Underground Space Technology
Prof. Dr. Priti Maheshwari
Department of Civil Engineering
Indian Institute of Technology, Roorkee

Module No # 03
Lecture No # 12
Underground Excavation Failure Mechanism

Hello everyone, in the previous class we discussed about the planning of and the exploration for the underground excavations in rocks. So, today we will learn about some of the failure mechanisms which occur in case of the underground excavations.

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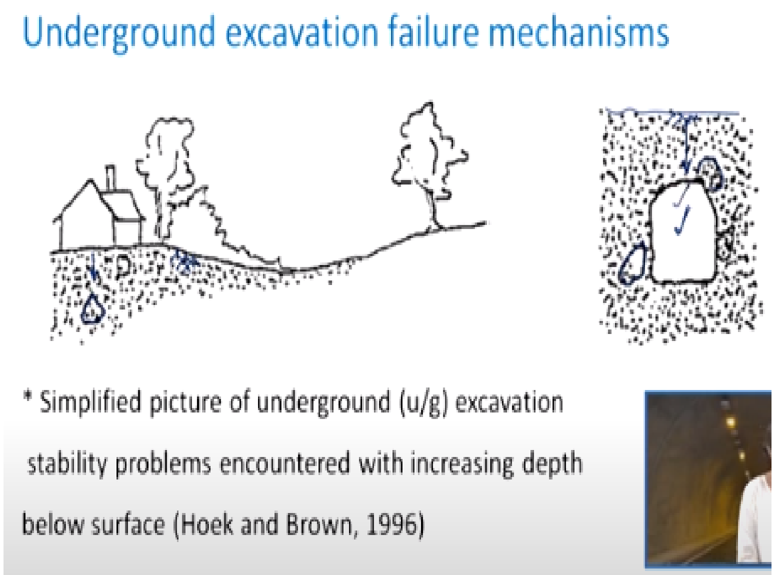

So, here are some typical 2 figures which gives us the idea in the most simplified manner that how the underground excavation stability problems, they are encountered with increasing depth below the existing surface. So, you can see that this is the existing surface here, and as you go deeper you can come across this kind of, say cavity or the loose zone where this which can cause problem to the underground excavation.

Further, here you see that this is the, maybe the some surface here and as you are going below the ground surface. Let us say, if you are going for the tunnel construction, then you see that there are some zones, which may cause the instability to this underground excavation.

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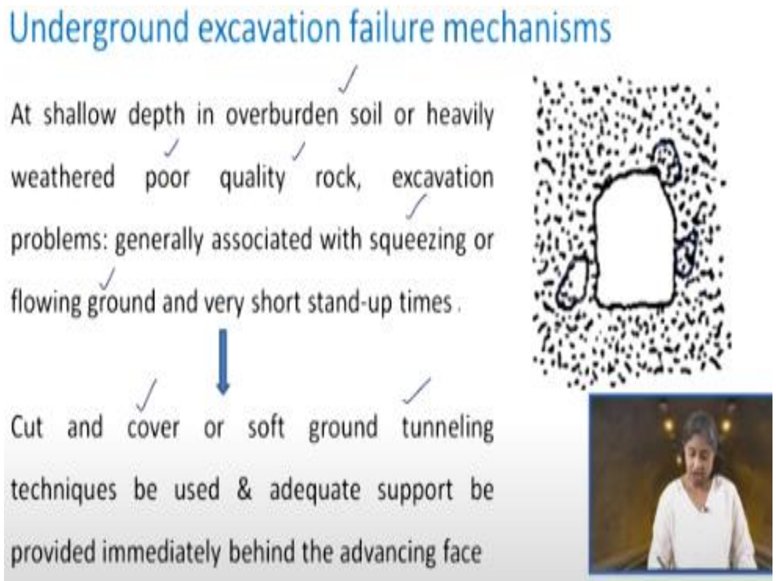

Let us take a look in detail of these, one by one, so add the shallow depths in overburdened soil or heavily weathered poor-quality rock. In general, the excavation problems are associated with squeezing or flowing ground or very short stand-up times. So, in such case, cut and cover or soft ground tunneling techniques should be used and adequate support should be provided immediately after the excavation behind the advancing phase. So, you can take a look here that some of such zones weak zones which may cause the instability problems are marked here.

