Earth Sciences for Civil Engineering Part-2
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Civil Engineering applications - geological considerations in dams, tunnels (Part-2)
Module 3
Lecture No 11

Welcome back so in the previous lecture, we were talking about the importance of the folds and putting the the dam structures here. Now, let us see very quickly the faults. We have discussed quite a bit about the the fault and its importance that why we should know fault plains and all or the fault lines of the surface. Now, there is an example of the shear zone which we located close to again Chandigarh.

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This is what you will find okay in this shear zone so you will have the very shattered rock in this shear zone because of the deformation and this will result into the the extreme problems when you are putting structure on this because they they don’t have good shear strength along that and there is a movement on this then you will have problems on the the structures sitting right on the top of that okay.

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So this is another example which shows the shear zone here you can you can see the shear zone now what we have we we did here was that we have the young deposits which we call the quaternary deposits in terms of the period so these are very young deposits which are sitting on the top and this youngs deposits are also displaced okay so this is another example of the sectional view of the strike slip fault here okay.

So we have a bedrock here. This is the the level of the bedrock and here on this side, we have the level of the bedrock here okay and this is a, this is what we call, we are marking as a fault here okay so there is an displacement where this block has moved down, this has moved up and this is for typical strike slip fault which we are (lak) looking at and probably we are having a thrust component in this okay where the right inside has moved up okay compared to the left one okay. So so this is we come across like in terms of if we have to look at the shear zone okay so we need avoid putting structures on the top of this okay.

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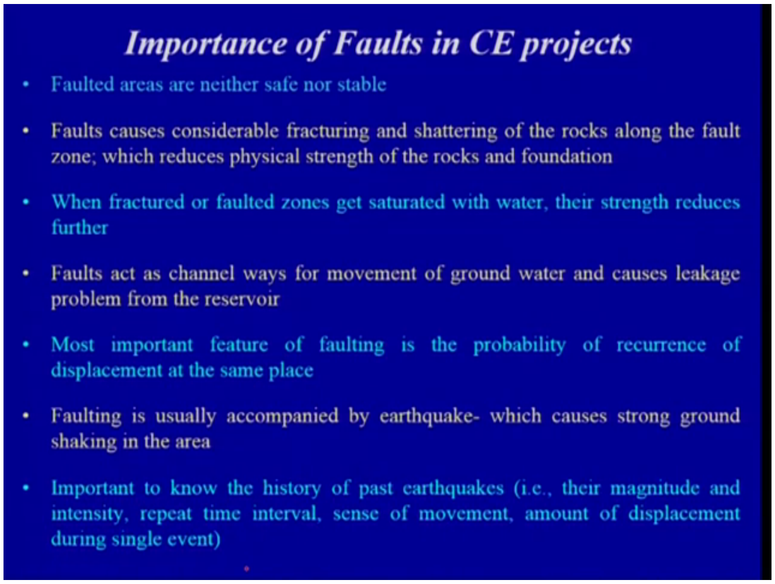

Now coming to the the importance here. Faulted areas are neither safe not stable okay. Faults causes considerable fracturing and shattering of the rocks along the fault zone okay which reduces the physical strength okay so shear strength of rocks goes down okay so we these are not good for the foundation, putting foundation or buildings and the they are not like very good.

And when fractures and faulted zones get saturated with water so in hilly terrains mostly you will slippage of water is going on and if you are having faulted and fractured zones, they will be most ideal zones for water to pass through okay so that further reduces the shear strength okay and then fault acts as channel ways for the movement of ground water and causes leakage problem from the reservoirs okay.

So we this we were talking in terms of the folded areas where we are having fractures and all that or may we are having the bedding plains which are inclined okay. Most important features of the fault is probability of the recurrence of the displacement on the same, at the same place okay so you will have because we were talking about the recurrence interval okay so the (Sa) the same similar magnitude earthquake will may recur on the same fault okay so that means that they they are having the potential of displacing a surface in the near future and triggering a large magnitude earthquake.

