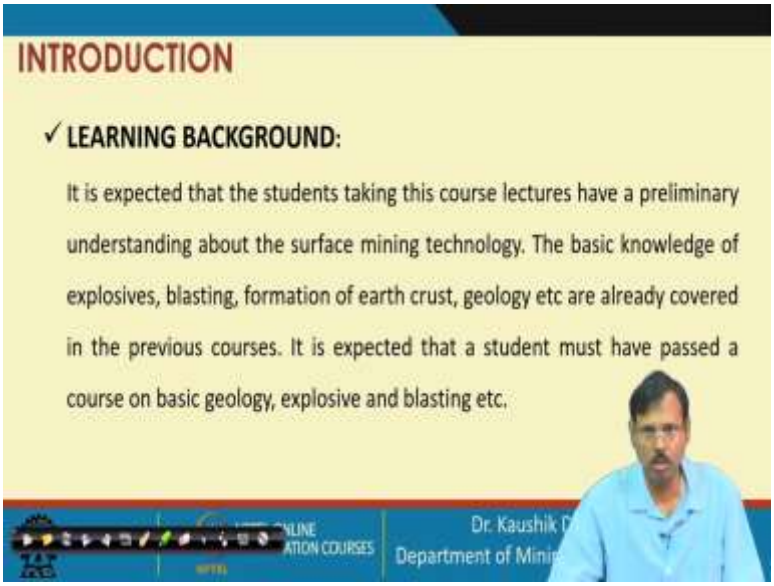
Surface Mining Technology
Professor Kaushik Dey
Department of Mining Engineering
Indian Institute of Technology, Kharagpur
Lecture – 57
Stability of Bench Slopes – II

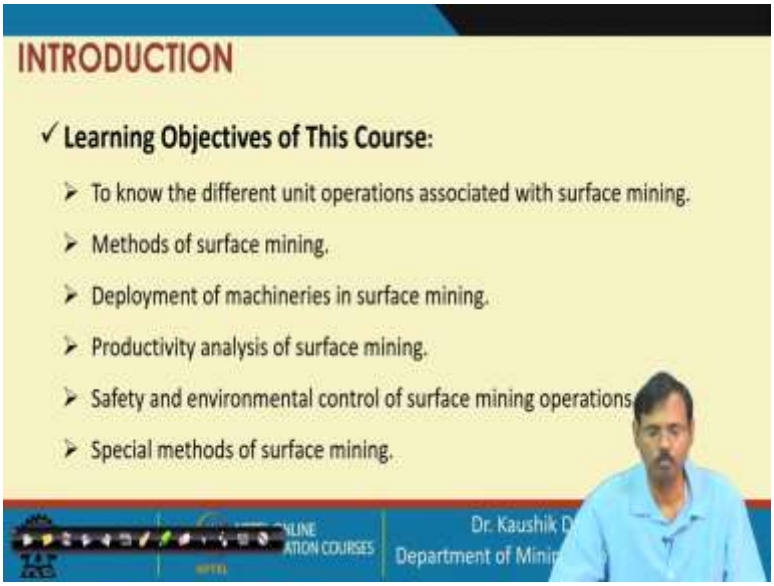
Let me welcome you to the 57th lecture of online NPTEL online certification course surface mining technology. We are continuing with stability of bench slopes; this is the second lecture on this. And in this lecture we will talk about the slope failure in mines with special reference to the wedge failure.

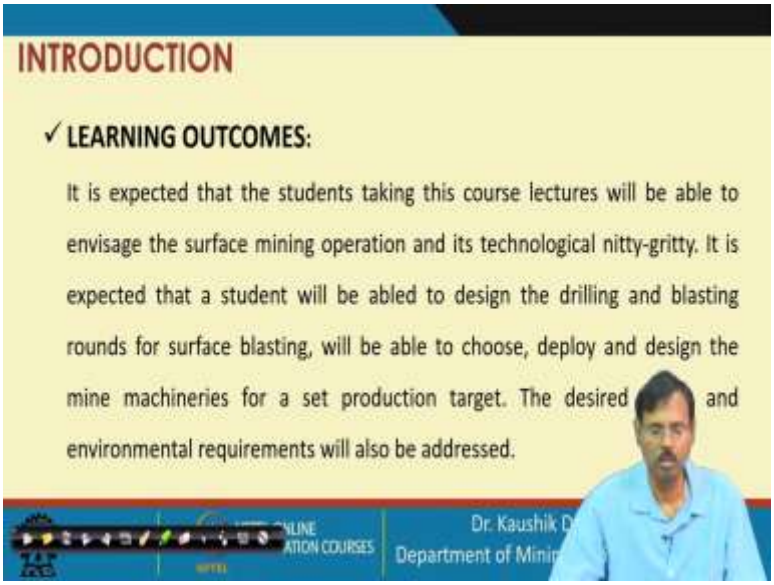
(Refer Slide Time: 00:42)



So, before continuing in the details of this, let us look into the learning background, required for the surface mining technology course.

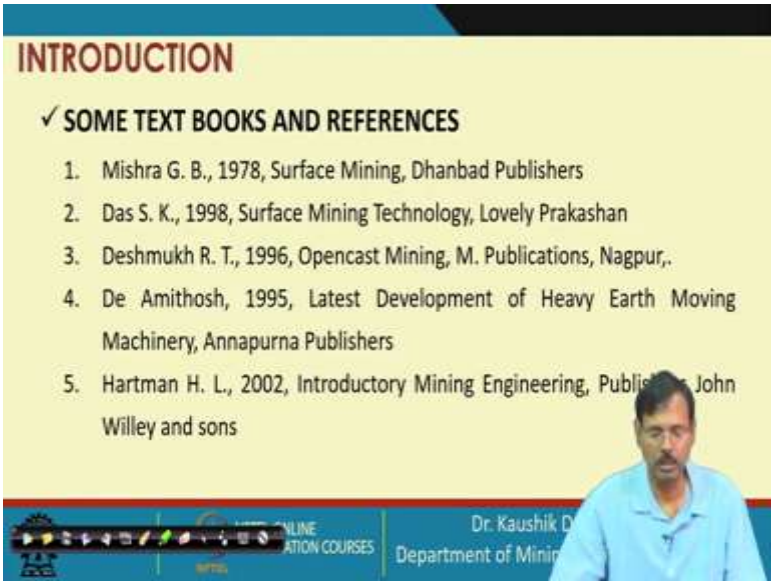
(Refer Slide Time: 00:55)