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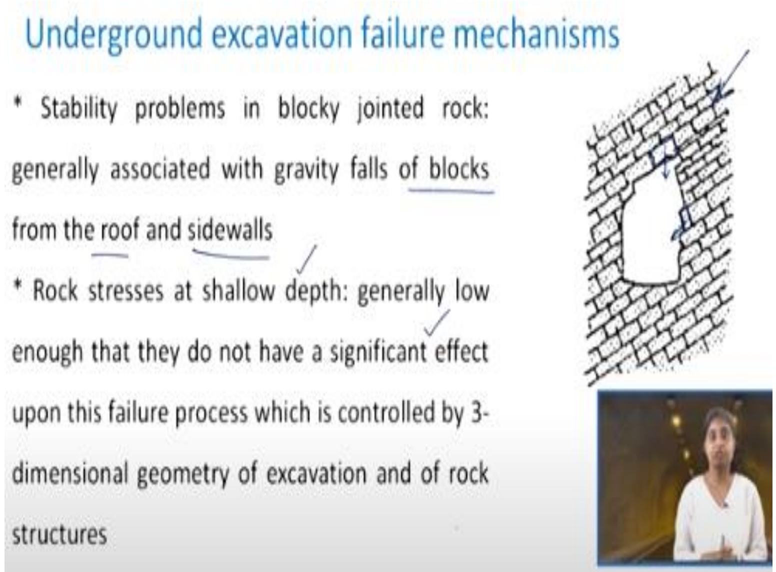

In case, if you have a blocky jointed rock which may look like this which is shown in the figure. These are generally associated with the gravity falls of blocks, from the roof and the side wall. So, you can see here in this figure that say this is a joint and the moment you excavate. Now there is no confinement and this particular block may have the tendency to fall through gravity in the excavation or maybe you if you just take a look at this small block it may slide from this side wall.

So, the rock stresses at the shallow depth they are generally low enough that they do not have any significant effect upon this failure process, which is controlled by the 3-dimensional geometry of excavation and of the rock structure.

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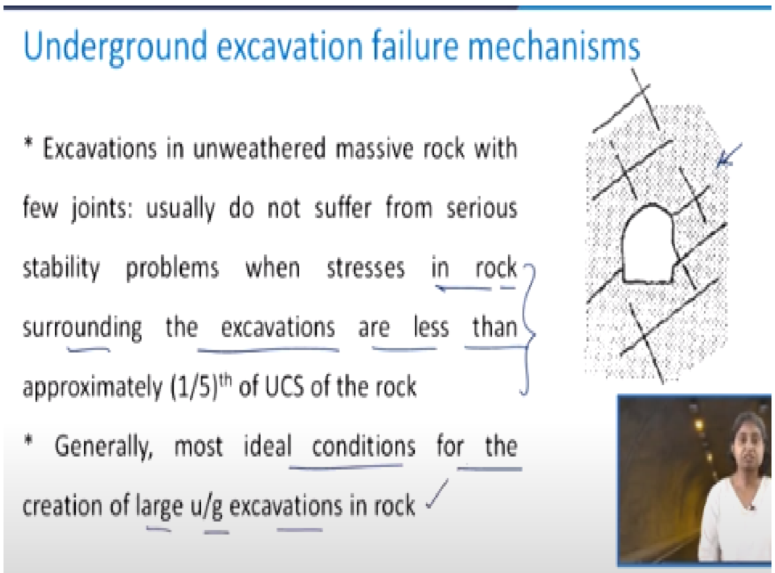

In case, if you have excavations in un-weathered massive rock with few joints, which is looks like which looks like this particular figure. So, these usually do not suffer from very serious stability problems when these stresses in the rock, surrounding the excavation are less than approximately one-fifth of the UCS of the rock. So, if this condition is satisfied, we really do not need to bother about any serious stability problems. So, generally, it is the most ideal condition for the creation of large underground excavations in rock.