Faulting is usually accompanied by earthquakes which causes strong ground motion okay so how far you are sitting from the fault that is also important because that will result into the ground shaking, strong ground shaking so important to know the history of past earthquake. This is what we are now slowly getting into the this mode where this type of studies will be extremely important and mandatory okay for any structure which is coming up close to the the faults or may be in the seismically active regions okay.

So if you look at and go back in the and look at the seismic zonation map so at least in 4 and 5, any structure is coming up, you need to have this understanding okay. That means you need to know the history of the past earthquakes, their magnitude and a repeat time that is recurrence interval and the sense of movement, amount of displacement in a single even. This all information will be required for any upcoming civil structures or the construction in that area okay so this information will be required by the planning planners, town planners to design the building accordingly okay.

Now in most of the parts In India, we don’t have this information available okay so still the the studies are going on a very large scale may be in couple of years, we will be having very good information on this um on this aspect okay.

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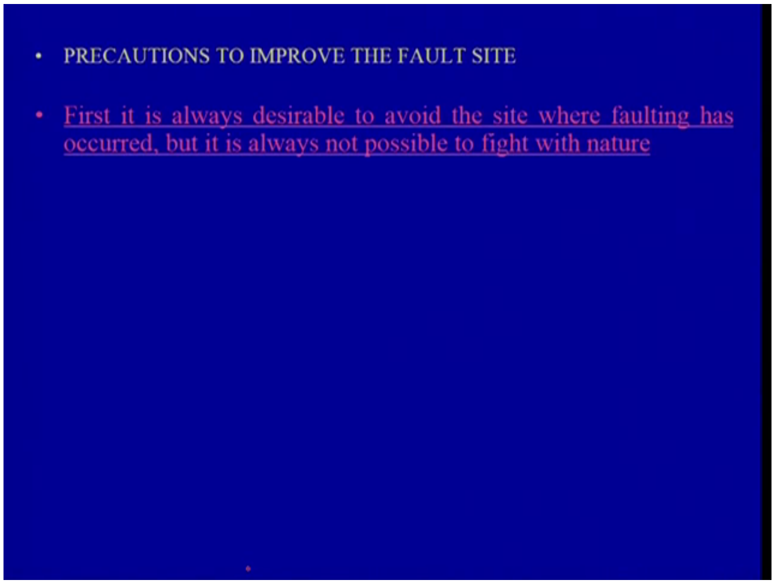

Now precautions to improve the fault sites okay. People have been talking about in many research groups have done this okay so what precautions have been taken if you come across the fault the fault zone so first of all it is always desirable to avoid a site where the faulting has occurred but it is always not possible okay because we cannot say that okay I cannot I will not cross this fault.

You need to cross the faults and some locations okay otherwise the cost of the project will increase and it may be difficult that you avoid the faults okay. You make you have to cross the faults so you need to know that what will be the possible recurrence on that, what will be the amount of displacement on that which is expected and then what will be the magnitude of earthquake which is expected on that particular fault okay. So what is the sense of movement etc, you need to know and accordingly you can un like come up with your building plans and all that okay.

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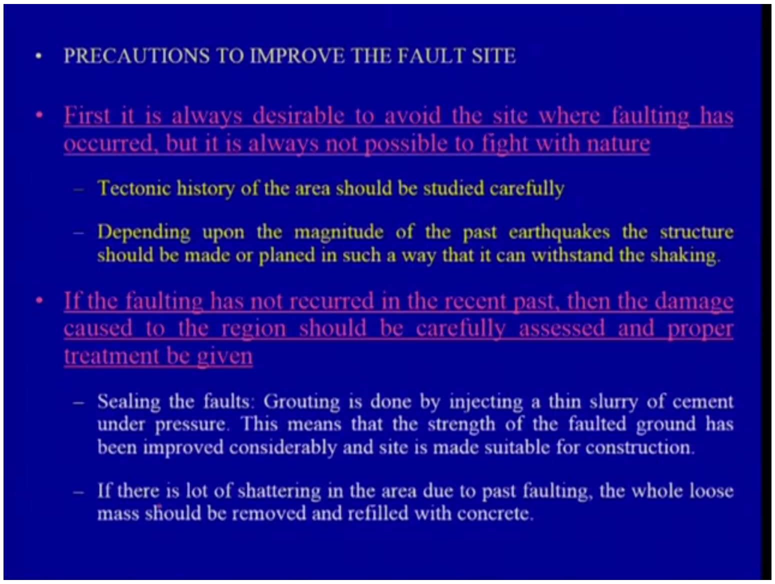

