Surface Mining Technology
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Lecture – 56
Stability of Bench Slopes – I

Let me welcome you to the 56th lecture of NPTEL online certification course Surface Mining Technology. These are the lectures related to stability of bench slopes; there will be 3 lectures on this. This is the first lecture, in which we will introduce you to the bench slope; and we will discuss about the planar failure, which is one type of failure occurred in the bench slope.

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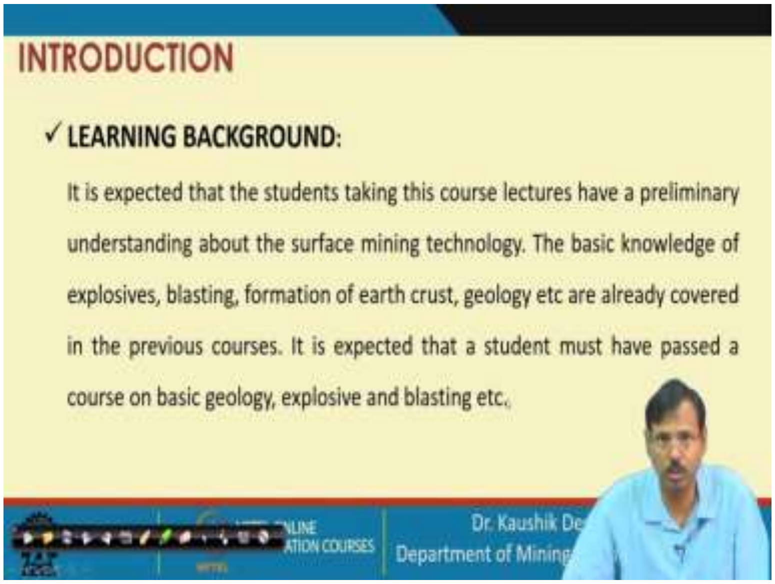

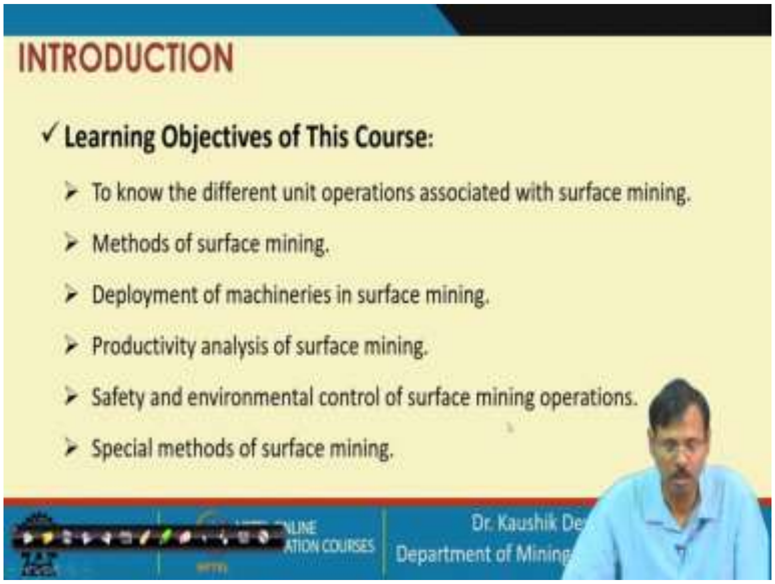

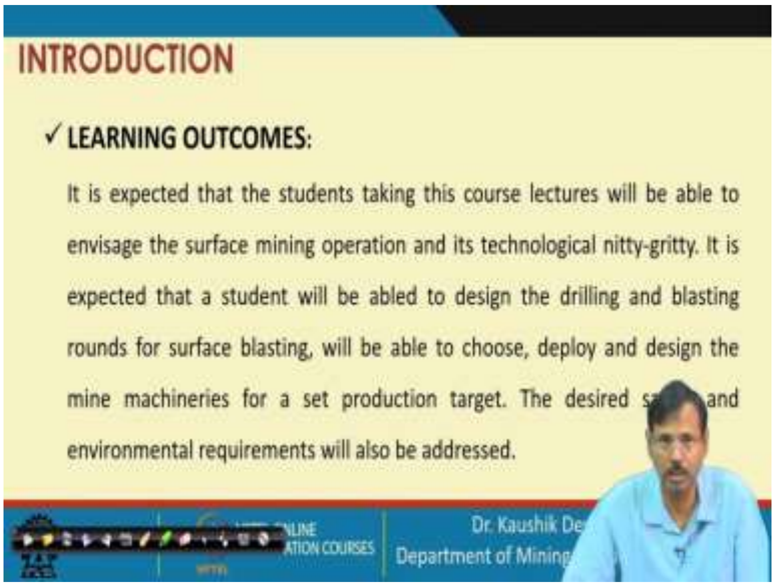

But, before that going into the details of this, let us look once again into the learning background required for surface mining technology course. The set learning objectives for the surface mining technology course, and expected learning outcomes.