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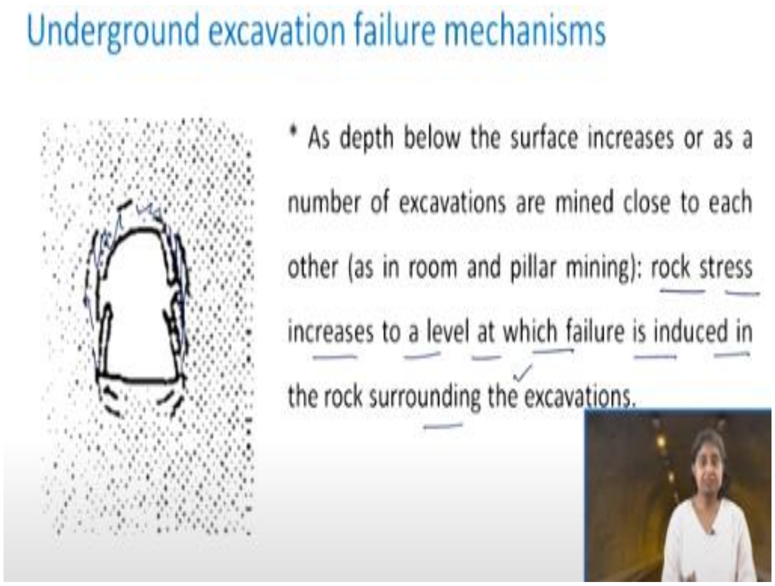

Now, what happens when the depth of this underground excavation it increases? As far as the shallow depths are concerned, we saw that in case of the massive rock or blocky jointed rock how the situation is going to be, but then when the depth below the surface increases. For example, if the tunnel is to be excavated much below the existing ground surface, or there can be second situation, that number of excavations are made near to one another, so in that case, also, such type of failure can take place.

So, in this case, what happens is at the large depths the rock stress increases to a level at which the failure is induced in the rock which is surrounding the excavation. So, you can see that the rock which is surrounding the excavation here the failure is induced.

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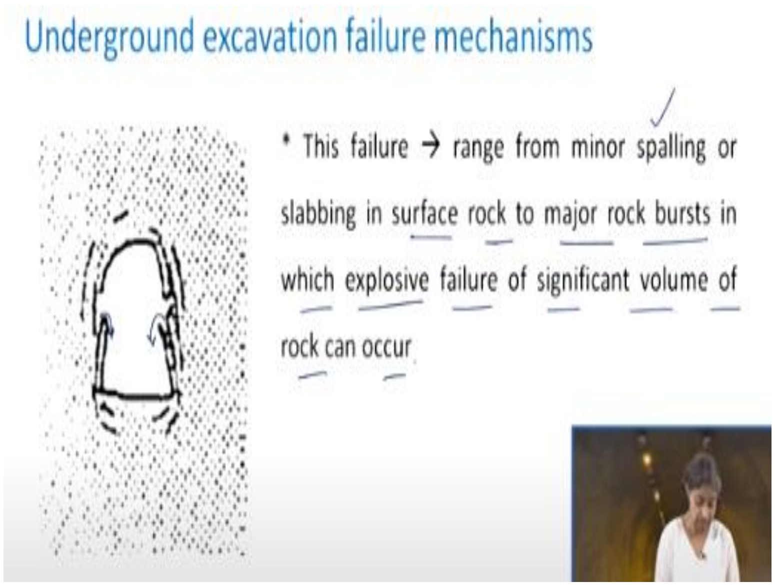

Now, this failure may range from minor spalling to slabbing in surface rock to major rock burst in which explosive failure of significant volume of rock can occur. So, you see that, take a look at this particular figure, so some spalling or slabbing can occur let us say like this or there can be the situation of the rock burst. That you I have already, discussed with you when we were discussing, about the various ground conditions.