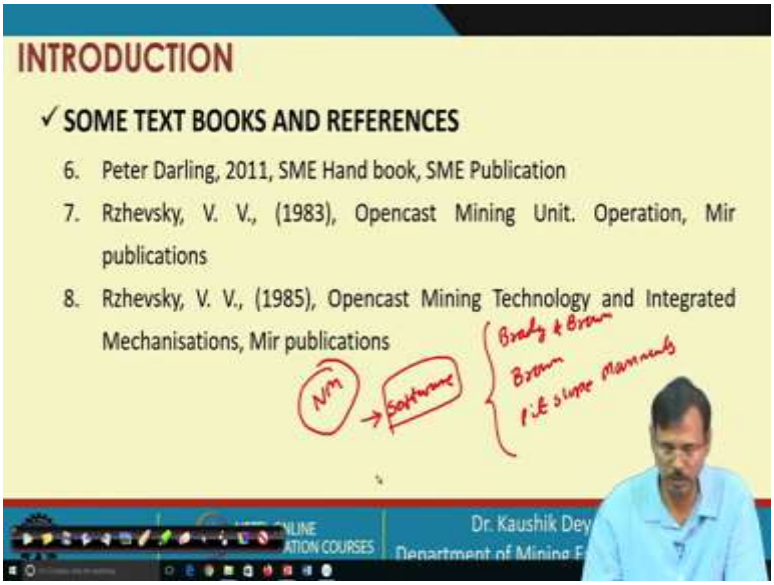




These are the set learning objectives of the surface mining technology course. These are the expected learning outcomes from a participant, who will undergo this surface mining technology course; these are few more learning outcomes.

(Refer Slide Time: 01:20)

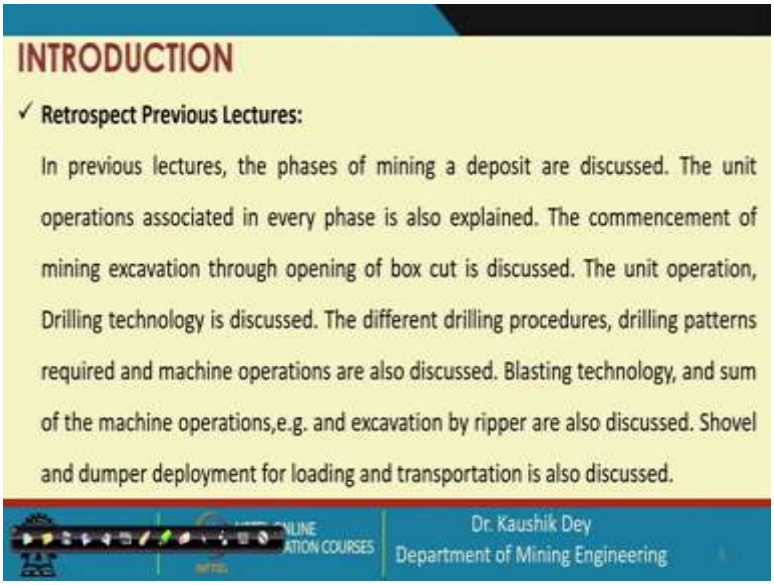


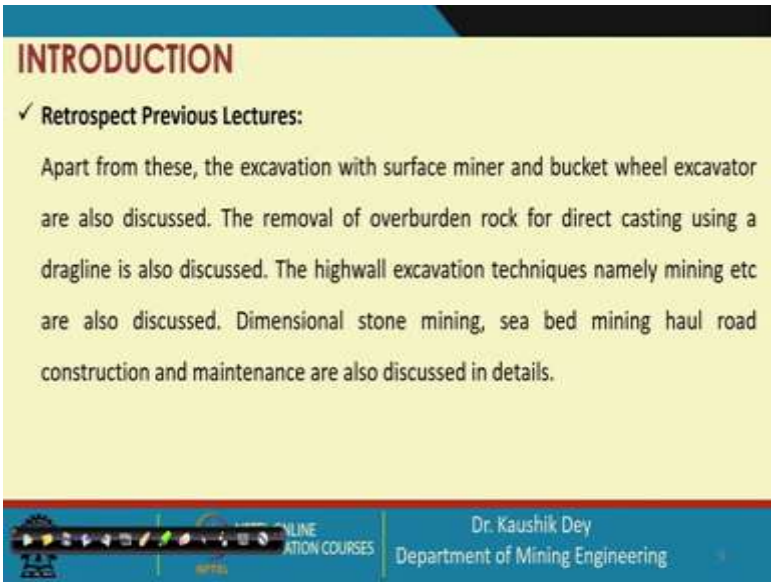


And these are some of the text and reference books, when we are talking about this particular slope stability. There is a book written by Brady and Brown; there is a book written by Brown only. Apart from that pits slope manuals are also there. And there are many more books, if you search with the slope stability, you will find out the open books are available. Apart from that, nowadays, slope stability analyses are carried out with the numerical modeling technique. So, numerical modeling technique open source codes are available. Apart from that, numerical modeling several softwares are also available; so the slopes stability analysis is nowadays carried

out very easily. And these are very important thing. All the participants can download those open source to carry out the slope stability analysis in their own computer.

