is flanked by supporting alternating strata of cretaceous marls and limestone which dip almost vertically.

Situation 4:
If the case of beds is with steep downstream dip, this situation has all the disadvantages (as shown in fig.)



Further, the resultant force and the bedding planes are nearly parallel, which means that the beds will be less competent.

Effects of Faulted beds:
If the dam site shows any occurrence of faulting, irrespective of its attitude (i.e. dip & strike), under no circumstances, dam construction should not be taken. This is not only because of the fear of possible relative displacement of the site itself but also due to the possible occurrence of earthquakes which endanger the safety and stability of the dam. Further, if the fault zone is crushed or intensely fractured, due to the water pressure or construction load pressure, it becomes physically incompetent to withstand the forces of the dam. In such cases normally there will be more porosity and permeability of water leading to further reduction in competence.



Though the faulted site or fault zone is undesirable for dam construction, if the need arises and if one knows the tectonic history of the faulted region indicates that the site become stable and has no threat of possible recurrence of faulting, it can be recommended for dam construction after necessary treatment. Yet the following points should be considered.

1. If the faults occur in the downstream side, they will not be much harmful.
2. If the faults occur in the upstream side, the downstream dipping faults are dangerous because of the risk of uplift pressure and leakage. But if the faults dip in the upstream side are sealed properly avoiding the leak, there could be benefit of dam stability.
3. If the dam has to rest upon inactive faults, stringent precautions have to be taken to overcome the drawbacks of faulting.

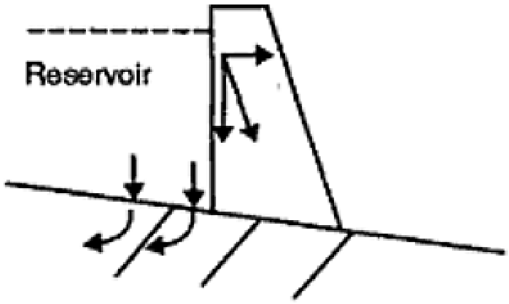
Effects of jointed beds:

Joints are most common geological structures found everywhere. They represent clear-cut opening and gaps of different magnitudes, contributing to weakness of the rock, porosity and permeability. As the rocks with the joints are not under any strain, they can be easily treated and the sites can be used for construction activities, unless the joints are prominent, closely spaced. Grouting is generally capable of overcoming the adverse effects of joints because it fills the gaps of joints; bring cohesion to the rocks, increases compactness and competence of the rock. It also reduces the porosity and permeability. (If the joints are comparable with the bedding planes, the effects are similar which have been discussed along with the folds).

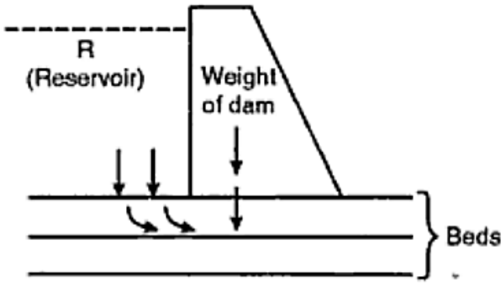
Effect of Geological Structures on location of Reservoirs:

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

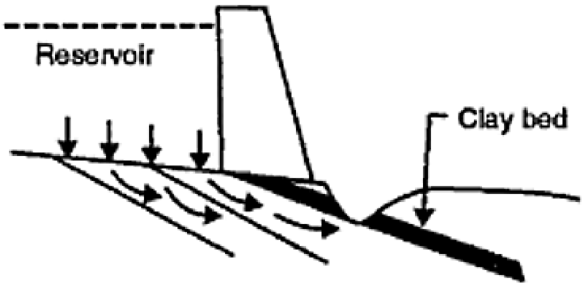
1. The case wherein beds of the limb dip in the upstream direction, there will not be any effective leakage of water from the reservoir. This is so because all percolated water will be directed in the upstream direction only, along the bedding planes.



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 bedding planes.



