Underground Space Technology
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Module No# 02
Lecture No # 09
Tunneling: Underground Excavations

Hello everyone, in the previous class, we discussed about the empirical failure criteria for rocks and rock masses. And we finished our discussion on basics related to rock mechanics and rock engineering. So today, we will start our discussion on tunneling and underground excavations. First, I will be telling you the various types of underground excavations along with the ground conditions. So to start with, we have different types of underground excavation. So, first in this category include rock tunnels.

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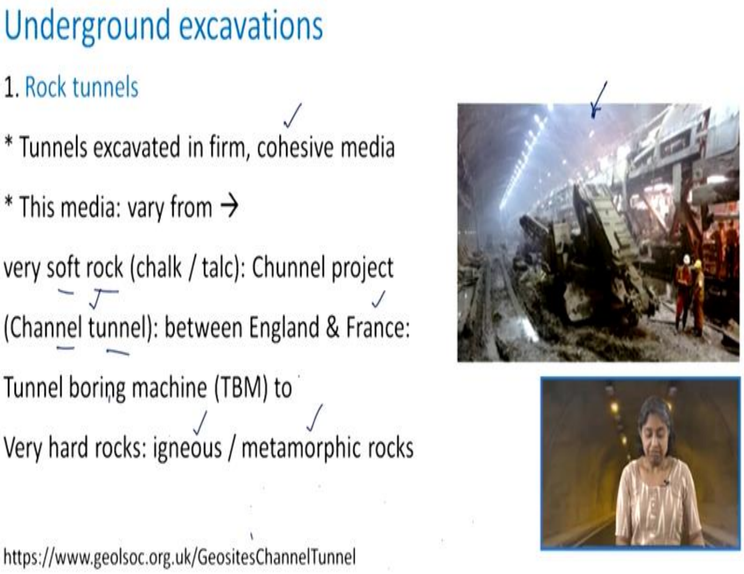

So, these tunnels are excavated in firm cohesive media, and this media can vary from very soft rock such as chalk or talc, and this was used in this project channel tunnel which is between England and France. And the tunnel boring machine was used so the media can vary from very soft rocks to very hard rocks, which can be kind of igneous rocks or metamorphic rocks. So here this picture is one picture from this channel tunnel which is between England and France.

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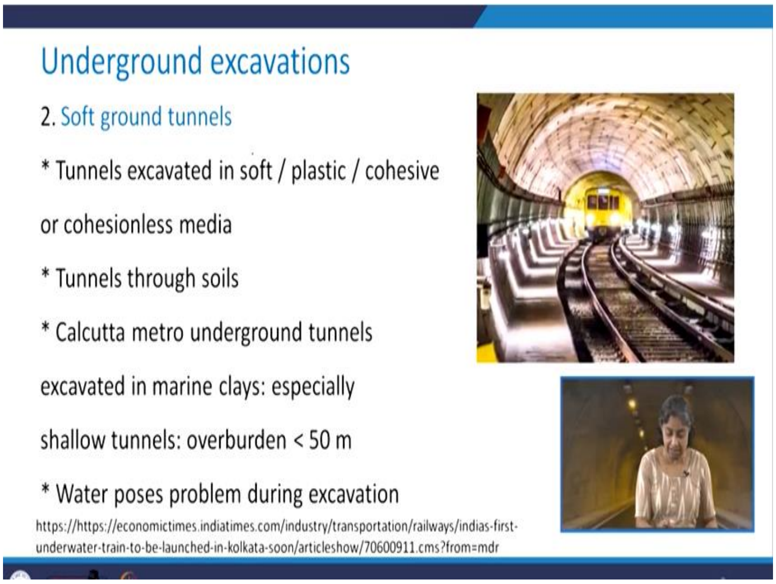

Then the second category includes soft ground tunnels. These tunnels are excavated in soft plastic cohesive or cohesion-less media basically tunnels through soils. They fall under this category. An example of such a tunnel is Calcutta metro underground tunnel which is excavated in marine clays. These are especially shallow tunnels with an overburden of less than 50 meters.

So, this is a picture that has been taken from one of the sources presenting the Calcutta metro underground tunnel. Now, in this case, the water poses a problem during excavation. We need to have specific instruments for tunneling.