(Refer Slide Time: 02:38)



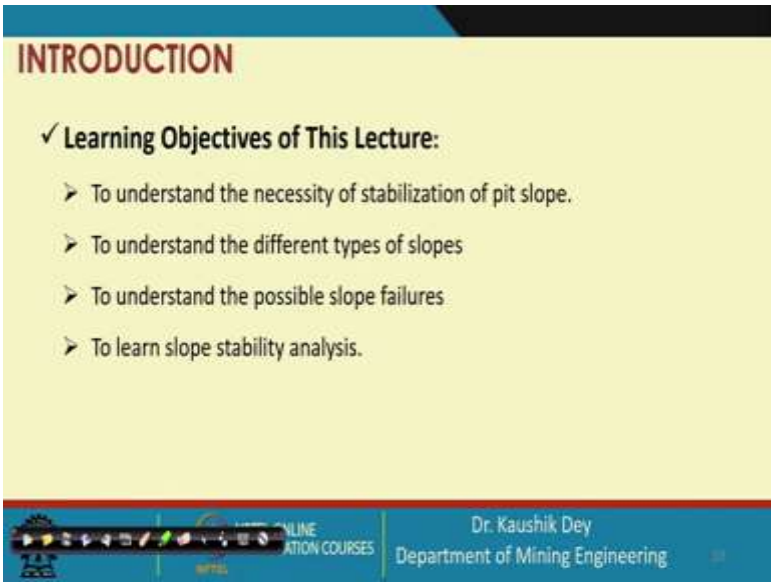


Now, before going into the details, let us once retrospect so far whatever we have covered. So, far we have covered the current state of surface mining in the world. We have covered the phases of mining a deposit, we have covered the commencement of surface mining through opening a box cut. We have covered drilling technology and different drilling patterns required for surface blasting. We have covered the surface blush designing and execution of the blasts. We have

covered, material handling after the blasting using shovel dumper combinations, and other excavators and material transport systems.

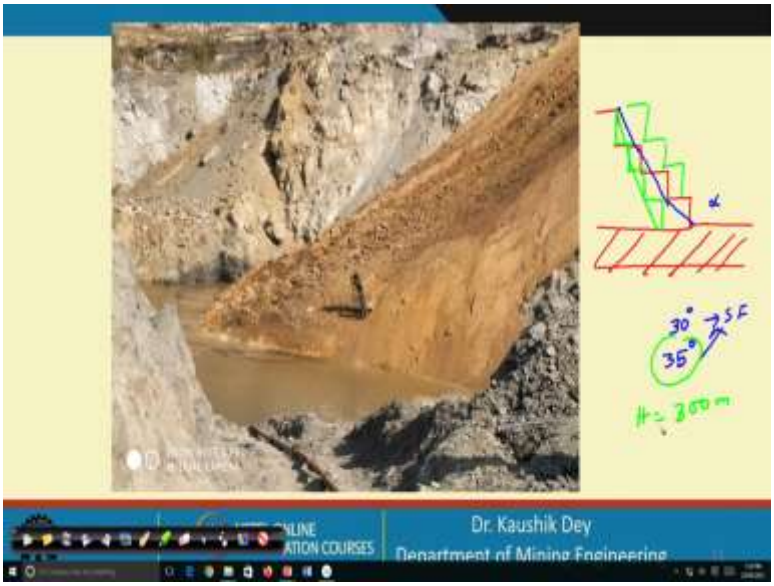
We have covered excavation by ripper, which is a blast free technology. We have covered the excavation by surface miner, which is another blast free technology commonly adopted in the soft rocks. We have covered the operation of dragline for direct casting of the overburden material. We have covered the excavation by the bucket wheel excavator; we have covered the excavation by highwall miner, where the materials are locked under the highwall slopes; how that material can be excavated we have covered. We have covered the maintenance of haul road construction of haul road. We have covered dimensional stone mining, sea bed mining, these are covered. And we have covered different auxiliary operations also. So, this is the current topic is the stability analysis of the slope; so, we are continuing with this.

(Refer Slide Time: 04:17)



In our first lecture on the stability analysis, we have covered the planar failure analysis; we have seen why the slope stability is required. And we have covered the planar failure analysis. In this lecture, we will continue with the other modes of failure. So, our set objectives for slope stability in mines is to understand the necessity of stabilization of pit slope, to understand the different types of slopes, to understand the possible slope failures, and to learn about slope stability analysis.

(Refer Slide Time: 04:53)



So, so far we are trying to observe these things, and here we would like to give one idea about the importance. If we carry out the slope analysis, suppose as we have seen; this is our slope current design slope. And this is the quantity of the ore material we are carrying out taking out from this. And suppose in this case, this is when we are carrying out this analysis, we have found. This is our slope angle, and this slope angle alpha is giving us the opportunity; say alpha is equal to 30 degree, giving us an opportunity to excavate in the mine; and we are having some safety factor associated with this.

Now, if we have carried out a detailed analysis of the slope. And for this, we are able to without compromising with the safety factor; we have come out with a conclusion that this alpha value can be increased 30 to 35 degree, without compromising in this. Then, we can have our new slope profile; we can have our new slope profile like this. So, this will give us some additional ore rock mass; or in other way it is reducing the quantity handling of the overburden. So, if we are considering it, then the quantity requirement of the overburden will be changed. So, that means, if we are carrying out our mining at a depth H is equal to 300 meter, then we can see a pit.

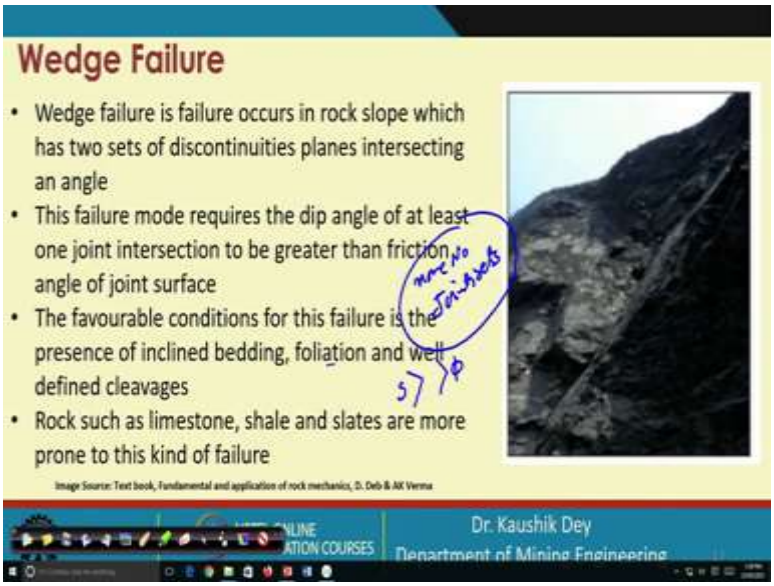
We are carrying out our mining at a depth of 300 meter; and we are increasing a alpha from 30 degree to 35 degree. Then, we are basically, then we are saving a quantity of. Then we are saving a quantity requirement, handling requirement of this much, which is significant one. Now, along with that, if you multiplied with this quantity for a length of, say, 2 kilometers; then this quantity

is becoming a significant quantity. So, this is increasing the cost significantly, and that is the benefit of using this one. So, you can see in this figure how the slope fails, and you can understand the consequence; where you can see, this is the drill machine.