And now then we need to know the tectonic history of the area should be studied very carefully depending among the magnitude of the past earthquake, the structure should be made or planned in such a way that it can withstand the shaking or if you are having a flexibility, it can accommodate that displacement also okay. Now if suppose the the the if the faulting has not recurred in the in the recent past so there is no earthquake in the recent as we were talking about that the in Pinjore Garden fault did not experience any earthquake in last 400 to 500 years but then the likelihood is okay so it's more on that part okay to trigger an large magnitude earthquake.

So if you are not having any (occ) occurrence of any earthquake on this then the damage caused by the region should be carefully assisted because this long time which has been passed since the last earthquake on that area so people have very short memory and people forget and we will be not be able to take into consideration what happened at the past so if it is possible, if you are having good historical chronicles you can try to look at that what type of damage was there during recent, during those earthquakes okay.

And accordingly the assessment of the hazard should be done okay. Now, some locations what they do is that they they try to grout fault and then strengthen that area by injecting some thin slurry of the cement and all that okay so that to some extent you will be strengthening the fault area, you may remove the shattered zone or you may shattered rocks and the crushed sheared rocks and then you can refill it by the concrete or something like that to strengthen that part but my only point is that the fault is not so short okay.

Fault is quite extending for a larger distance okay and rupture will not reach us in couple of meters okay. It will cover kilometers so how you are going to seal that particular fault okay. Of course if you know the history of the fault and if you know and understand that this there will be no earthquake in future on this fault however there is an old dormant fault, it's not an active fault then the shear zone or the shear (mat) material, shattered material can be removed and you can do the grouting part so that at least we are putting the heavy structure on the fault or the shear zone, it will not allow it to slip okay because of the overburden otherwise you may not be able to fix up in a proper sense okay if it is active.

So you need to know that at what at the past activities, okay past earthquakes whether it has triggered or not okay so if there is lot of shattering in the area due to past faulting the whole loose mass should be removed and refilled okay. So if you are having an old fault and then you are doing that then you can you can consider that concreting and grouting part okay. There is absolutely no problem for that.

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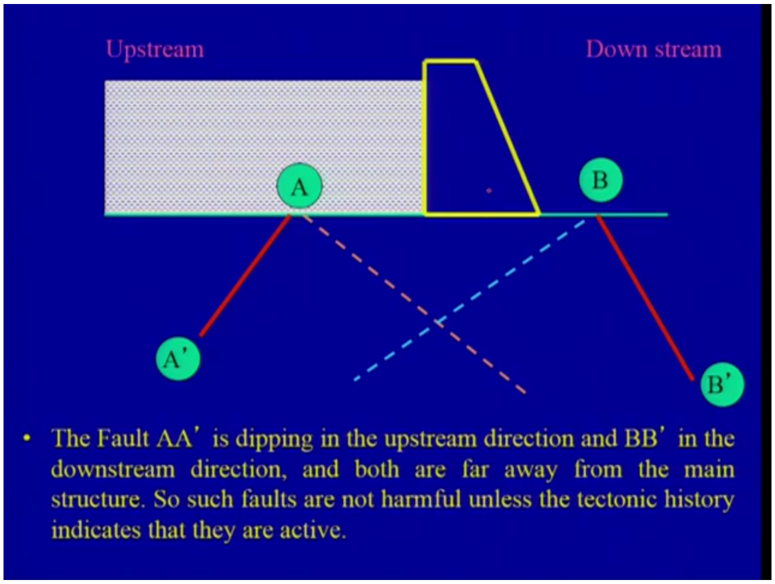

Now suppose we have the same part. Let us take actually we are having a dam here and then we we put, we have this is the upstream direction this is downstream directions we are having. And we have fault like A A dash okay and then we are having a fault so one fault, both the (bo) in both the cases, the faults are away from the the main structure because we in any case we need to safeguard the dam structures for example. Both the faults are away and both are dipping in different directions okay so one fault for example if you take this is south and this is north, so one is dipping towards north and another dipping towards south okay so both are away from that okay.