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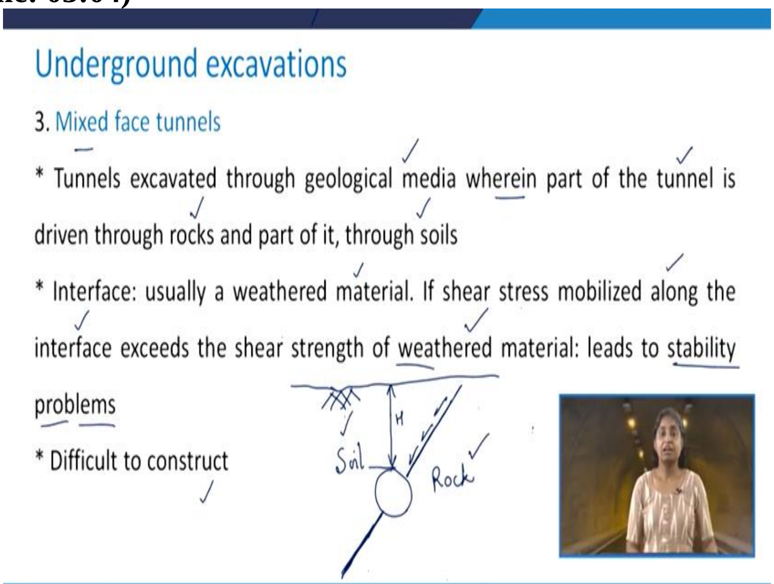

Coming to the third type, which is a mixed phase tunnel. In this case, tunnels are excavated through geological media wherein part of the tunnel is driven through rocks and part of it through soils. That is why it is called mixed face tunnels, so the interface is usually a weathered material. Now, if the shear stress that is mobilized along the interface it exceeds, the shear strength of weathered material leads to various stability problems, and it is extremely difficult to construct.

So, to show you that how it looks like? Let us say this is the ground surface. You must have the excavation here and say this is the interface where you have on this side as the rock media. On this side, you have the soil, and the overburden here in this case, is say H so along the interface here along the interface.

You will have the weathered material, and that is what I mentioned, that in case if the shear stress that is mobilized along the interface if it exceeds the shear strength of the weathering material weathered material, that leads to stability problems. Because of the 2 different types of materials here, that is rock on this side and soil on this side, it is clear that it will not be that easy to construct such type of tunnels.

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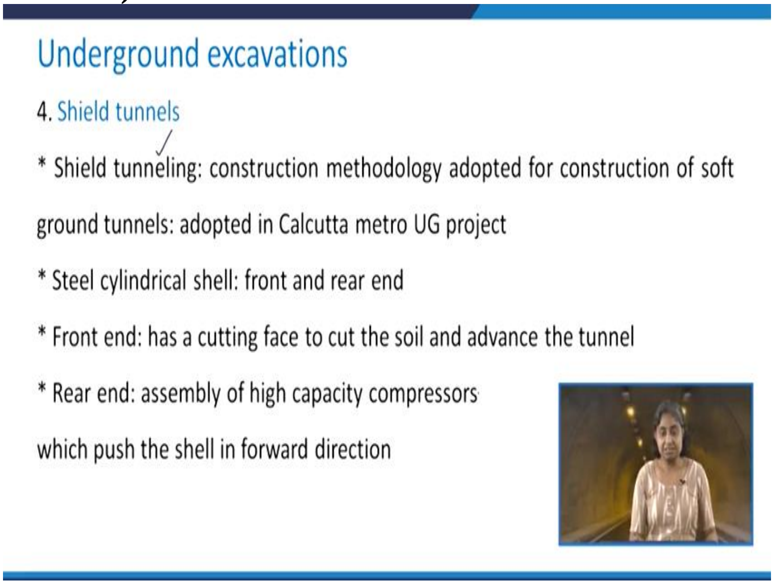

Coming to the fourth category, that is shield tunnels; the tunneling process is called as shield tunnelling. This is the construction methodology which is adopted for construction of soft ground tunnels. This was also adopted in Calcutta metro underground project. So, steel cylindrical shells they are used at front as well as the rear end. The front end has a cutting face, and the objective of this is to cut the soil.

And hence advance the tunnel; however, at the rear end, there is the assembly of high-capacity compressors which push the shell in the forward direction, and hence the tunnel is advanced.