Because of the failure of this slope, the drill machine, which was working at this position is toppled down; and it is broken completely broken in pieces. This is the mast of the drill machine, you can see the mast of the drill machine; and drill machine is already plunged into the, into this soil. So, this is one particular case study recently occurred in a one in one coal mine in which three drill machines are lost; so, these are the consequences of the slope failure.

So that is why proper slope analysis is very important, along with this loss of these three drill machine; the million meters cube of this soil material has to be re handled. So, there is a huge loss in this failure. So, it is essentially required that we should take care of the slope properly to reduce our loss time, having the increased safety, and that must be considered.

(Refer Slide Time: 09:55)

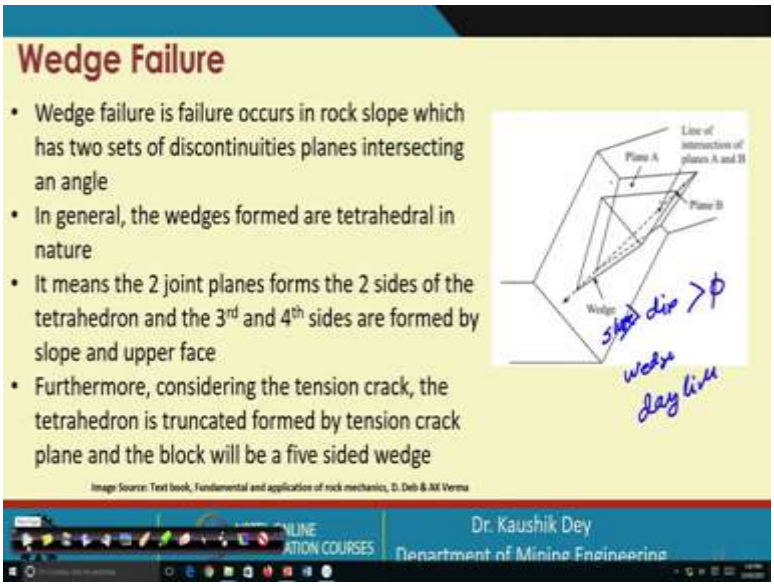


So, we are discussing about the planar failure in the last class that is already covered. Now, we are discussing the next type of failure, which is called the wedge failure. So, as its name is telling wedge failure is when the rock is pumped in a shape of which, and that because of that formation, the rock is basically dislodged from the intersection plane of the wedge; then it is called a wedge failure. So, it can be seen here, a wedge is formed; and as the wedge is formed, the rock is slided down along this wedge; and that is why it is called wedge failure. So, this

failure mode requires the deep angle at the least at of at least one joint intersection to be greater than the friction angle.

And favorable condition for this failure is similar to the planar failure; presence of the inclination of the bedding plane, foliation, and it must daylight also. And this type of failure is mostly occurs in mines, where the number of more number of joint sets cells are, more number of joint sets are available. And these joint sets are intersecting with each other, forming a wedge; and the intersection angle, intersection line of this wedge is having the inclination more than the friction angle, but less than the slope angle. Then, this is the condition of the wedge failure, we consider as exists; and that is required the analysis with due weightage to all the properties.

(Refer Slide Time: 12:06)

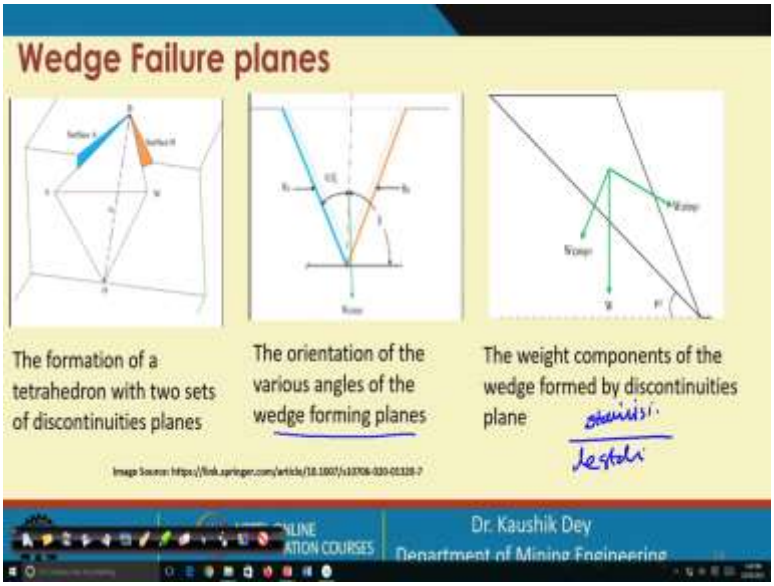


So, now if we are looking at this, we can see. This is the first joint sets, or plane of discontinuity; this is the another joint sets or plane of discontinuity. So, this joint sets, these two joint sets are intersecting each other at the line of intersection; so, this is the line of intersection. So, these two joint sets are intersecting is in this line AB; and that is why a wedge is formed. So, the wedge this is the wedge, this is the formed; and this wedge is now able to dislodge in this. If this line of intersection is having a dip, more than the friction angle, but less than the slope angle.