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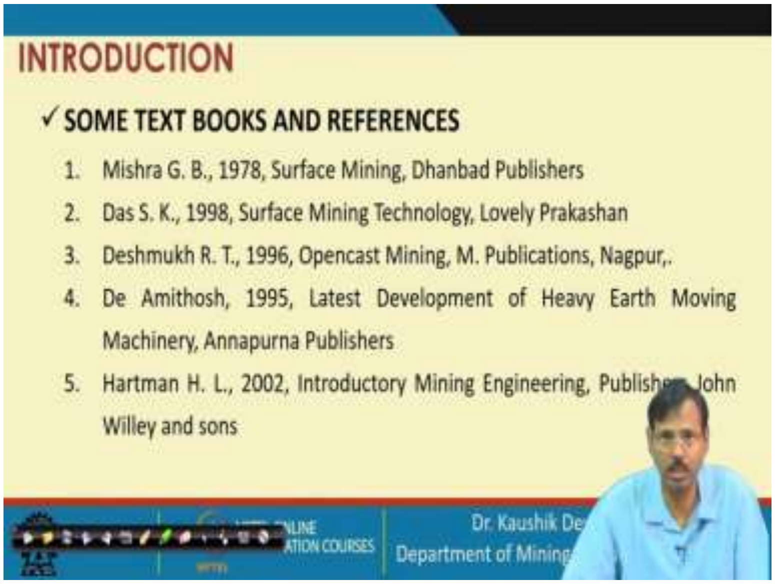

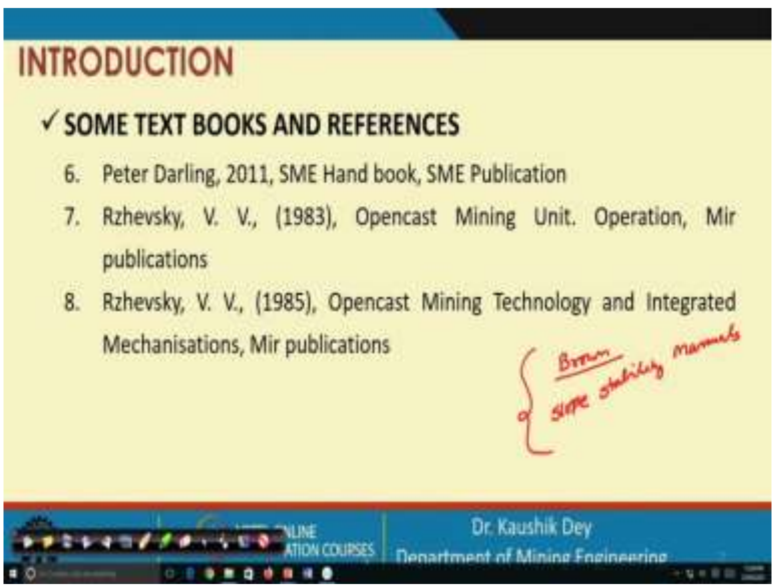

And these are some of the text and reference books; this particular topic slope stability can be looked into the other various books available Brady and Brown, a book on slope stability is very famous. Apart from that, there are other slope stability books available, even if slope stability manuals are also there. So, these books are very common and can be used for further study.

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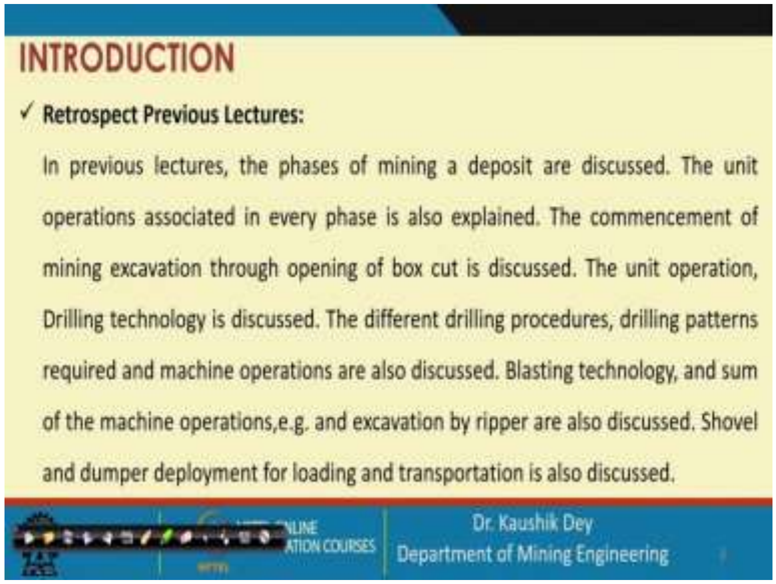