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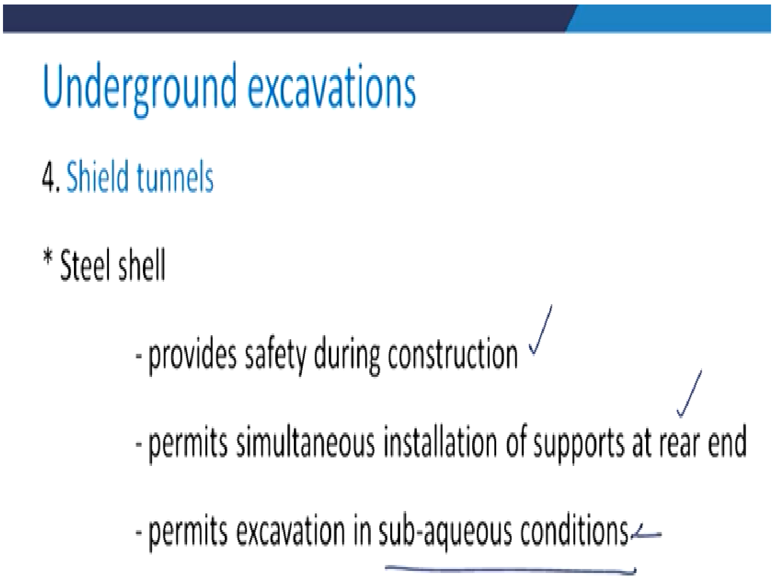

This steel shell they provide safety during the construction. They also permit simultaneous installation of supports at rear end and permit the excavation in sub-aqueous condition. As I mentioned to you that Calcutta underground project, excavation project was mainly through the marine clay. So that is why this shield tunneling was adopted because it is helpful in excavation in sub-aqueous condition.

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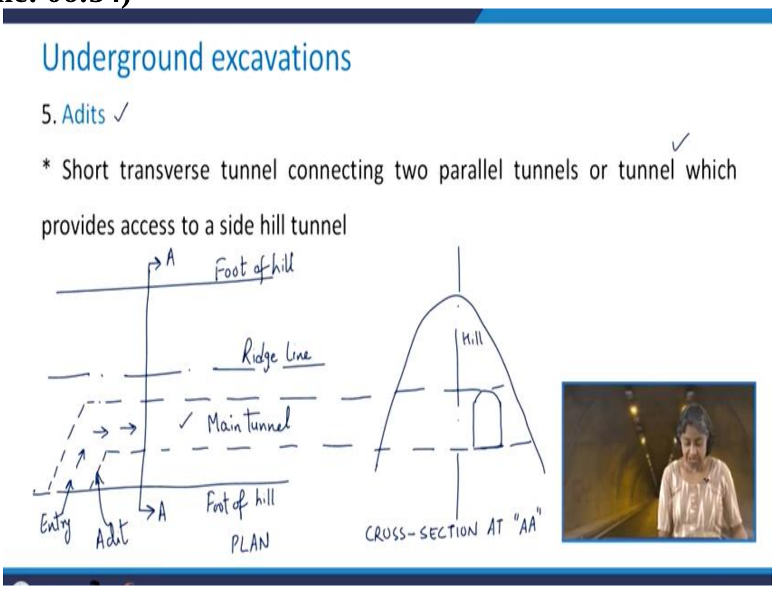

So, the next type of underground excavation it includes adits. So, these are short transverse tunnel which connects to 2 parallel tunnels. These are the tunnels that provide access to a side hill tunnel so let us look with the help of a figure that is how it looks. So here, I will draw the plan as well as the cross-section to give you the idea. So let us say that here this is what is the foot of the hill. And I take a section which is say it is AA.

This is basically foot of hill and here also foot of the hill at the centre you have the ridge line. If I take this section AA, it looks like this is what is your hill? And basically, here this is your main tunnel, and from this side, you have the entry, so this is what we call as adit. So, this is what your plan is, and this is a cross-section. So here, I showed you the example that how the edit looks like when it acts as a tunnel which provides access to the side hill tunnel. So, you can see this was the main tunnel and how the through adit the entry to the main tunnel is constructed, so this is what is adit.