So, in that case, it can slip from this; but it will slip when, if this is the orienting towards the face of the bench. If the wedge is orienting towards the face of the bench, and this is daylighted in

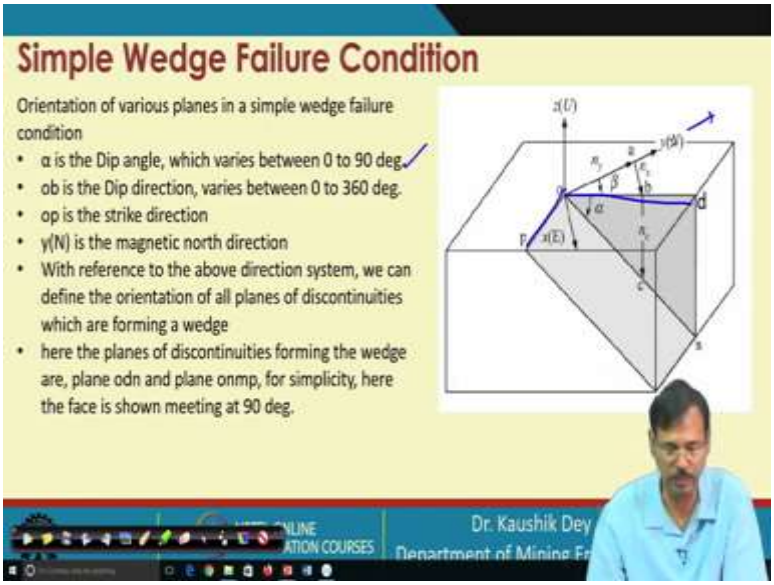
this, in this case; then only this will, there is a chance that wedge the performed wedge can fail; and we have to consider that case for our analysis.

(Refer Slide Time: 14:18)



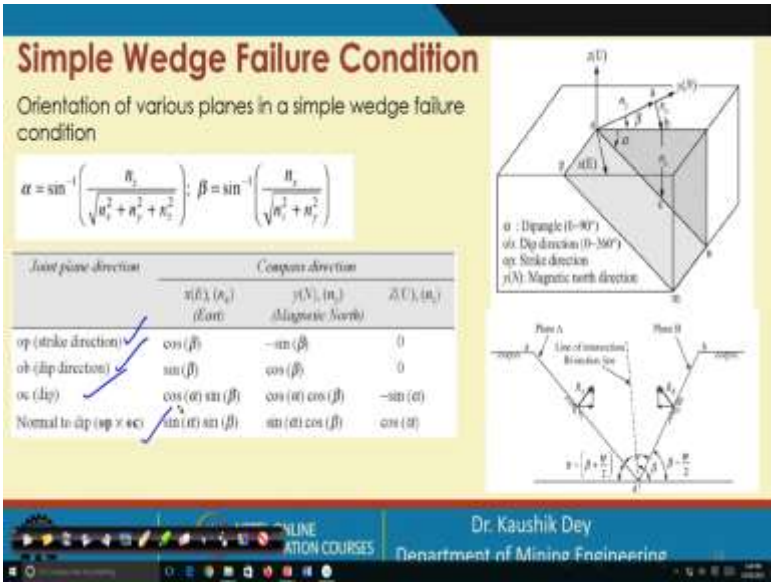
So, the first case is the formation of a tetrahedron rock piece, with the two sets of discontinuity plane. Second condition the orientation of the various angles of the wedge forming plans; so these are the angles, we have to consider. And finally, the weight component, that is the destabilizing and stabilizing forces; that has to be considered in the analysis of the wedge failure. So, this is not only the formation of the wedge is important, but we have to check whether this is having the potential to fail, considering the stabilizing and the destabilizing forces. So that has to be considered here.

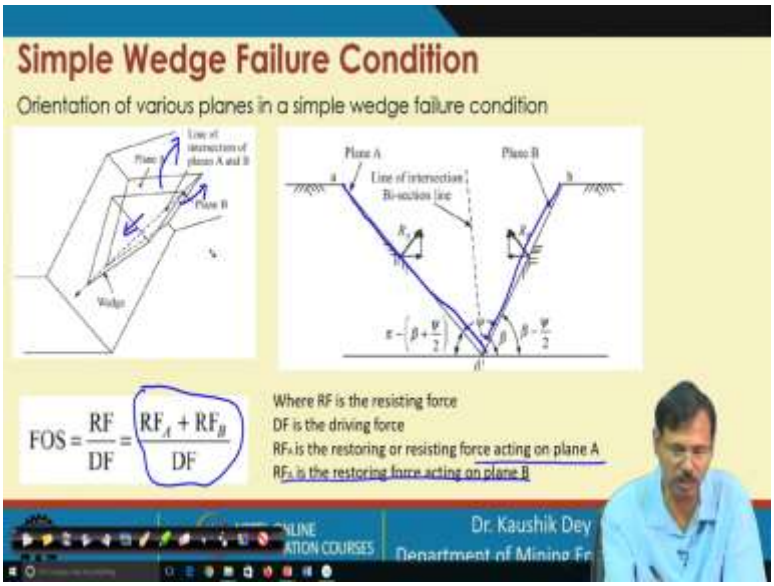
(Refer Slide Time: 15:15)



Now, let us look into the different terminology, alpha is the deep angle, ob is the line which is showing the deep direction; so this is the deep direction. Then, op is the strike direction, so this is the strike direction; and this is the magnetic north. This is the north with respect to that; these are measured, only these angles are measured. And with that is why that the joint mapping, joint mapping is very important to check whether any wedge is being formed here or not.

(Refer Slide Time: 15:55)



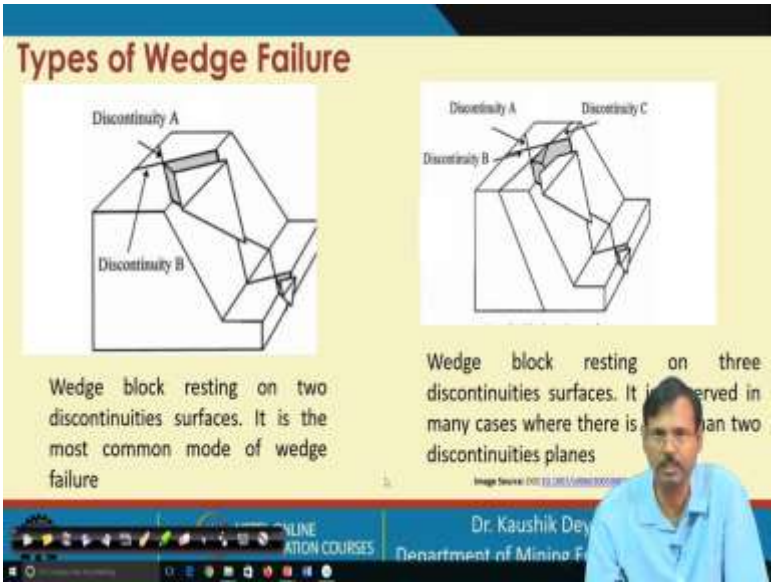


And based on that, the different conditions are found. And these are the sin alpha and beta sine beta values can be obtained from the measured values. And these are the strike direction, direction, and all these are measured using the joint mapping. And with this the factor of safety is obtained with the resisting force, acting on plane; resistive force acting on plane B.