So fault A A dash it is it dipping in upstream direction okay and then B B dash is dipping in downstream direction and both are far away from the main structure so such faults are not harmful unless the tectonic history okay indicates that they are active because of they are active then they will trigger large magnitude earthquake. They will not damage directly but indirect damage will be there to the structure and here, then in that case we have to take into consideration what will we the ground shaking, the intensity of ground shaking at this particular place because of these 2 faults okay.

So that has to be taken into consideration (hen) (acc) accordingly the the structures can be designed okay. Now, there is another fault again from the same place if you are having but one is dipping, no doubt the surface manifestation. If suppose they the the geologists take up the studies and then they found that okay fine there is a surface manifestation here of the fault and then there is another surface manifestation of the fault here okay so in the initial cases what we were looking at and that is extremely important because what we are looking at the attitude of the fault plain okay or the fault.

One is dipping in the away from the flow in the downstream direction, another is dipping away again in the upstream direction but these 2 faults which is remarked in the pink dash line and the dash line, they are having the same surface manifestation here but they are dipping in such a way okay one dipping for example in the upstream direction, another is dipping in the downstream direction okay and both are crossing this structure somewhere so when there will be a movement, movement will be along this plain okay so and that will result into the damage to the structure.

So the the these 2 faults are okay yeah but these are not so we need to know that in which direction the the faults are dipping and what will be the sense of movement on that so just saying that okay fine my my (fau) fault on this surface is not crossing or the structure is not crossing the fault, that is that that will not be enough okay. Where you are sitting okay, where your structure is sitting with respect to the attitude of the faults okay. That is extremely important. Another one is here so in this case, okay this is absolutely not ideal okay so this is absolutely not ideal.

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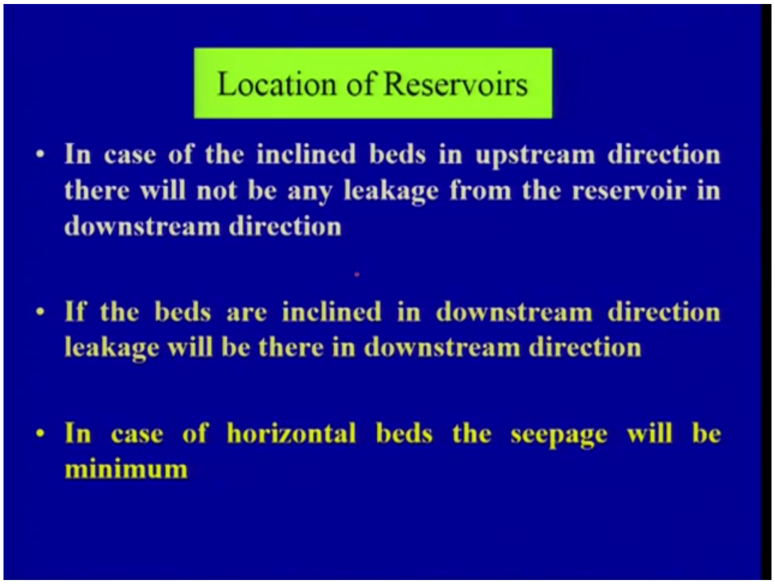

Now I am just I am going ahead, I think this we have already discussed. Now location of the reservoir in case of the faults if we take into the consideration faults, in case of the inclined beds and the upstream direction, this we have talked about the types of holes okay so there will not be any leakage from the reservoir if the downstream in the downstream direction if you are having the beds which are dipping in the upstream direction okay. So this is one one thing which is important.