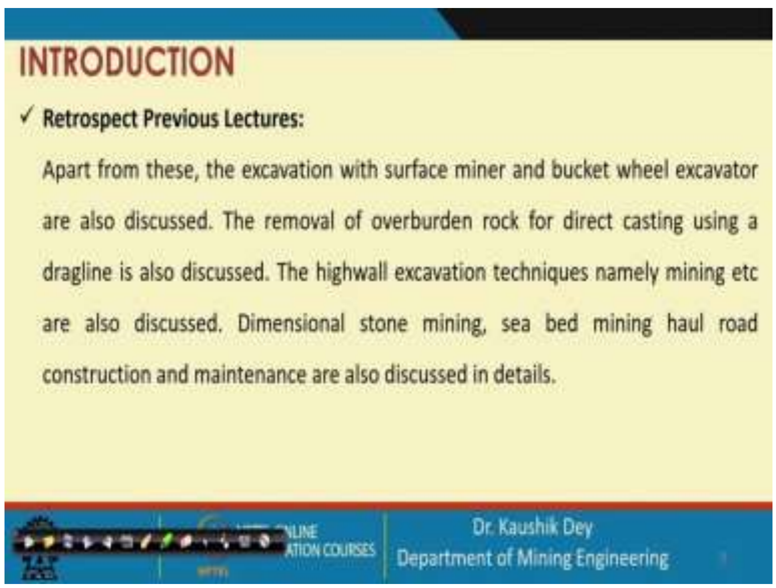

And let us retrospect our previous lectures; we have almost at the end of the syllabus. So far, we have covered the status of the surface mining worldwide. We have covered the phases of mining a deposit; we have covered commencement of surface mining using box cut. We have covered the drilling technology, blasting technology; we have covered excavation by ripper, we have covered the handling of fragmented rock mass by shovel and excavators. And transportation of the same using a dumper or other mode of transportation system. We have covered excavation with surface miner; we have covered excavation with dragline and direct casting of the material.

We have covered the excavation with bucket wheel excavator; we have covered other auxiliary operations required in the surface mining. We have covered the haul road construction and maintenance, we have covered dimensional stone mining, we have covered sea bed mining; and haul road construction also we have discussed, highwall mining is also discussed. So, these are mostly the topics we have covered during this course of surface mining technology. And this is before except the closure of the mine, the last topic we are discussing here, the slope stability.

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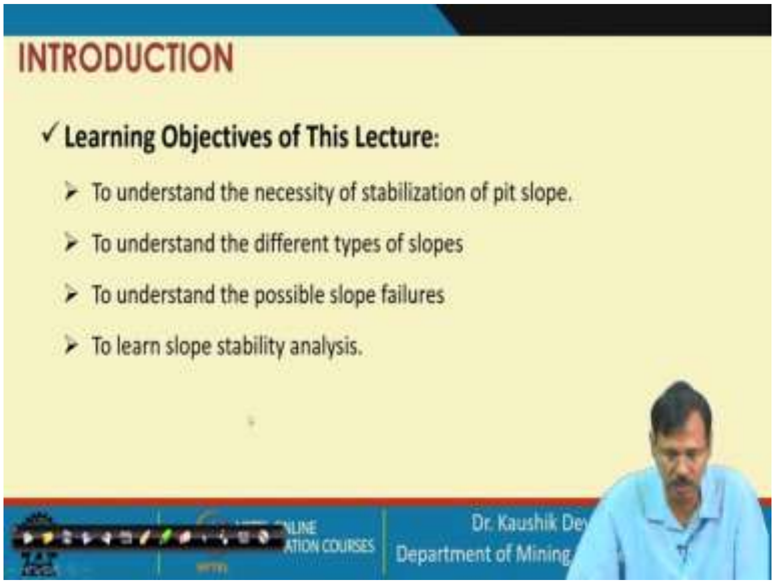

The set objectives for the lectures pertaining to slope stability are set as, to understand the necessity of stabilization of pit slope, to understand the different types of slopes, to understand the possible slope failures, and to learn the slope stability analysis.

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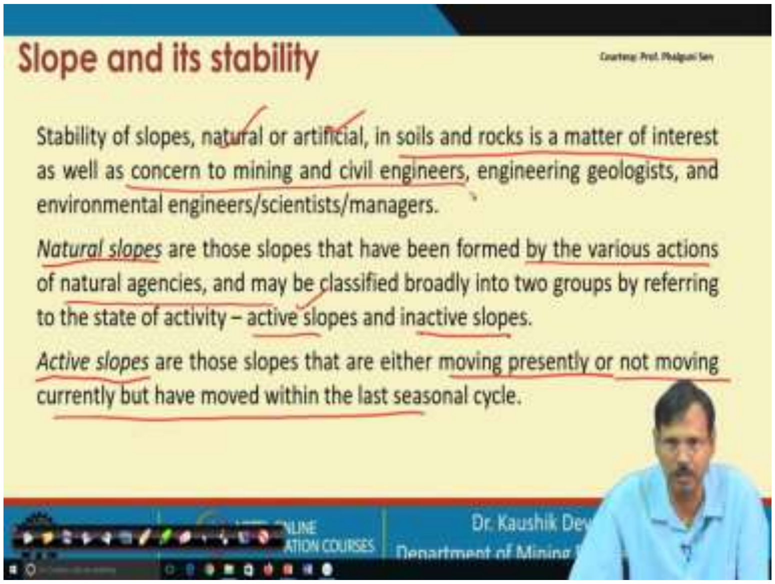

So, first let us understand what is slope, or what we understand by meaning of stability of slope. The slope is basically characterized as natural slope, and it is of two types; active slope and inactive slope. Slope can be natural or artificial; generally in solid soils and rocks is a matter of interest as well known concern of mining and civil engineers. We are discussing about the slopes. Natural slopes are slopes, which are formed by the various actions of natural agencies, which maybe the flow of the wind; which maybe the flow of the water. And these are classified in active and inactive slope, where active slope is the slope that are moving presently or not moving currently; but have moved within last seasonal cycle, is considered as the active slope. That means if it is a hilly terrain, and there was some movement of the terrain, with in the near past; then that is considered as the active slope.