That in case, if you have the hard massive rock masses then, in that case, the rock burst creates the violent failure of the significant volume of the rock and that is really very dangerous, because it does not give us any signal before the failure the failure just happens.

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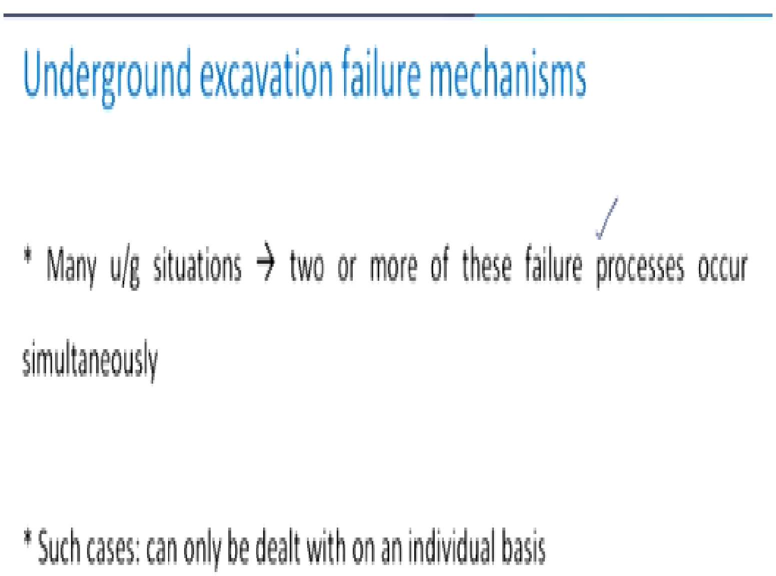

So, in case of the many underground situations, 2 or more of such failure processes can occur simultaneously. So, it is not that only one type of the failure will occur at one underground excavation it can be the mixture of, 2 or 3 types of the failure processes. So, how to deal with such cases? So, we need to consider these on an individual basis that is case, to case basis we need to handle such situations

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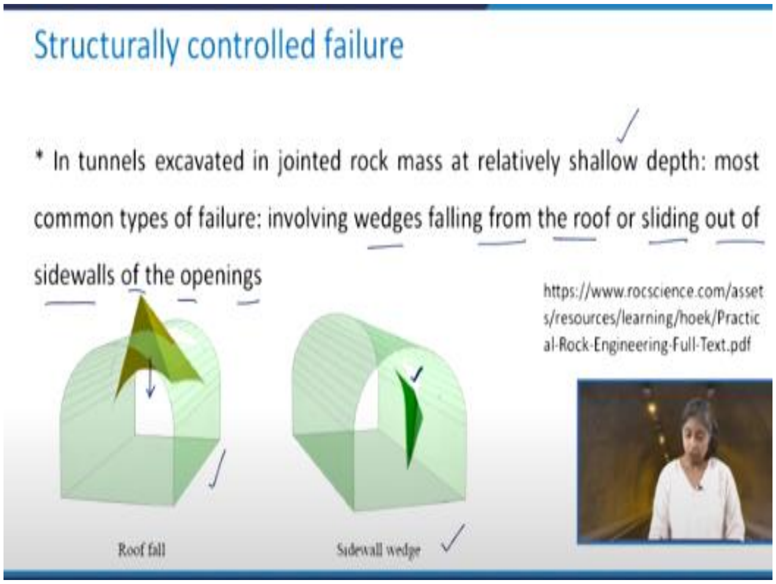

Now, coming to some of the structurally controlled failure, so, first we will discuss about the roof failure and then maybe we will go to the side wall failure. So, basically these 2 are the structurally controlled failure as shown in this particular figure. So, when the tunnels are excavated in a jointed rock mass, at relatively shallow depths most common type of failure involves, the wedges falling either from the roof or the wedges sliding out of the side walls of the opening.

Now, take a look at the first figure, so you see, that the wedge is formed here and then it is falling like this in the excavation from the roof. And, in case, of the second figure, it is the wedge that is being formed in the side wall and, it will not just fall with respect to gravity, but it will just slide out of the side wall of the opening, as has been shown in this figure.