So, this is plane A, the resisting force acting on this; the resisting force acting on this plane is also considered. And we consider the destabilizing force that is the weight component, moving towards this side. So, the w sin alpha is considered as the destabilizing force; and the stabilizing forces are the fictional component of this one, frictional component of this one.

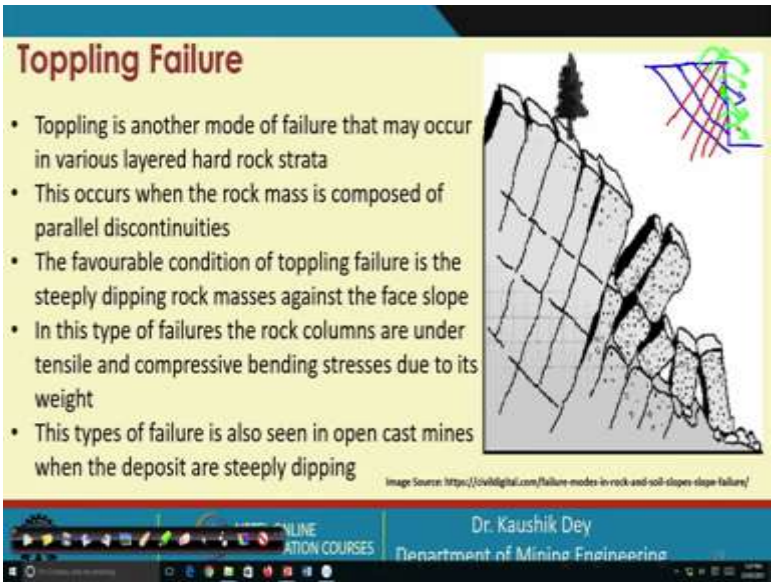
We do not consider line of intersection because it is a line; there is no area considered at this. So, these two frictional components are considered plane A, plane B; and these are based on that, whatever the resistive force is obtained. Along with that, so it is the resistance plus cohesion also considered for both the cases; and by this way this analysis is carried out.

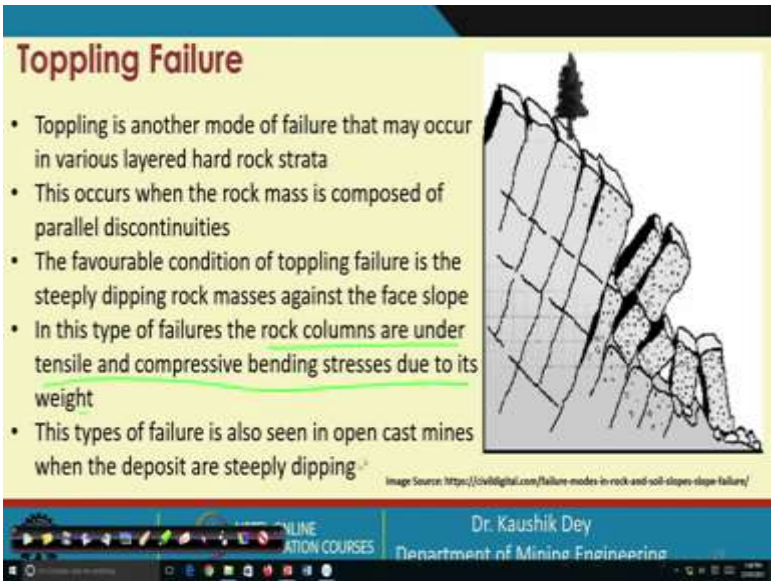
(Refer Slide Time: 17:40)



So, these are the different types of wedge failure which can occur. So, wedge failure resting on two discontinuities. It is the most common mode of wedge failure, resting on more than two also is possible. So, in that case, its multiple discontinuities are considered here. So, this is the more or less wedge failure; the detailed analysis of wedge failure is not in the in this syllabus. That is that can be covered in the advanced surface mining syllabus at a later stage. So, this is only the wedge failure and how the analysis is carried out that is mentioned here. Nowadays, wedge failure analysis can be very easily carried out in the software packages.

(Refer Slide Time: 18:25)





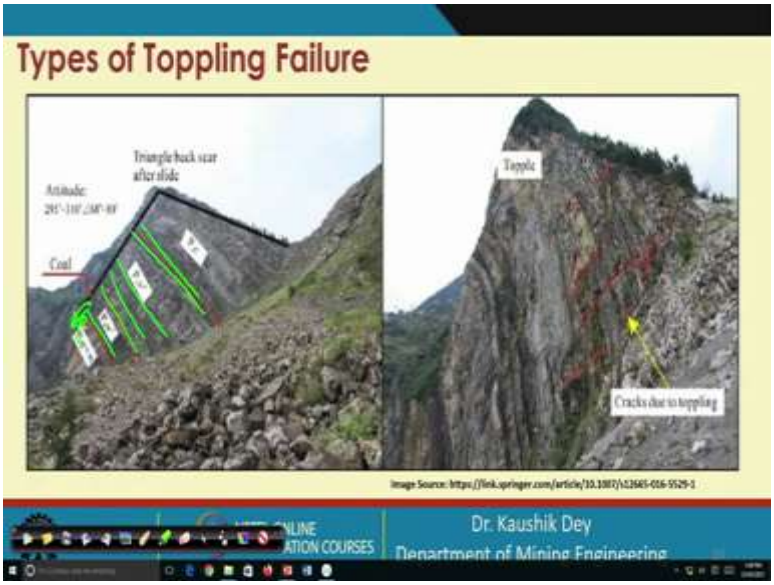
Now, let us look into the toppling failure. Basically, toppling failure is also types of planar failure, but that planar failure and wedge failure is combinely acting here. In this case, the conditions of planar failure needs to be exist. So, if we are considering this is the condition of planar failure; to this is tending to fail at this position.