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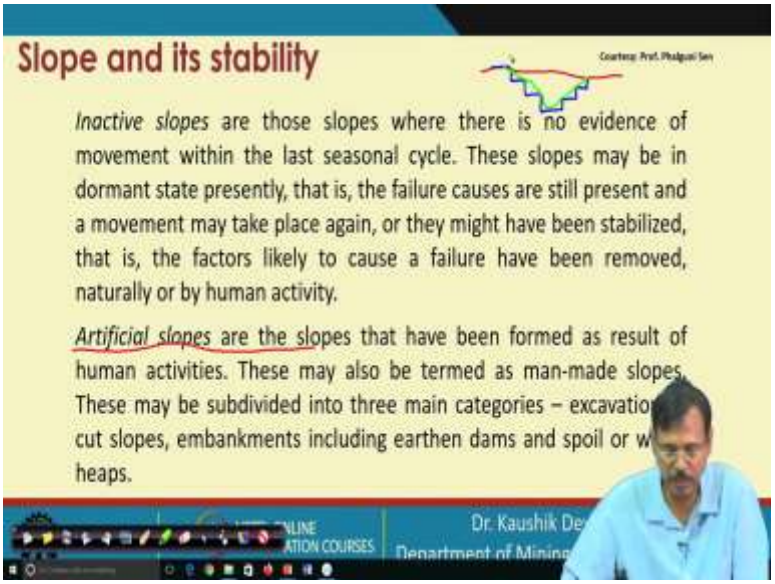