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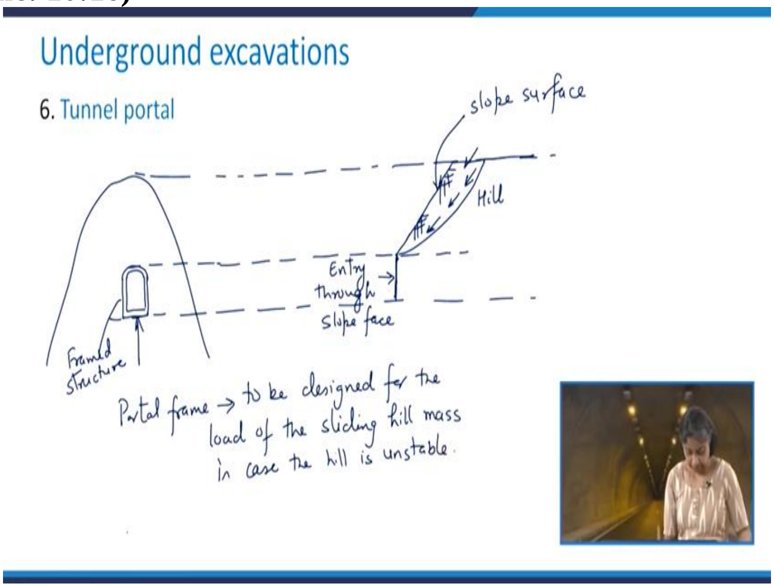

The next is the tunnel portal. So here you have a frame structure, and see this is how it looks like. So, we have a hill, this is what we call the framed structure. And here you will have entry through slope face. Now you see this is the slope surface and see there will be chances. That this material may slide along this failure surface, so this is the part of the hill. So basically, this portal frame which looks in the other view, looks like this.

This will have to be designed in such a manner that it can take the load of this sliding material. So, this portal frame is to be designed for the load of the sliding hill mass. In case the hill is unstable, so basically the load on the frame will depend upon that how much of the mass from the hill is going to slide. So, this is what we call the tunnel portal.

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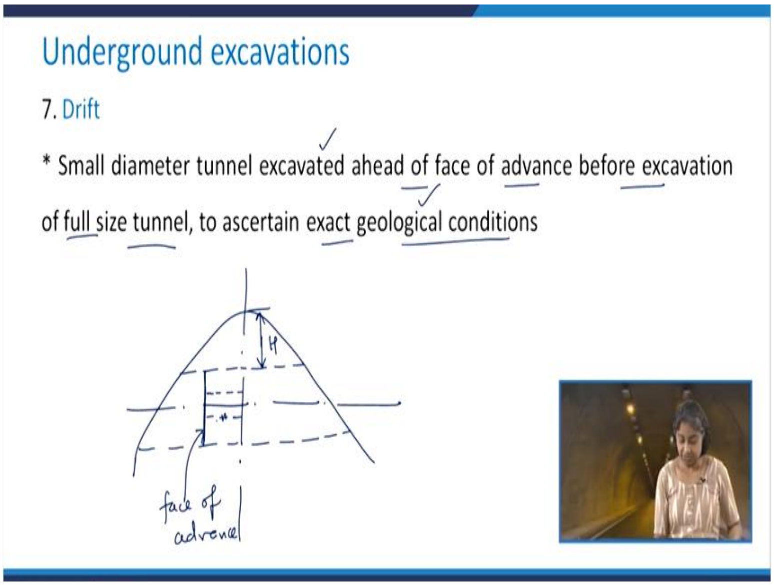

Now, the next structure is called as drift. It is the small diameter tunnel which is excavated ahead of phase of advance before the excavation of a full-size tunnel to ascertain the exact geological conditions. You know that these rocks and rock masses they are naturally occurring material and lot of uncertainties are involved which may not be clear during the exploration program. So sometimes, you get a few surprises when you go for the tunnelling.

So, to avoid such things, we can go for the small diameter tunnel which is excavated ahead of phase before the excavation of full-size tunnel. So this will help us to get the exact idea about the geological conditions that are prevailing at the tunnel site. This is how it looks like let us say this is the ridge line. And maybe this is the hill now that is the centre line of the tunnel and say this is the main tunnel.