But, this is more or less stable, but the stability will become under threat, when another sets of joints are existing at this. Say, this another sets of joints are existing in this position like this. So, over the pre-order time, gradually these portions of rocks are trying to fail. So, one by one, one by one these are toppled down; and when the toppling of this one completes, the toppling of this one starts.

So, this is, this is called toppling failure. So, in toppling failure, if modified planar failure we can consider, when the rock mass is composed of parallel discontinuities; and favorable condition for toppling failure occurs, because this is steeply dipping rock masses. And these are more than the angle of friction, and obviously less than the bench angle.

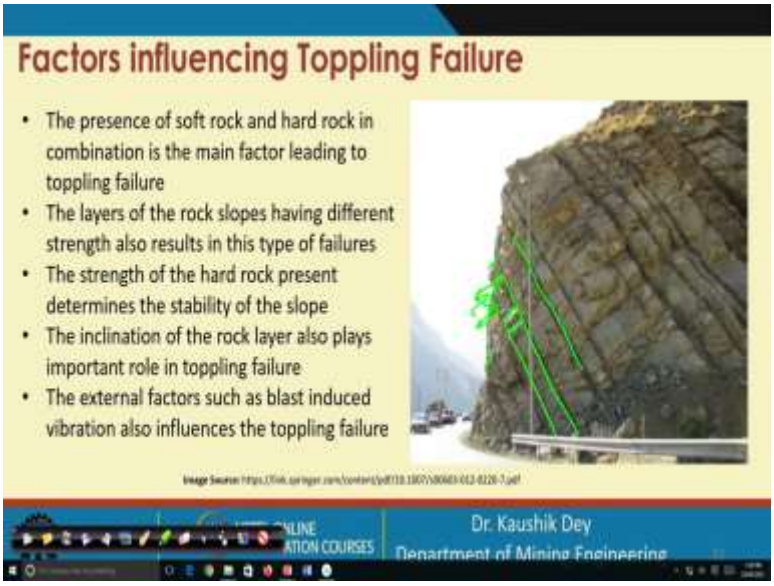
And these small portion rocks pieces are formed, which is toppled down as the blocking rock before it is fall down. So, before is felt, so after that this also tried to fail; so this is called toppling failure. Rock columns are under tensile and compressive bending stress due to its weight; and this try to fall down one by one.

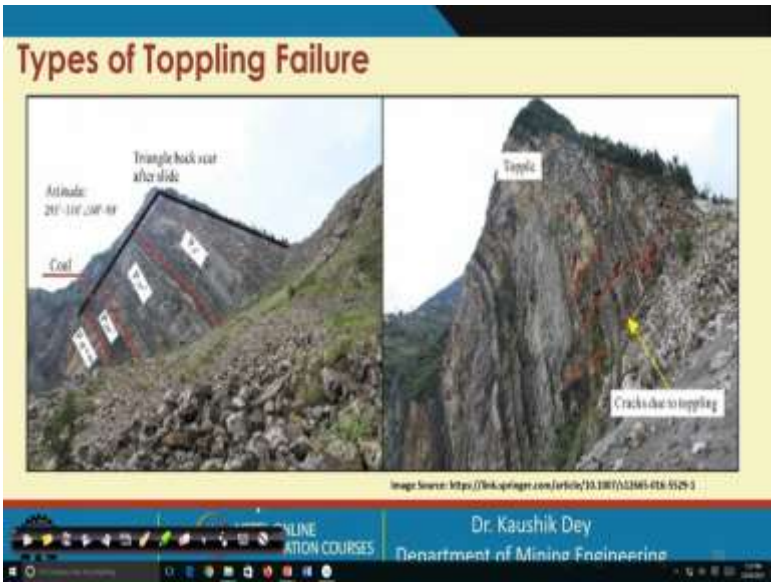
(Refer Slide Time: 20:59)



So, these are mostly occurred toppling failure, can be seen in the natural slopes. It can be seen in this cases that these are the parallel joint sets are existing. And whenever this person rock fall down, this one is also subjected to fail. So, this is the condition; I think there are few more pictures available there. This is a better picture you can see.

(Refer Slide Time: 21:30)

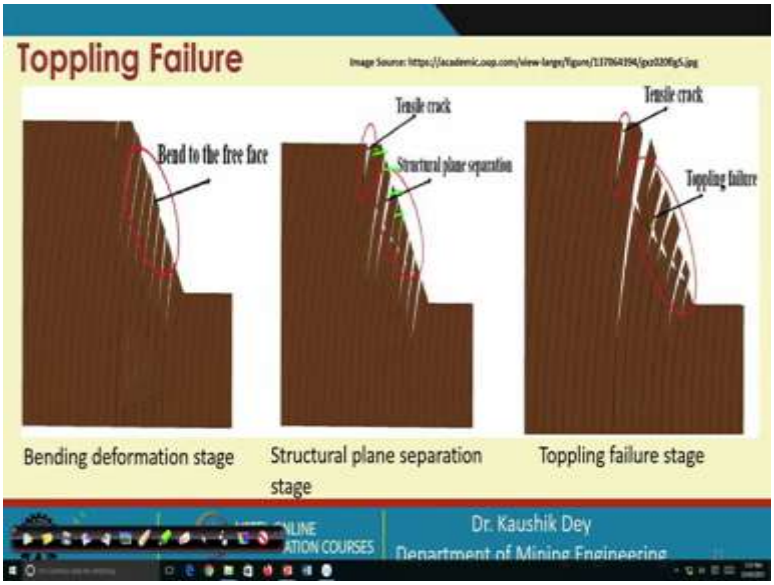




So, as these rock joint sets are already available; along with you can see the second joint sets are also available here. So, as these joint sets are existing, some of these blocks you can see; the block at this position has already fall down. So, this mass is now exposed to this. So, when this one will fall down, then this wall will be exposed; and this one will again fall down at this place. So, this is one by one, the rock blocks which occurred because of the multiple joint sets are all down one by one.