Now, if the leakage, if the beds are inclined at the downstream direction then you will face the problems with the leakage and all that we have discussed that this is this side is extremely important or not not not ideal to to put okay and then in case of the horizontal, it may be minimized okay so in any case, if you are having folds here like this okay what we have talked about so this may be the ideal one okay but this is not okay this will result into the slippage and all that.

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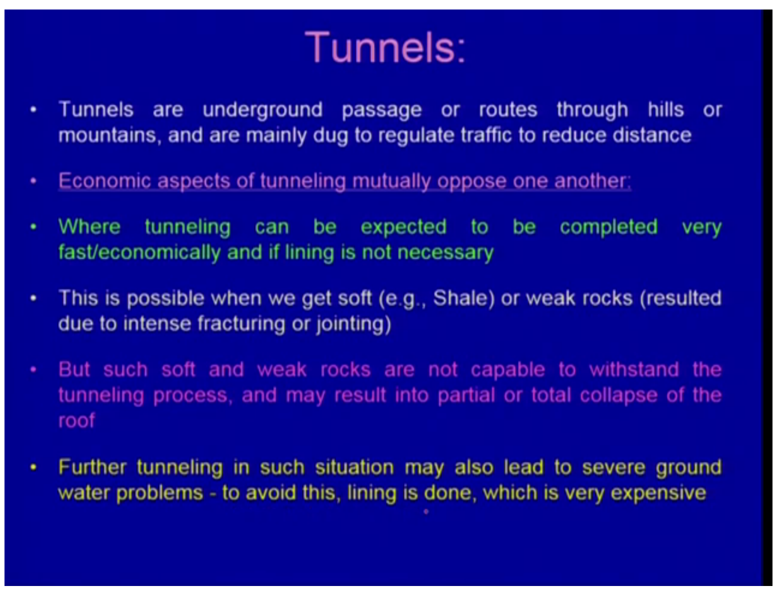

Now coming to part of the tunnels where we are taking into consideration mostly we are crossing the the folded limbs or the folded folded areas okay so tunnels are underground passages either to route for the your regulated traffic or sometimes we use regulate also from one reservoir to another one okay so and then the most important part is why we put tunnel is to reduce the distance otherwise we will be covering a long distance to just to reach across the hill okay so economic aspect of the tunnel is, it mutually oppose one and another this is what has been found okay.

Okay wherever where the tunneling can be expected to be completed very fast okay economically and if lining is not necessary of such areas are been found the it’s fantastic but to some extent it is difficult okay so economically if we have to put the tunnel, we have to see that okay find how fast you will be able to complete that project. How economical it will be in terms of the cost and all that and so and if you are coming across, the excavation part can be finished very fast. No lining is required inside then that that (a) that project is fantastic okay, but this is possible when we get a very soft rocks okay.

So excavation will be very fast and you will be able to do that or weak rocks because you will be able to excavate fast okay so either you come across the shale, you come across the rocks which are weakened because of the fracturing and jointing okay so those areas you will be able to excavate very fast but such soft and weak rocks are not capable to withstand the tunneling process okay and it may result into partial or total collapse of the roof because you are removing the the or removing the strain part on (tha) from that okay and then that can result into the collapse because of the already the rocks are fractured okay so that can be one of the problems and then you will have the slippage also. Further tunneling in such situation may lead into severe groundwater water problems okay.

Okay to avoid this, lining has to be done okay which is again will be very expensive. So you want to do project in a very quicker sense but at that the same time because you are excavating in the softer rocks, you may face these problems okay so you may the collapse problems, you may have the water slippage problem a lot okay and that will end up in having more of the project because you have to put the lining and all that okay.