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Now, here these 2 pictures give you the idea that, how the upon the excavation the blocks fall under the gravity from the roof, you take a look here in this zone and see how the rock pieces which are fallen. Here, in this case, similarly here on this you see a wedge has already been fallen from this particular part of the excavation.

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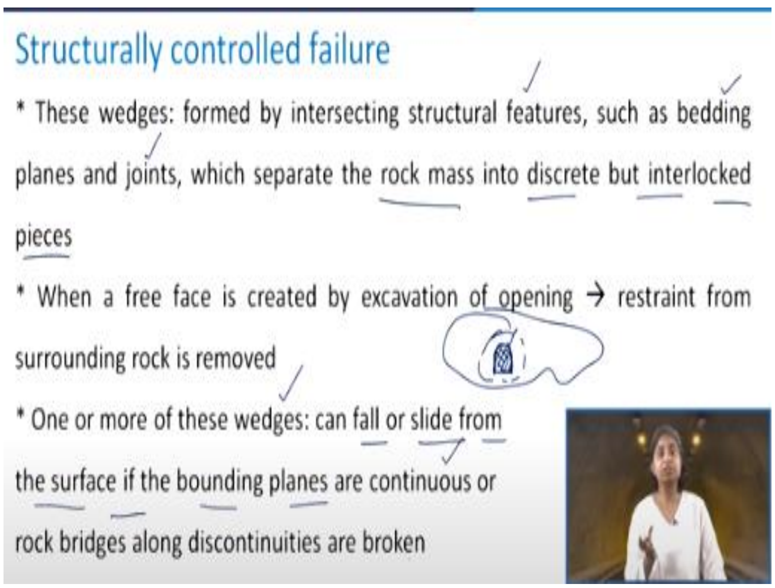
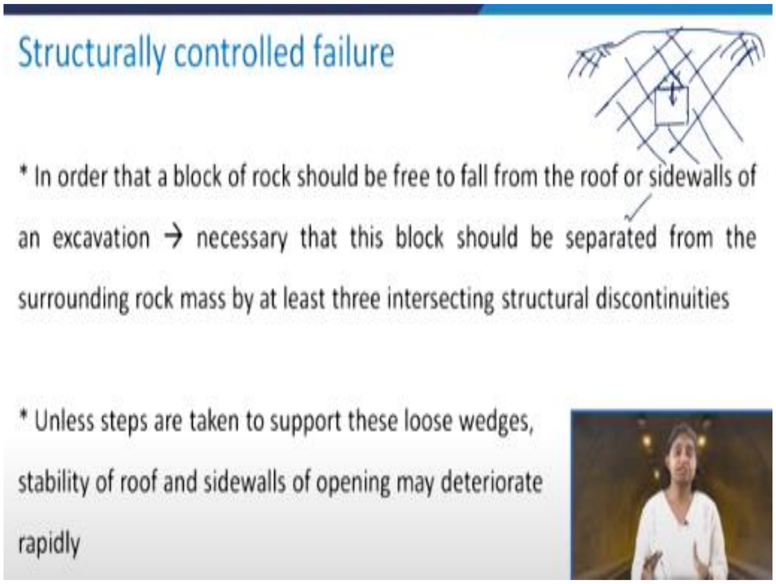


Now, these wedges, these are formed by intersection of these structural features which can be the bedding planes and joints. And this separate the rock mass into discrete, but interlocked pieces when a free surface is created by excavation of the opening the restraint from the surrounding rock is removed. Take a look here, that let us say if this is the complete rock mass and say this is the excavation.

So, before the excavation this mass was restrained by the surrounding rock here but the moments you excavate this, you have a stress-free boundary here and this free face will not be restrained by the surrounding rock. So, 1 or more of such wedges can fall or slide from the surface, if the bounding planes are continuous or rock bridges along the discontinuities if they are broken. **(Refer Slide Time: 10:39)**



So, in order that the block of rock should be free to fall from the roof or the side wall, an excavation it is necessary that this block should be separated from the surrounding rock mass by at least 3 intersecting structural discontinuities. So, let us say that if this is the say, the excavation this is the ground surface and this is what is the excavation and you have the say, the rock mass and the jointing condition like this.