Now the, let us see the face of advance is this now what we do is ahead of the face of advance; we have this small tunnel like this. So, what will happen? Once you have excavated this portion, this part it will be exposed so you can get the idea about the exact geological condition. So basically, this is what is your face of advance, and of course, here this much is the overburden, so this is what we call as drift this small diameter tunnel, this is what is drift?

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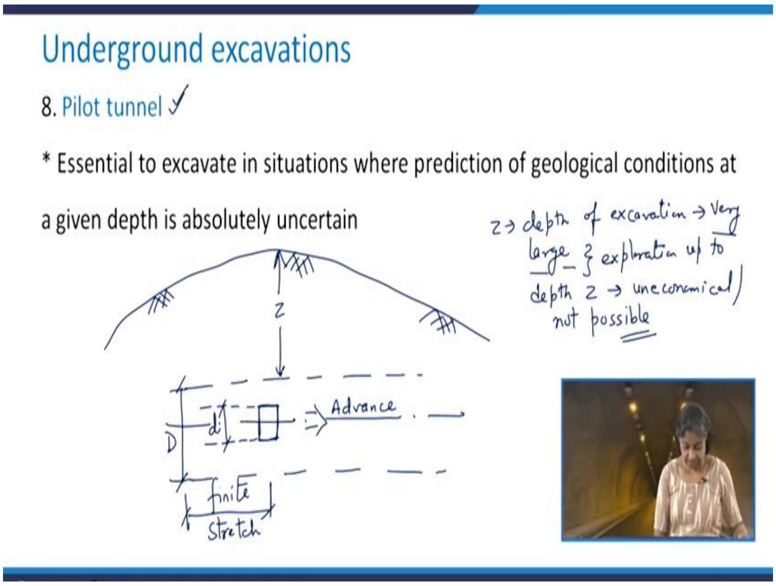

Now the next type of the underground excavation it includes the now the next type of underground excavations includes the pilot tunnel. Now, this is essential to excavate in situations where prediction of geological conditions at a given depth is absolutely uncertain. So, before we go for the main tunnel, we have to construct the pilot tunnel. Let us see how it looks like, so this is what is your ground condition and say this is the centre line for the tunnel.

And may be so in this case, this z is the depth of excavation, which is very large. Why we say very large means that the exploration up to that depth is going to be extremely uneconomical. The exploration up to depth z will be uneconomical, or it may not be possible. So, in that case, what is done is the tunnel is advancing in this direction. So that is the direction of advance, so what we do is we have the small tunnel maybe if the diameter of the main tunnel was let us say D.

We have here the d diameter, and of course, it is to be done for the finite stretch, so this small diameter tunnel, which is this one is called as the pilot tunnel.

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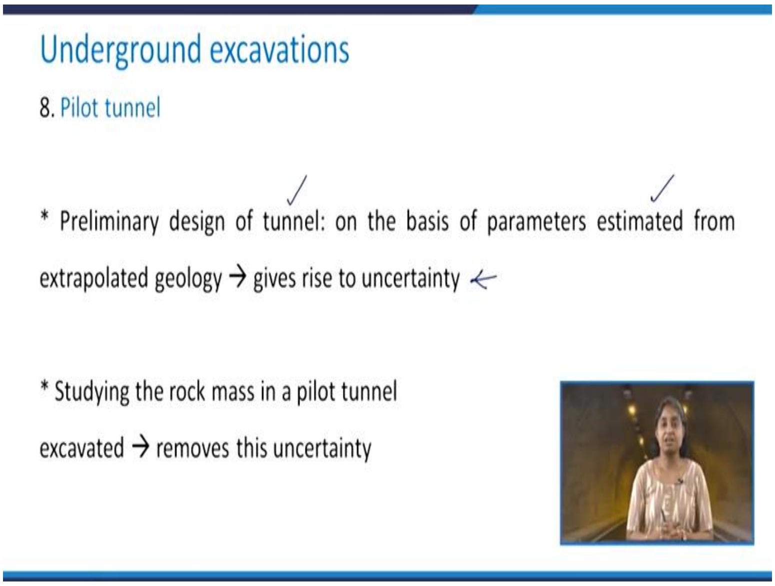

So basically, the preliminary design of the tunnel is on the basis of the parameters that we estimate from the extrapolated geology. This, of course, gives rise to the uncertainty, so studying the rock mass in a pilot tunnel, which we excavate it removes this uncertainty and therefore, this is extremely helpful.