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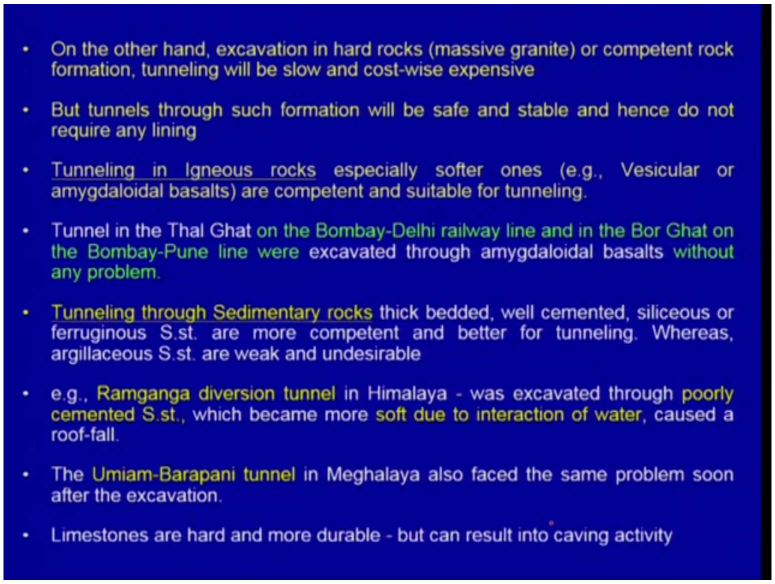

On the other hand excavation in the hard rock okay because you want to avoid the collapse, you want to avoid the the water slippage and all that okay for example if you are coming across a massive granite or competent formations okay. Tunneling will be extremely slow and cost wise it will be expensive okay but the tunnels through such formation will be safe and stable and hence do not require any lining okay so you can you can try to look at such but it will be time consuming and expensive but it will be safer okay. Now tunneling in these igneous rocks especially in softer ones like for example we are having vesicular and amygdaloidal Besalts and are competent and suitable for tunneling so we will see couple of examples here now.

Now this is what happened in tunneling in Thal ghat on the Bombay-Delhi railway line and Bhor Ghat on the Bombay Pune line were excavated amygdaloidal without any problem. Tunneling through sedimentary rocks, thick bedding well cemented siliceous and ferruginous sandstones are more competent and better for tunneling whereas argillaceous sandstones okay fine grain sand stones or you are having shale and all that that will be weak and undesirable okay so this what one should keep into mind so whatever you have learned in the previous one, all you are applying here actually okay so you are talking in terms of the the the the bed rocks, what type of rocks you are coming across whether they are sedimentary metamorphic or igneous whether they are soft, hard and then you are talking about the fold structures and all that okay.

Let up move ahead okay. Another example, Ramganga diversion tunnel in Himalaya was excavated through poorly cemented sandstone which became more soft due to (inter) when it came with an interaction with the water okay. Slippage problems resulted into the roof collapse okay. This is another one Umium Barapani tunnel in Meghalaya also faced similar problem when it was excavated through a softer rocks okay.

And this is we have commonly observed the limestone okay was mostly the the um the basic composition is the calcium carbonate and it will react with water and because of the dissolution activity, you may face problems of caving subsurface okay. The surface you will see okay fine is it good but subsurface there will be dissolution activities and formation of cavities will be there so you were having hollow portion at the base and you are having a structure on the top, it will result into the formation of the sinkholes and it will collapse okay so this is another problem in terms of the limestone okay. Again limestone is the sedimentary rock.

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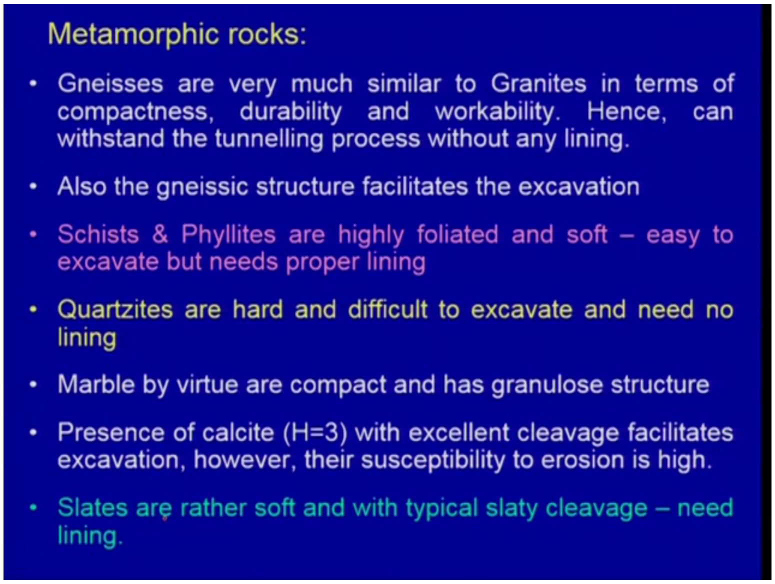