So, you see that here this block, it has three discontinuity planes the first, second and then, the third which is created because of the excavation. So, in case if it has at least 3 intersecting structural discontinuities then only, this wedge can fall in the excavation either from the roof and similar is the condition from the side wall of the excavation. So, unless and until the steps are taken to support these loose wedges the stability of the roof and side walls of the opening they may deteriorate rapidly.

So, as soon as you excavate one should make sure that the support systems are installed, so that such deterioration do not take place in the rock mass

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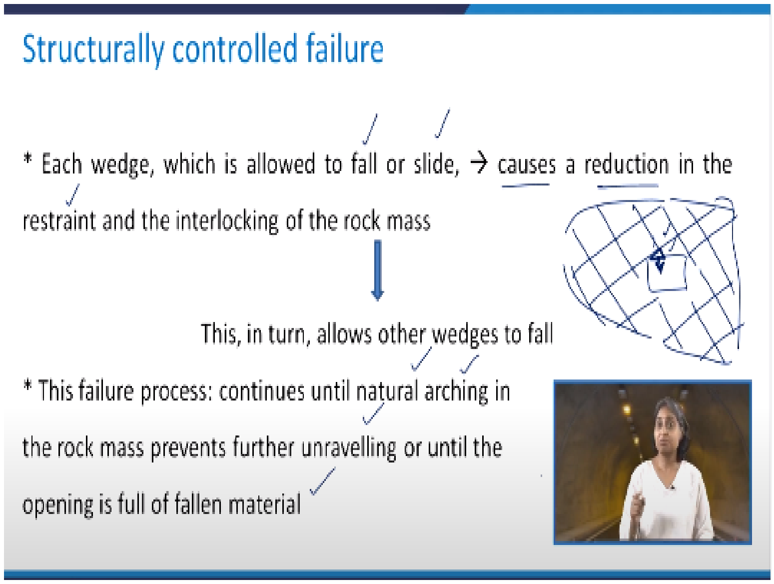

Now, this each wedge which is allowed to either fall from the roof or slide from the side wall, these cause a reduction in the restraint and the interlocking of the rock mass. So, let us say that you have the rock mass and the excavation is made something like this. So, what will happen let us say these blocks fall here. So, what happens to the restrain and the interlocking of the surrounding rock mass? That means, here this particular wedge was restraining this portion this portion and this portion the moment it is removed that restraint is also removed.

So, what happens because of that that the other wedges will also be allowed to fall, or even though if they are not falling they will become bit loose. So, that will deteriorate the quality of the rock mass so, this failure process it continues until there is a natural arching which prevents the rock mass from further un-raveling or until the opening is full of fallen material. So, one needs to be therefore extremely careful about the support system provision after the excavation is made.

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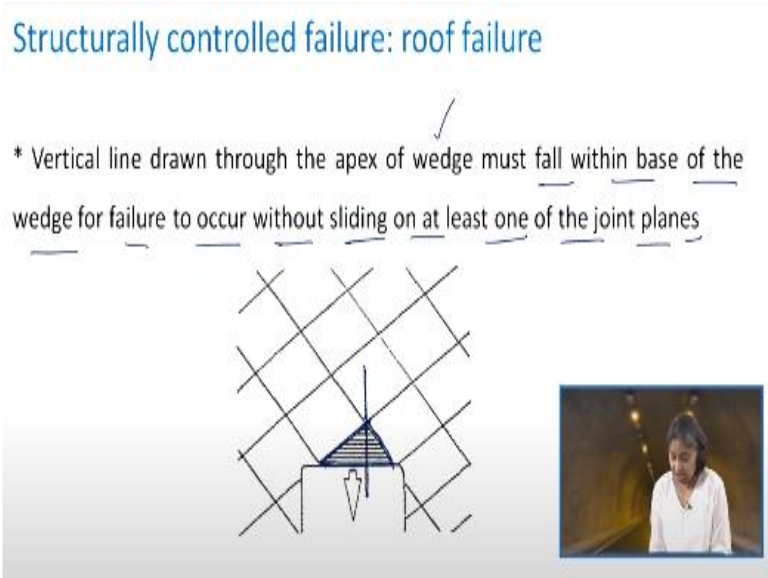