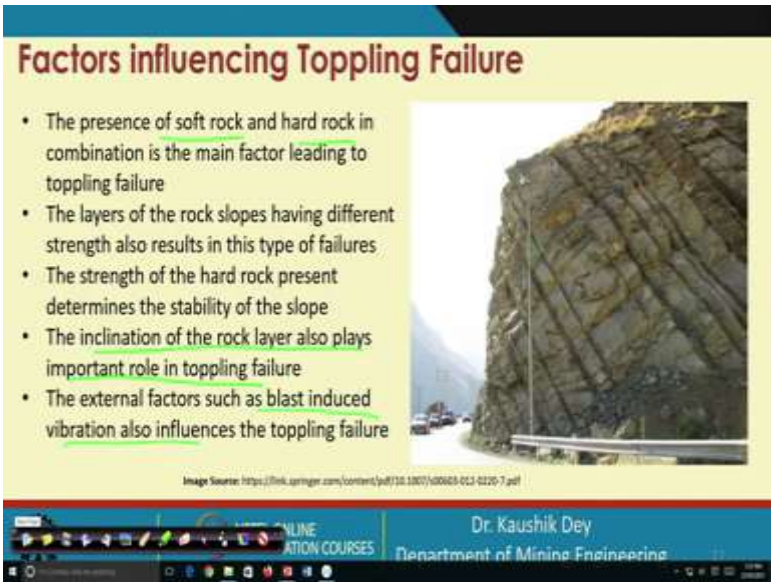
So, first initially, these are remaining intact because of the intact joint sets; then, over the period of time, initially the joint sets were intact. But, over the period of time, as this is a thin layer; thin layer of rock shelf's are standing. So, the cracks are initiated cracks are initiated along the joint planes; and these are trying to be apart from each other.

(Refer Slide Time: 23:11)



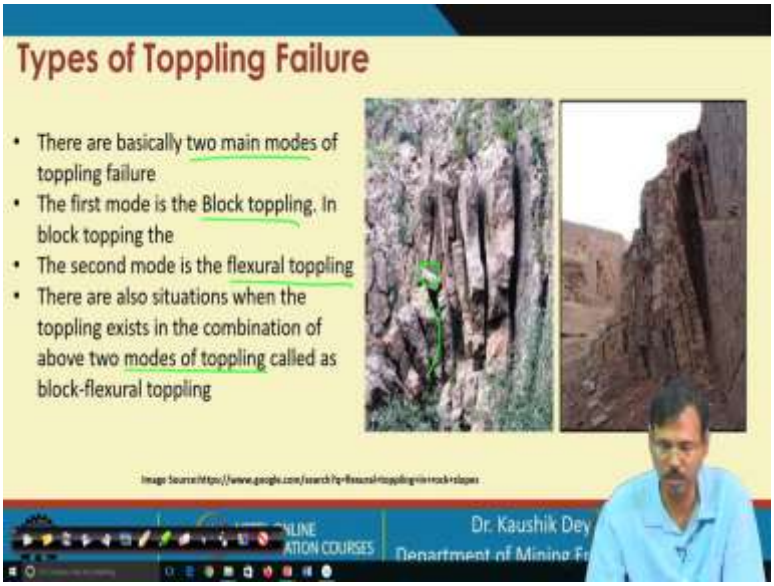
So, as this happened, they try to bend; they try to bend towards the free faces. And as they are trying to bend towards the free faces, the cracks are occurred to this; and gradually they are being toppled down, topple down from the top one by one; and then it is toppling failure occurs.

(Refer Slide Time: 23:39)



So, the conditions can be considered presence of the soft rock, hard rock in combinations occurs. The inclination of the rock layers plays an important role in toppling failure. And often, it has not found toppling failure are induced with the vibrations or other seismic effects; those are basically creating problems.

(Refer Slide Time: 24:09)

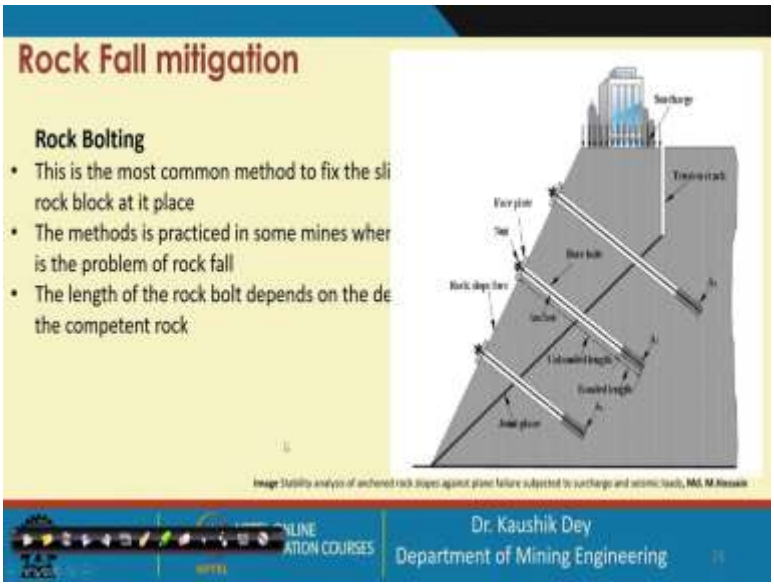


Apart from that, the erosion of the rock with the movement of the air and water is also very important. So, there are two modes of failure, one is the block toppling. In block toppling, second one is the flexural toppling, so this is the block. These are the combinations, also observed in the block toppling; these are called block toppling and this is flexural toppling. So, this both cases can be occurred simultaneously.

(Refer Slide Time: 24:50)

And these are the way one can try the further, especially for the natural slope, to arrest or to provide some safeguard from the toppling failures. Toppling failures are very common specially for the natural slope it is observed. In mining, toppling failure is not common; because the mine is an active place, active operation operating place, where the slopes are controlled in a better way. And it is not led inactive for a long period. So, once the mining is complete, for abundant mines toppling failure may occur; but for active mine, toppling failure is not very significant one.

(Refer Slide Time: 25:40)



So, these are the different rock fall mitigation techniques. This is also rock bolting technique commonly used for the wedge failure, planar failure, toppling failure. This is more or less about the wedge failure and toppling failure. We will continue with the circular failure in the next class. Thank you.