Metamorphic rocks if you at, Gneisses mainly which are similar granite in terms of the the their hardness and durability okay, so they are hence can be withstand, can withstand the tunneling process without lining so if you are coming across Gneisses is good okay. Also the Gneisses structure facilitate excavation because they will be having some short of an structures which are seen in the in the typical rocks okay so that will allow you to excavate things faster as compared to if you are coming granites and all that okay.

Schist, phyllites are highly (fo) foliated structures so we in the previous part, we talked about the foliated and non foliated rocks in the metamorphic part okay so you please refer that. So schist and phyllites are foliated and soft, easy to excavate but will need proper lining okay so again there will be a problem with that. Quartzites are massive rocks, okay they are very hard and difficult to excavate and need to no lining.

Then marble again, there is a part where you metamorphous limestone, you will get marble so virtual are compact and has granular structure so this will be good in terms of that okay but the present of granite, calcite okay, which is having the hardness 3 with excellent cleavage facility of excavation however they are susceptible to the erosion okay so if you are having like similar to limestone, you are having you will having high erosion if you are having marble okay, but in terms of the compactness and the they are good. Slates again when we are looking a sedimentary rocks, we are having shales and here we are slates okay (metamorpho) metamorphous rock. Now shales are rather soft and with typical slaty cleavage okay need lining so if you come across slate, you will have to go for lining okay.

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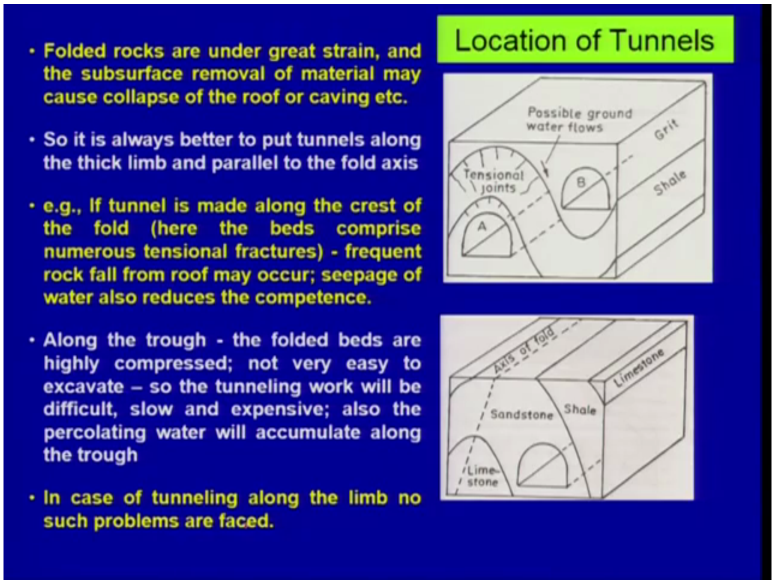

Now location of tunnels if you look at very quickly so we are having a folded structure so the sketch shows your anticline and syncline here okay and then there are two tunnels which are been given here like tunnel A and tunnel B. Now tunnel A is been taken up across the core or it is traveling along the core of the the anticline and here also the B is along core of the anticline and the sands, the rocks which we are having like shale or grate or we say conglomerate okay.

Now a the problems which will be faced here will be something like this okay so folded rocks are under great strain so we may we will have, we will see lot of tensional cracks or the joints which are developed here which may continue for couple of kilometers or may be meters and keep on like in continuing for a longer distance okay. So folded rocks are under great strain and in subsurface removal of the material okay may cause collapse of roof or caving. So if you are removing the material from here, of course you are releasing the the strain, this may result into the collapse of the roof and all that okay because you are excavating the the part which is ban extreme like under strain okay.