Now, this structurally controlled failure can be analyzed with the help of stereographic projection technique, some of these techniques we learnt in brief in when we were trying to learn about the basics of rock engineering. So, we are going to make use of that knowledge here in case of the structurally controlled failure. So, the simple example of the application of this method, include the wedge of rock falling from the roof of an excavation in the jointed rock.

So, as I was drawing earlier also, so you see that the excavation is made and we saw that, the at least three discontinuity planes are needed for a wedge to either fall from the roof to the excavation or to slide from the side wall in the excavation. So, here take a look this is what is the excavation and this is first plane, second plane and this, the third plane that is formed from the excavation.

So, here there are 3 planes, so this wedge is free to fall from the roof, so the vertical line that is drawn through the apex of the wedge must fall within the base of the wedge for failure to occur without sliding on at least one of the joint plane. Now, take a look what does this mean that here there are 3 joint planes. So, this wedge has the probability of falling in the excavation from the roof but, the question is whether it will the failure will occur without sliding on at least one of the joint planes?

So, the condition for that is you draw a vertical line, through the apex and if it is passing through this base of the wedge then this condition will be satisfied.

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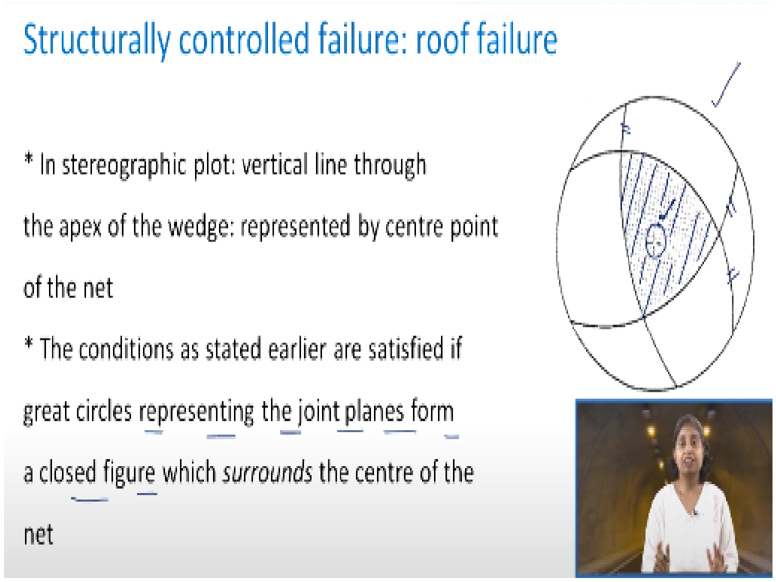

Now in the stereographic plot, how should we show this so in the stereographic plot vertical line through the apex of the wedge, it will be represented by the center point of the net which I have circled here. Now the condition, which were stated earlier they are satisfied if the great circles representing the joint planes form a closed figure which surrounds the center of the net.

So, you all know that any discontinuity plane can be represented by a great circle in the stereographic plot. So, we had these 3 discontinuity planes, whose strike, their dip directions they are known to us. So, based upon that we can plot the corresponding great circles, so say those great circles are these first, second and then the third one. Now, after plotting these great circles in the stereographic plot, we can see whether these are forming the closed figure or not.

So, you take a look, this shaded portion is the closed figure then the next check that we need to see is, whether this closed figure is surrounding the center of the net or not. So, yes in this case it is surrounding the center of the net, and hence the conditions which are mentioned here they are satisfied. And, therefore with the help of the stereographic plot, we can make sure whether such condition will occur or not.