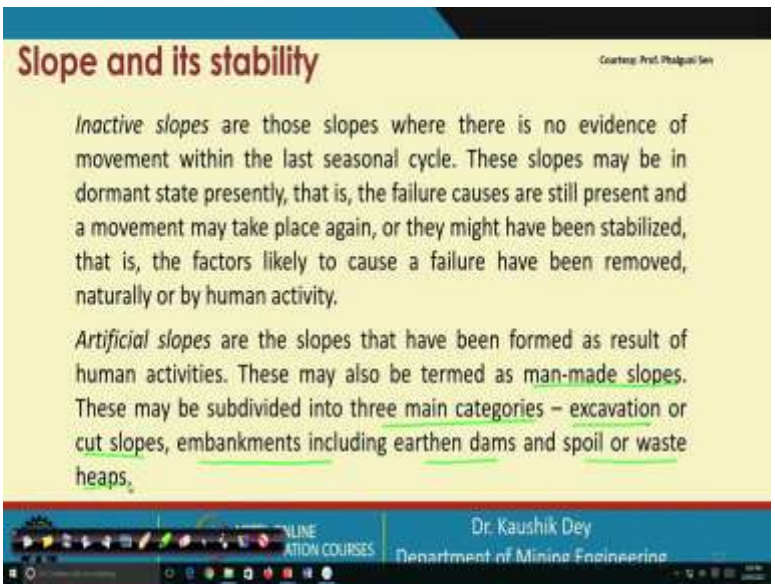

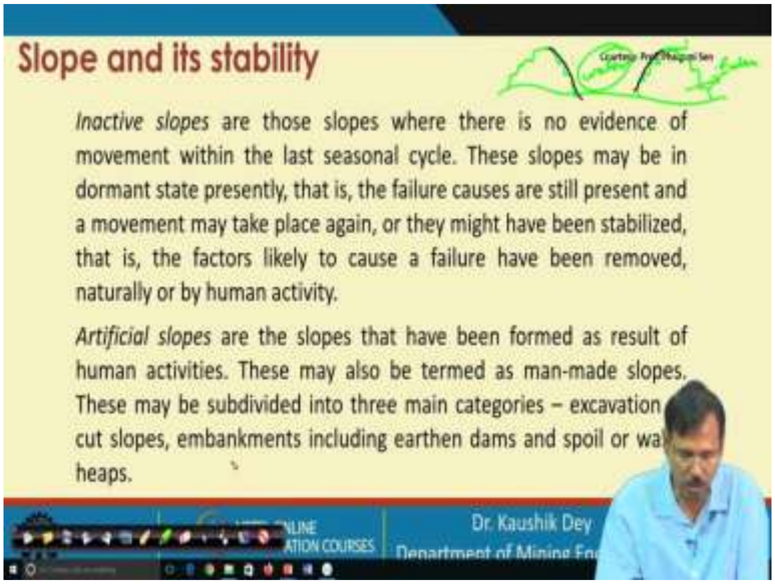

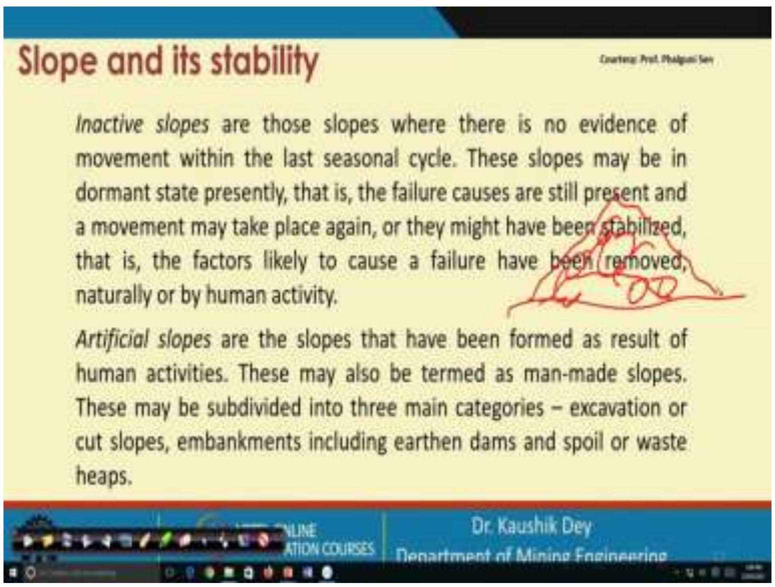

If there is no such movement in the near past; that is called the inactive slope. And we are very much concerned about these natural slopes, which are active; especially, stabilization of that work and the safety of the nearby passers, nearby dwellings are required. But, in mining we are creating the artificial slopes. Natural slopes are available with some hilly terrain, where the mining is being carried out in the hills; there are natural slopes existing.

But, apart from that, in mine, we create the artificial slopes also; because we have digged out the ground. And the slopes are being created as this is the earlier position. But, with the mining, we have excavated like this; so the slopes are new slopes generated. So, new slopes are generated like this. So, that is why we are creating artificial slopes at this position, which is very very important; these are the man-made slopes. And this is categorized as the excavation, or cut slopes, embankments, earthen dams, and spoils or waste heaps. So, artificially we have carried out slopes in three way.

First is that we cut this, as we have shown the earlier diagram; and this is one possibilities. Second possibility is that this is a natural ground; we are depositing something. These are often carried out for some water movement or making some cannels at these positions. So, or by constructing the roads, say roads are made here; so these are the embankment constructed. And because of that some slopes are generated at this position; so these are called the embankment. And often we do not do anything of this; we are just allowing the dumping of the materials like this. And that is creating the slope; that is the waste dump or waste heap slopes are often created. So, these are the main artificial slopes which are created.

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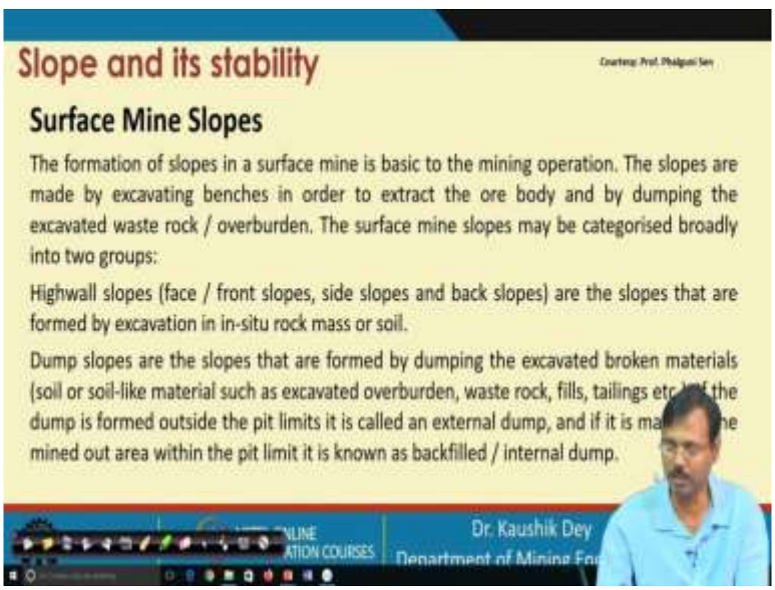

But, here we are basically considering the mining slopes. In mines, in general, we do not make the embankment; so we are concerned about that cut slopes or the overburden dump slopes. So, basically, these are the two types of slopes we are forming. The first one by cutting the benches, we are creating the depth; and that is why the slopes are created. So, that is called cut slopes and the second one is the dump slope, as we are dumping the overburden; that is creating the dump slopes. Often these are internal overburden dumping also; but that is also having the dump slopes.

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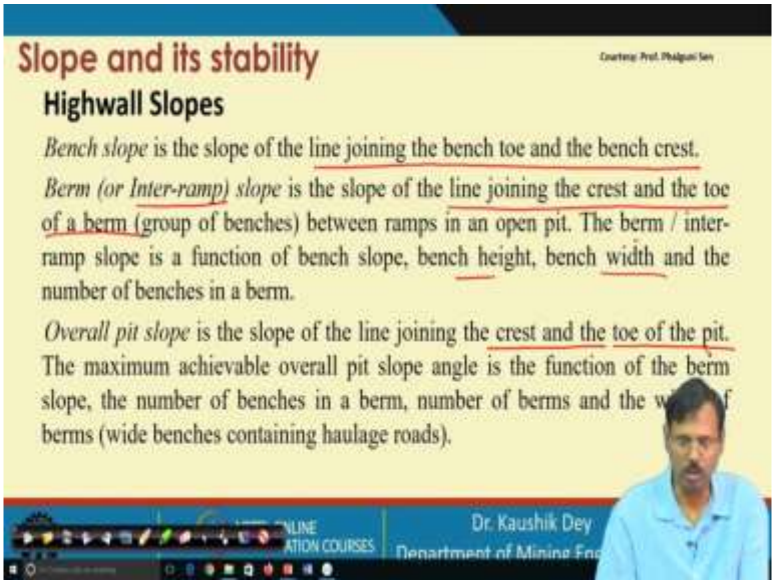

Bench slopes are classified in three way; one is the individual slope of a bench, where the crest and toes are joint. And the angle of that is representing the bench slope. Theoretically, all the active benches are having a bench slope of 90 degree; but we try to keep it as as steep as possible, so that the excavation can be carried out properly. The burden of the blasting should be same as the crest and as the toe also. In that consideration we will try to make the slope as high as possible, and theoretically it is 90 degree, we try to maintain.