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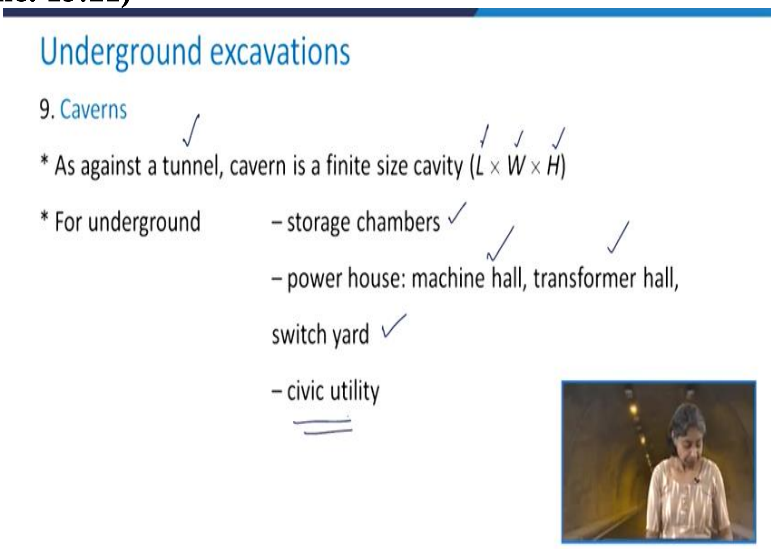

Now, coming to the next category, that is as against a tunnel whose dimension in the other direction is much larger than its cross-section that is the diameter of the tunnel is much smaller as compared to its length. The cavern is a finite size cavity having finite length, width, and height, so all these 3 dimensions they are comparable to each other or maybe of the similar order, so these are adopted for underground storage chambers for underground powerhouse which can make as a part of the machine hall, transformer hall and switch yard. And these are also used for underground civic utility purposes.

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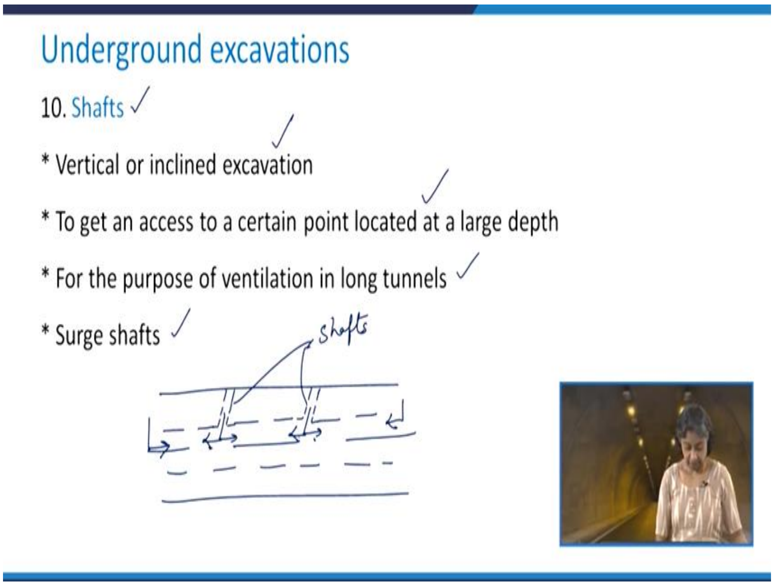

So, we have the next type that is shafts, so we have these shafts can be vertical or inclined excavation. Now, these are used to get an access to a certain point which is located at a large depth or they are also used for the purpose of ventilation in long tunnels or used in surge shafts as well. So let us see that how it is used for the purpose of ventilation in long tunnels. So, you see that let us say if this is the long tunnel and here is the centre line.

So, and here may be so need to come in this direction, so here so this is how it is used for the ventilation in long tunnels, so here you can see that these are the shafts.