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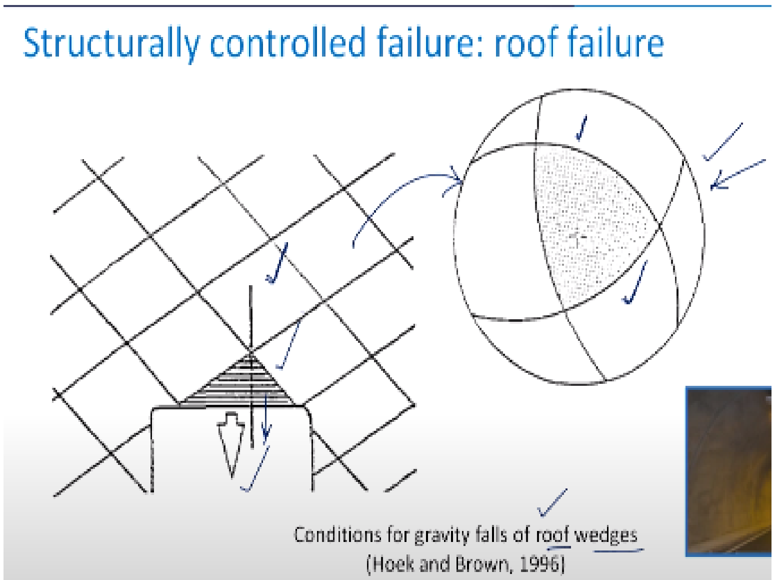

See, so both the situations, so this is what is the situation and this can be represented with the help of the stereographic plot in this manner, so here that shows that what is the condition for gravity falls of roof wedges. So, if this condition is not satisfied, that means there will not be the gravity fall of the roof wedges. So, for the wedge to fall under the gravity from the roof, to the excavation the stereographic plot gives us the idea, that if the stereographic plot looks like this then only this condition will happen otherwise not.

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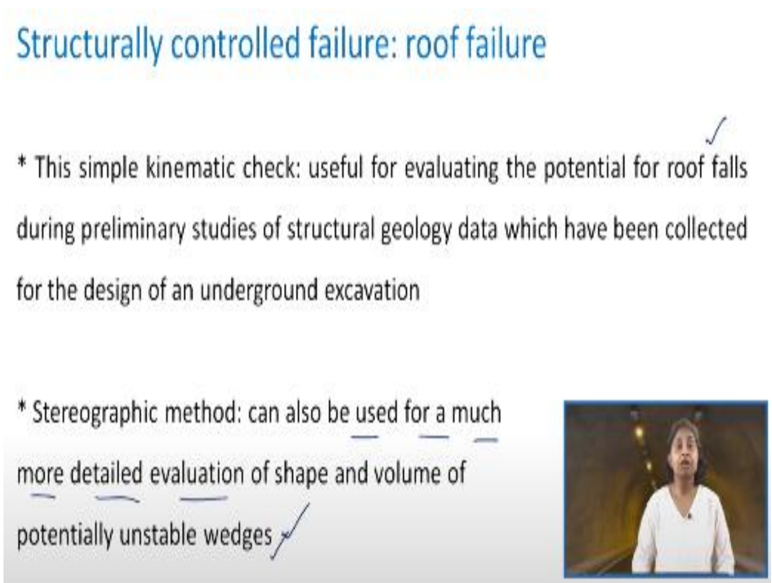

So, this is a simple kinematic check which is very useful for evaluating the potential for roof falls during the preliminary studies of structural geological data, which was collected for the design of an underground excavation. Now, this stereographic method can also be used for a much more detailed evaluation of shape and volume of the potential unstable wedges.

So, it is not only that it helps us in finding out, whether the roof wedges will fall in the excavation under gravity or not, but at the same time, we can get the idea about the shape and the volume of potentially unstable wedges from the use of the stereographic plots. So, we will see that how this can be done, how we can determine the shape and the volume of the wedges which are not stable in the next class, thank you very much.