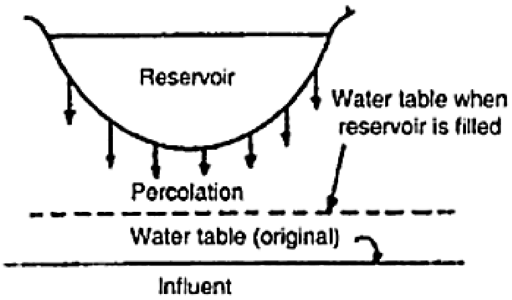
3. The case wherein strata dip in the downstream direction, there shall be considerable leakage of reservoir water along the bedding planes which are dipping in the downstream direction.

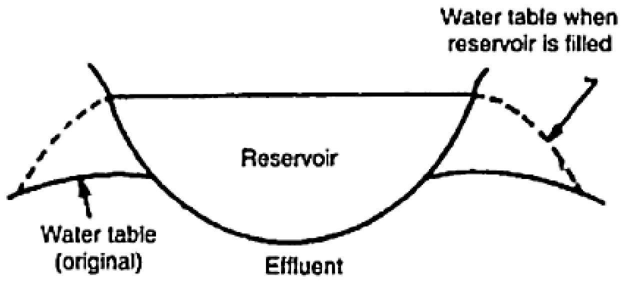


4. In the case of strata containing faults, the faults which dip in the downstream direction are more harmful. This is so because they not only cause effective and significant loss of water but also endanger the safety of the dam by creating, uplift pressure over it. However, if the water table occurs at or near the surface of the reservoir site, faults do not contribute to loss of water. If servere fault or shear zone occurs as outcrops along the upstream course of the river, they get eroded quickly and contribute heavily to the load of the river. This means sever silting problems in the concerned reservoirs.
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 of leakage.
    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 them off.

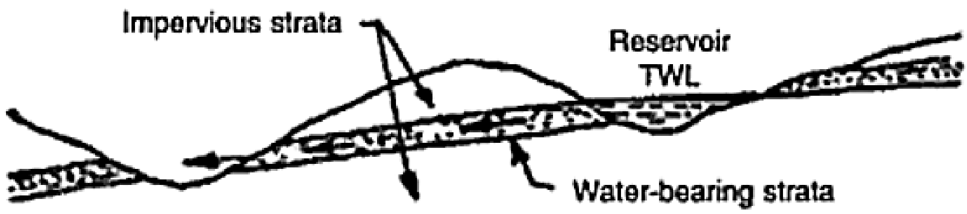
b. The other adverse effect of joints is similar to faulting when it occurs in the upstream side. If jointing has occurred in the valley in the upstream side, such disintegrated rocks under quick erosion and contribute to the river load heavily. This means that rate of silting will be very heavy in the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



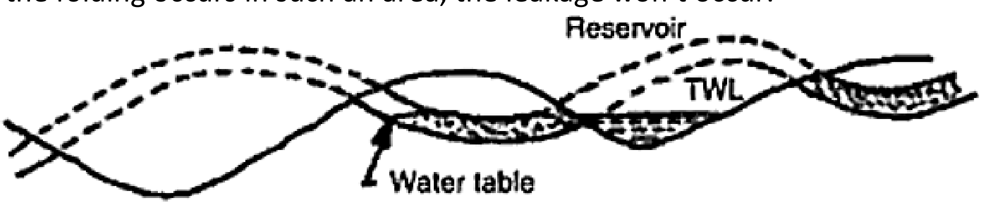


6. In the case where beds strike parallel to the length of the valley, topography and the position of occurrence of different beds at the reservoir site are taken granted for the same as, topographically, another parallel valley occurs at the lower level and adjacent to the valley containing the reservoir. 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 these conditions,

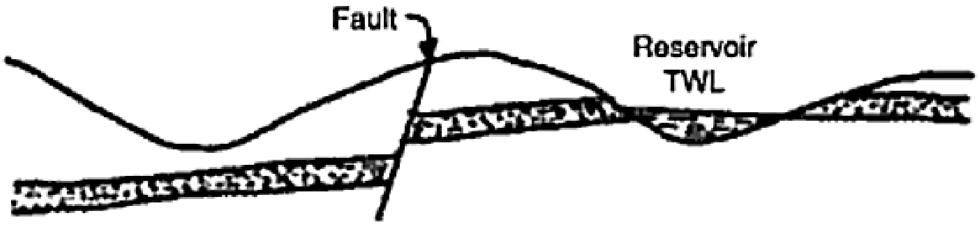
    a. When tilted permeable bed is exposed in the adjacent valley, there will be leakage of the reservoir water into the adjacent valley lying at the lower level.