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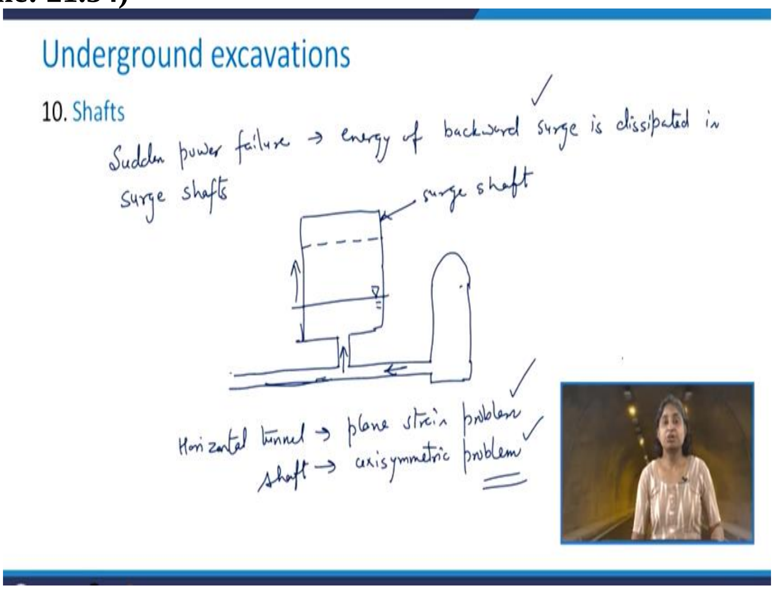

Then these shafts can also be used in for the surge tanks; let us see how they work. So in case if there is the sudden power failure, then what happens is that the energy of the backward surge is dissipated in surge shafts. Let us see how with the help of a figure, we can see this. So there is this surge shaft, so let us say the earlier the water table was here in this level of the water. And in case of the sudden power failure, this water level goes up, and it may be like this here.

So that is how the backward surge is dissipated in this surge shaft. So basically, these are the different types of underground excavation. When we have horizontal tunnel, we can treat it as the plane strain problem. And in case if we have the situation like shafts, these are treated axisymmetric problem. Kindly keep this in mind, and we have already discussed that what do you mean by plane strain problem, plane stress problem, and axisymmetric problem. So, this was all about the types of underground excavations.

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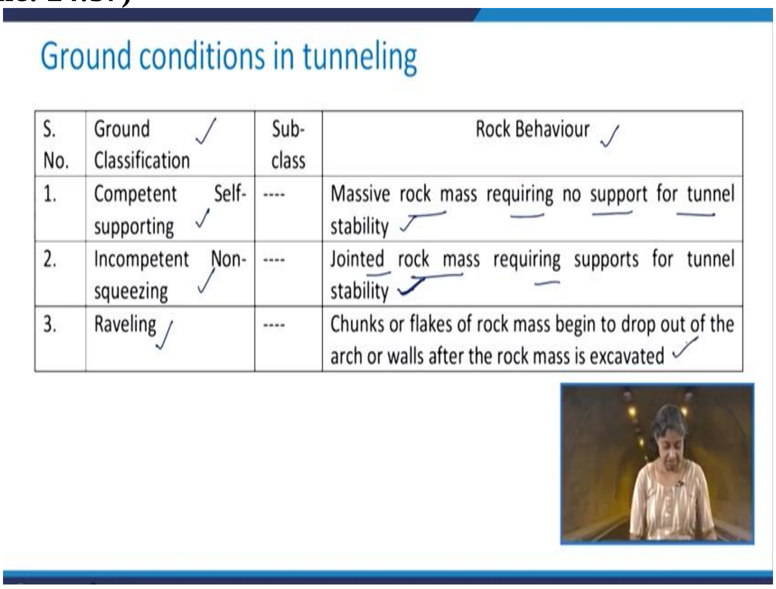

Now we learn few aspects related to ground conditions in tunnelling. So here is a table where the second column gives you the idea about the ground classification. And the last column tells us about the behavior of the rock when such type of ground classification or such type of ground condition is there in the field, so the first category is a competent self-supporting. So, in this case you have the massive rock mass, which requires no support for tunnel stability.

So basically, when the excavation is made in competent self-supporting ground condition then you may not require any support for the stability of tunnel. But then we just provide some nominal support. The second type is incompetent non-squeezing ground classification. So here you have the behavior of rock as a jointed rock mass which requires support for the tunnel stability.