So it is always better to put tunnel along a thick limb or and parallel to the fold axis okay so you have to identify what is the fold axis, how it is, what is the strike of the fold axis and all that and and try to identify the thicker limb, the thicker bed of in the limp and then accordingly you should put it okay. Now example if tunnel is made along the crust okay of the fold where it will comprise a numerous tensional fractures okay. Frequent rock collapse from roof may occur and along with this, you will have slippage problems also because here fractures will facilitate slippage into that tunnel okay so which overall in the sense which will reduce the competency.

Now along the trough, this is the B part which has been shown here okay. If you take this one along the B part, the folded beds are highly compressed there okay, not very easy to excavate again so tunneling work will be difficult okay and slow and expensive also percolation of water will be very high in the trough part so syncline is again not advisable. So in case of tunneling along the limp, no such a problems are faced so if you take this example okay so what we is been shown here, there is an thick limb of sandstone here and you are putting the tunnel along the thick limb so you are you are getting the same rock through and through this tunnel okay.

No doubt the limestone is sitting up, shale is sitting up but this is an competent rock and here you are also avoiding the limestone okay so you have excavated in the sand stone part okay which is good so depending on that what type of rocks you are coming across so you try to identify the thicker limb and along the limp which parallel to the this the fold axis should be taken for the tunnel, best best portion for the.

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If you look at, this is the photograph which shows the rail track here, it goes through this tunnel here okay and this which is crossing the limb okay so this is the limb here. If you see this part here, this is the edge of the limb, this is the another one. So this is the folded structure and this is the thicker limb so they have they have identified the one limb and through that they are putting okay close up of that and this is close to Shimla. When you when you go to Shimla, this on the way actually okay.

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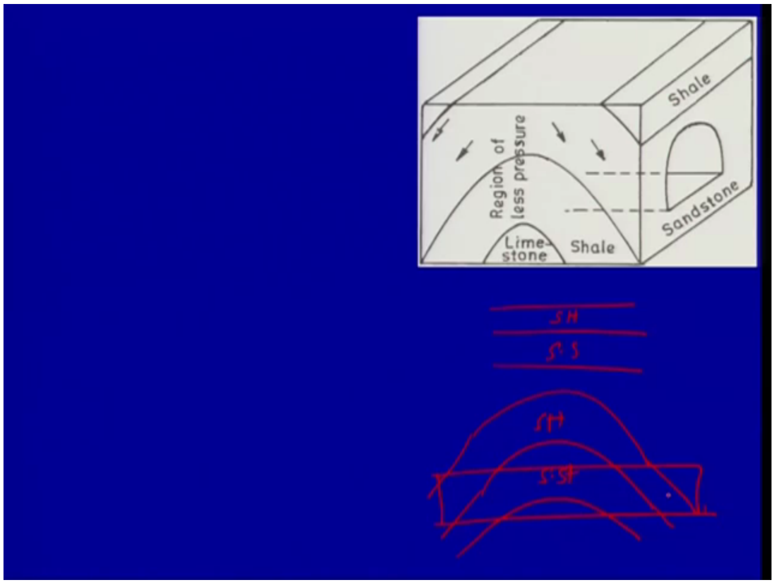

Now, another example, one we talked about that if you are having an thicker limb, we put the tunnel across along the strike of the fold axis but another is if you come across and put the tunnel perpendicular to the fold axis okay which is again not advisable because you are having different rocks which are getting folded so if you are an horizontal um layers like this okay and then when you are folding like this is sandstone here, this is shale here and when you fold it okay, what you are coming across, you are having this okay so you are having the you are having sandstone here, you are having shale here okay now if you are putting this, your tunnel, you are coming across different types of layers okay.

You are having these shale then you came across sand stone then sandstone and then shale again so you are coming across the the different layers. Okay we will stop here and then we will continue in the next lecture. We will talk about the the different type of like rocks and all that and how we have to put the tunnels up.