Berm slope is the slope that the line joining the crest and the toe of a berm; that is the group of benches is called the berm slope; or it is also called inter-ramp slope. The berm or inter-ramp slope is a function of bench slope, bench height and bench width in that number of benches. This is in general carried out, where say overburden having some number of benches; those are considered as a group.

Then, there is the ore body. We are keeping some width between this overburden benches and the ore body; so that is creating a group of benches in the ore body, a group of benches in the overburden. And by that way we are maintaining that called as inter inter-ramp slope or the berm slope. And overall pit slope is the speed slope considering all the benches; and we are in this case considering the crest of the top most or the surface, topmost bench or that surface; and the toe of the bottom most bench or the pit. So, in consideration of that one whatever slope angle is obtained; that is called overall pit slope angle.

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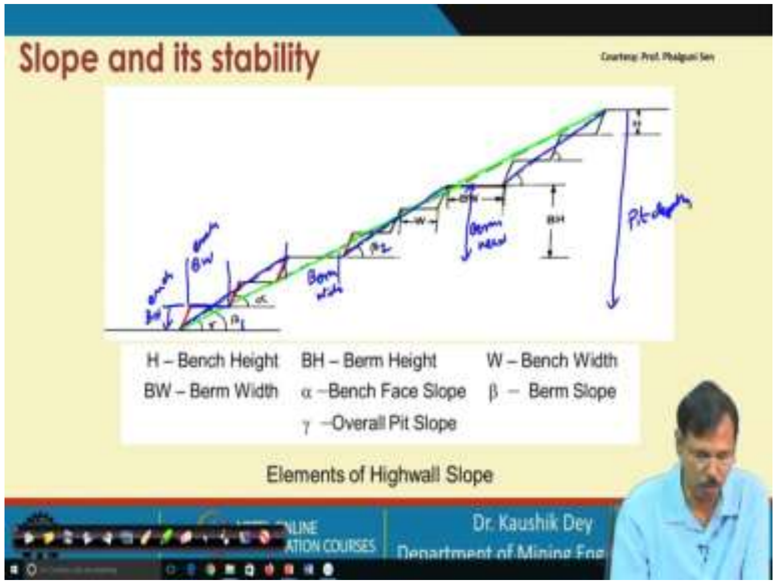

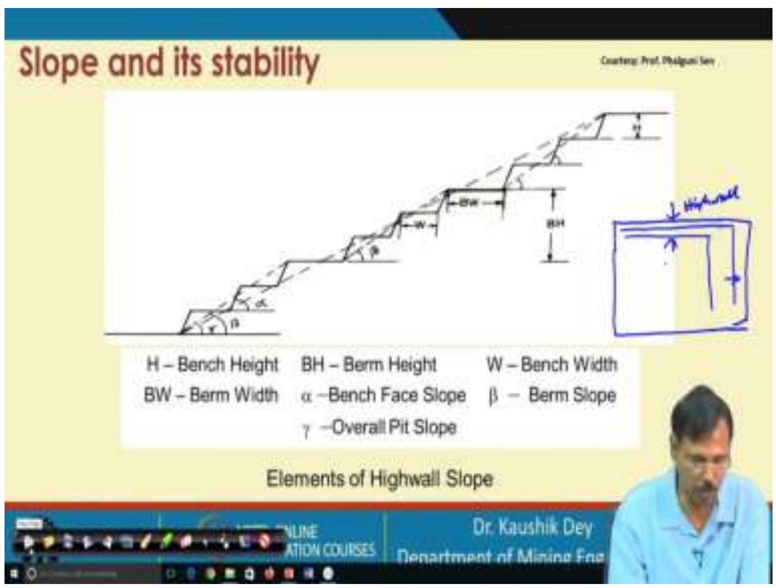

So, when we are presenting it in a pictorial form, it can be seen. This is a bench slope, this is a berm slope, and this is a pit slope or overall pit slope. But, the bench slopes, there are many bench slopes; these slopes maybe different. Similarly, there are many berm slopes; these berm slopes angle maybe different, depending on the type of benches and etcetera. So, we can tell that this maybe B1, B2, B3; and these are the individual benches, maybe alpha1, alpha2 or something like that. But, overall pit slopes remain same; these are the individual bench width. These are the individual bench width, and these are the bench height; these are the berm width, this is bench width. Let me write completely.

This is bench height, this is berm width, and this is berm height; and this is overall pit height, pit depth, so this is the general terminology. And we can understand this generally, whenever a mining is carried out as any mine is progressing. In general, a mine is progressing in this direction; in these places, we are having the operating benches. But, these are the side walls, where in general, we reach up to the pit depth; and this wall is are called highwall. And the slope stability we are concerned about in this highwall especially, because those are very steep in nature.