    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.

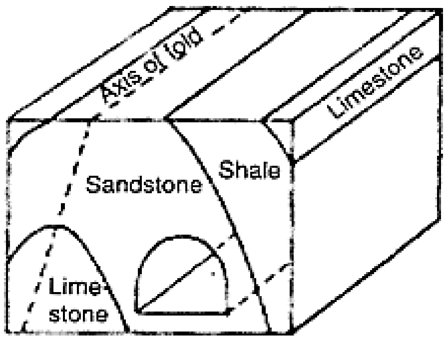


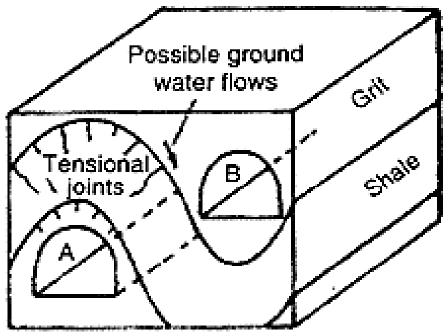
Effects of geological structures in tunnelling:

Case of Folds:

For tunnelling 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 tunnelling 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 may occur.

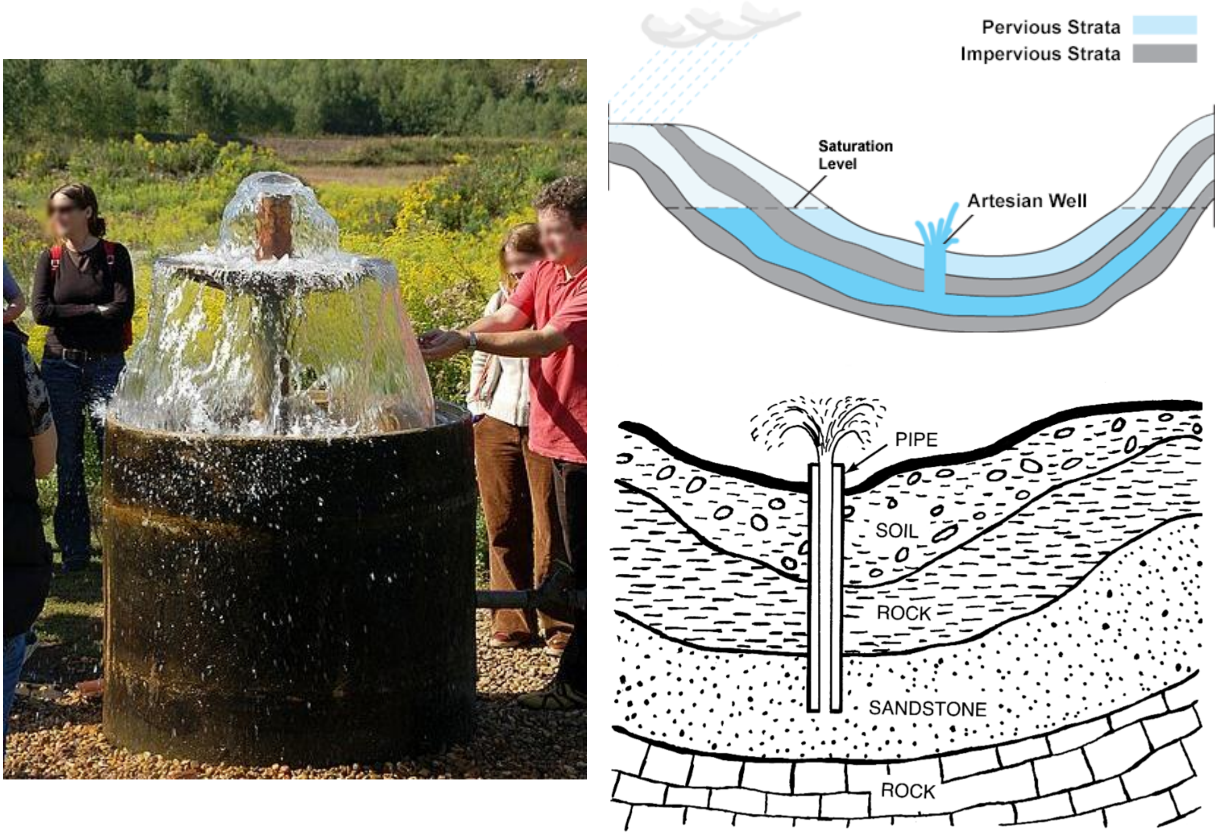




At certain situations, where folds occur with wedge-shaped rocks tapering downwards may provide a desirable situation for tunnelling. This is because the wedge-shaped shapes will lie perpendicular to the curved bedding and prevent rocks from falling as they act as key rocks in arches. In spite of this, 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, tunnelling by excavation in such ground is unsafe and unstable. Over break also occurs there considerably which means lining work will be costlier.

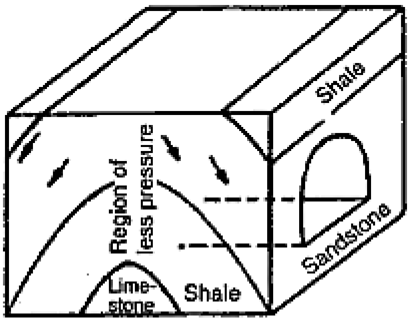
Along the troughs, rocks will be highly compressed. Therefore they will be tough and offer greater resistance for excavation. This means tunnelling work will be difficult and progress less. Further, by virtue of dip of limbs, water will be percolated along the bedding planes and accumulate along troughs. If the accumulation of water is of artesian[1] type then tunnelling along troughs may encounter sever ground water problems and shall be disastrous also.

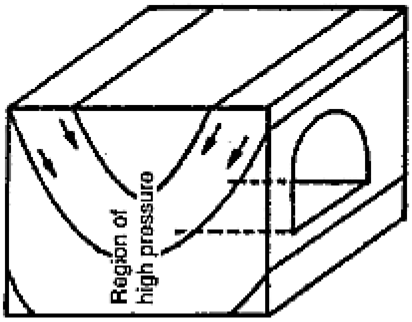
1-An artesian aquifer is a confined aquifer containing groundwater under positive pressure. This causes the water level in a well to rise to a point where hydrostatic equilibrium has been reached. This type of well is called an artesian well. Water may even reach the ground surface if the natural pressure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