In case, if you have the raveling kind of ground condition in this case chunks or flakes of the rock mass, they begin to drop out of the arch or maybe the side wall once you excavate the rock mass.

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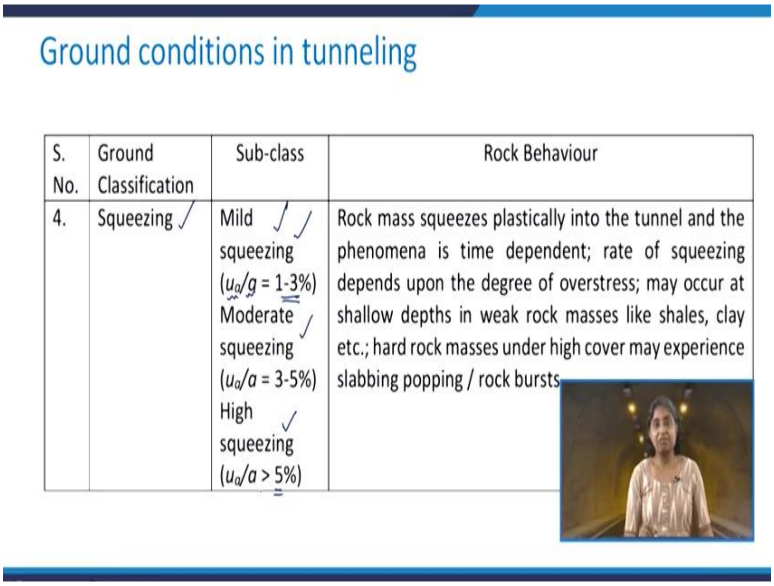

The fourth category is the squeezing ground condition. Now there can be different sub-classes to that the first one is mild squeezing then, moderate squeezing, and high squeezing. These are defined by the parameter u_a upon a, where this u_a is the radial deformation, and a is the radius of the tunnel. So, when it is to the tune of 1 to 3%, it falls under the category of mild squeezing, and if it is more than 5%, it goes to the high squeezing subclass.

So as far as the behavior of the rock is concerned, in this case the rock mass squeezes plastically into the tunnel, and this phenomenon are time-dependent and the rate of squeezing. It depends upon what is the degree of overstress. So, this kind of condition can occur at shallow depths in weak rock masses such as shales, clay, etc. And in hard rock masses under high cover, they may experience slabbing or popping or rock burst kind of situation.

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Ground conditions in tunneling

S. No.	Ground Classification	Sub-class	Rock Behaviour
5.	Swelling		Rock mass absorbs water, increases in volume and expands slowly into the tunnel, e.g., montmorillonite clay
6.	Running		Granular material becomes unstable within steep shear zones
7.	Flowing		A mixture of soil like material and water flows into the tunnel. Material can flow from invert as well as from the face crown and wall and can flow for large distances completely filling the tunnel in some cases
8.	Rock Burst		A violent failure in hard (brittle) and massive rock masses of Class II type, when subjected to high stress

Then the fifth type of ground classification includes swelling. Here the rock mass absorbs water, and it increases in volume because of that or expands slowly into the tunnel. So, such type of behavior, you can see where the mineral-like montmorillonite clays, they are available. Then the sixth condition is the running ground conditioning, this case the granular material becomes very unstable in steep shear zones.

We have another condition called flowing. This is little bit different than the running ground condition. See how in case of the flowing ground condition, a mixture of soil-like material and the water it flows into the tunnel. Now, this material can flow from invert as well as from the face crown and wall. And it can flow for large distances completely filling the tunnel in some cases. So, let us see if this is the tunnel say circular tunnel so this bottom portion we call as inward top portion is your crown and this is what is the side of the tunnel.

So, in case if you have the flowing dry type of ground condition, then this material can flow from any of these places, such as inward crown or the side wall. And then, it can flow for the large distance, and it also may happen that it completely chokes the tunnel in some of the cases. Then the last one is the rock burst condition. In this case, violent failure occurs in hard and massive rock masses of class 2 type, where these are subjected to high stresses. So, this is an extremely violent and a dangerous kind of situation.

So today, we discussed about various types of underground excavations and the ground conditions, and the behavior of the rock mass because of such ground condition. So, in the next class, we will earn few more things about these ground conditions. Thank you very much.