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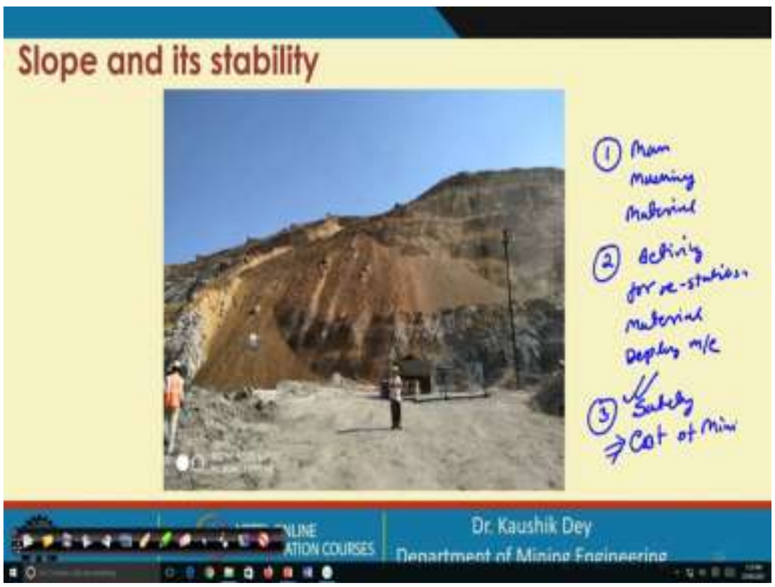

So, this is one photographs of a say failure slope; it can be seen how this slope is failed, this portion, how the slope is failed. And it is very understood that the failure of slope may result in the loss of man, machinery, material. Apart from that it involves in the activity for re-stabilization, material handling, deployment of machines. So, these are unwanted because it is threat to the safety; it is increase the cost of mining significantly.

So, these are the main drawbacks, so the slope stability is very very important. Considering this one very first requirement for this it is essentially required. Apart from that, these are very costly operations also, if million tons of million-meter cubes are materials are sliding down. Then, that is creating a problem, and the re-handling cost of this million-meter cube of material is becoming very costly operation.

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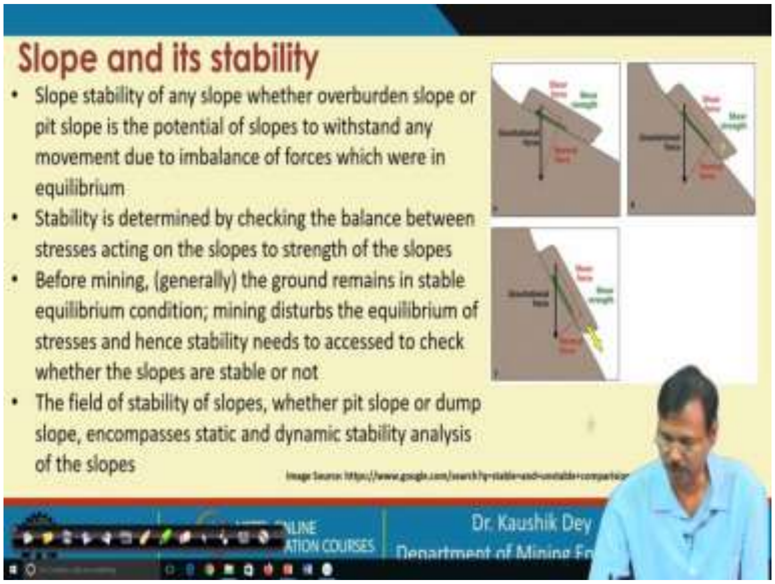

So, slope stability: stability of any slope whether overburden slope or pit slope, is the potential of slopes to withstand any movement due to imbalance of forces, which were in equilibrium. So, suppose whether it will be moving in this side or not, that is depending on the changes in the forces acting on this. And that is why whatever the shear force is coming at this position; that is depending on the shear strength of this one. That is frictional forces depending on the normal force, which we are providing; so, weight of the material is also important. Safety is determined by checking the balance between the stress acting on this.

Before mining, the ground remains in stable equilibrium condition; mining disturbs the equilibrium. And that is why this stress are being induced, and the static and dynamic stability analysis should be carried out, for the pit slopes and dump slopes; while, the mining is being carried out to ascertain the stability of the place.