Artesian wells

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 of anticlines and synclines. These two factors bring heterogeneity in the physical properties of rocks and also in physical conditions in anticlinal parts. In synclinal folds, the conditions are exactly reversed.





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.

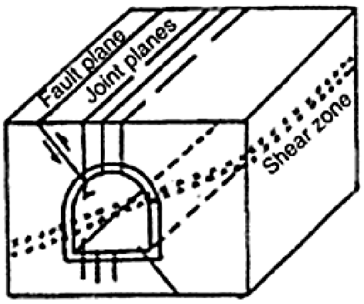
1. Active fault zone: These are the places where there is scope for further recurrence of faulting which will be accompanied by the physical displacement of lithological units. Such faults will lead to dislocation and discontinuity in the tunnel alignment. So occurrence of any active fault in tunnels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

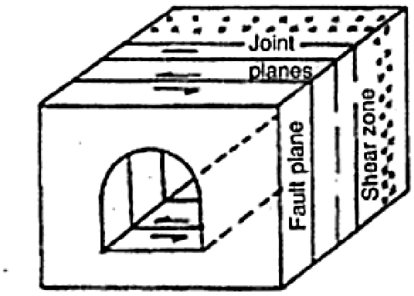
Effect of Joints on Tunnelling:

Joints interfere with tunnelling work as follows:

1. They cause serious ground water problems, unless the water table position is reasonably below the level of the tunnel floor.
2. If the joints re too many, they may severely hamper the competence even inherently strong rocks and render them unsuitable for tunnelling.
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 tunnel site.
4. If joints occur unfavourably, they may cause fall of rocks from the roof of the tunnel. This means tunnelling will be unsafe and needs lining.
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-bearing waters.

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 tunnelling. On the other hand, joints which strike oblique or perpendicular to the tunnel axis will obviously have a limited effect on them.





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.