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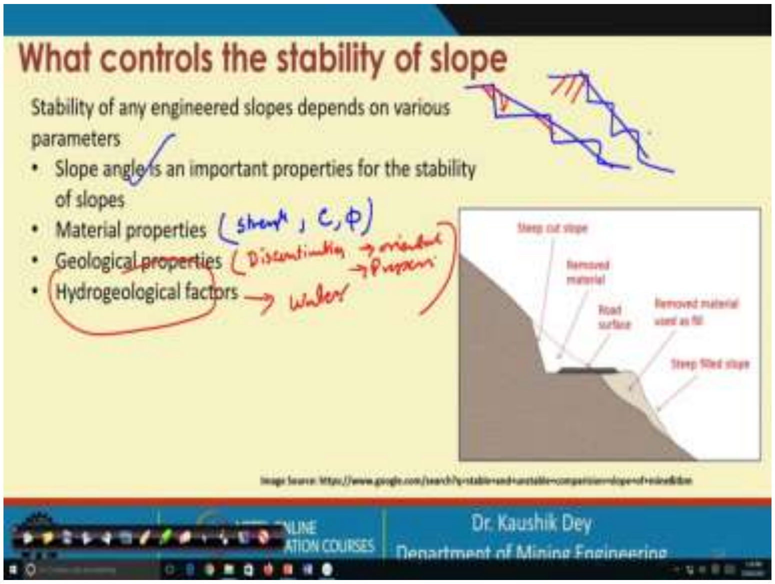

So, let us look what are the influential factors; that is controlling the stability of a slope. Slope angle is very very important; that means if we are having a bench, this may not be stable. But, instead of if we are having a bench, this angle maybe stable, because it is much of reduced inclination; so, the slope angle is very one. Second is the material properties- if the material here is very strong, then it can withstand this one. But, if it not much that strong, then it cannot withstand. In this material property, the major material property is the strength of the rock; especially, the shear strength, the cohesion, the friction angle all these are important in this case.

Next, is the geological property; that means if we are having some discontinuity plane; let us draw it in different color. Say, if we are having some discontinuity planes like this; this, then this allows the falling of this discontinuity planes, but material over this. But if we are having a discontinuity plane like this, this is stable enough; and this will not allow the fall of material along that discontinuity plane in this direction. So, the orientations, discontinuity plane and their orientations, and their properties; these are some important parameters and needs to be considered, while we are considering the stability of a slope.

And finally, the hydrogeological factors, that is the in-situ water, surface waters, what are the stress coming on to this mass rock mass, which is tending to falling from the slope. And what is the saturation, increase in the weight of the rock mass because of the saturation of the water; so, these two are the factors. That is the factors pertaining to water needs to be considered in this as the hydrogeological factor, which are influencing the stability of one slope.

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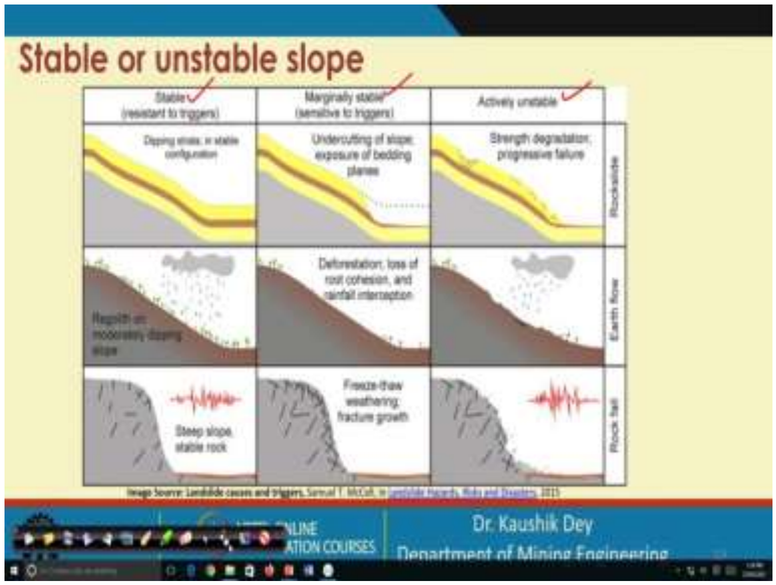

Now, these are the different considerations, whether a slope is stable or marginally stable, or it is a active one. And what are the different factors, which are affecting these things are basically shown in this figure.

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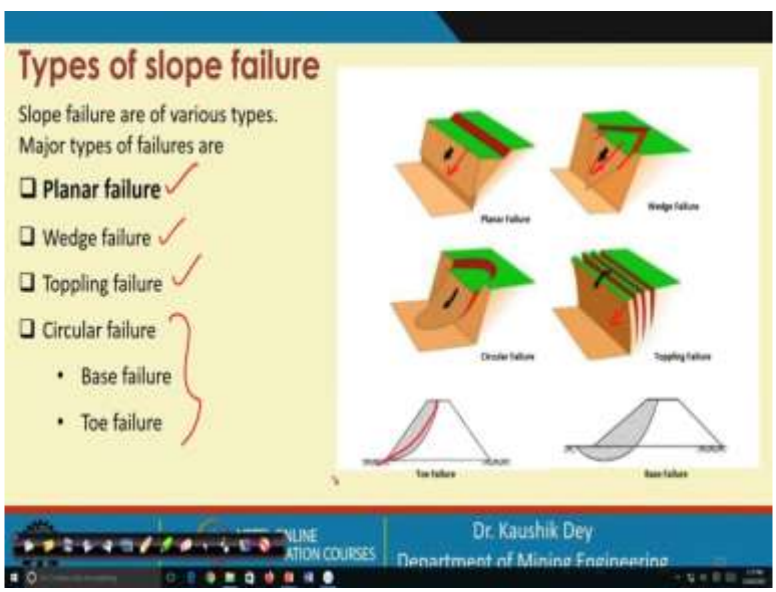

And these are the different types of failures, which we observed commonly in a mining slope. First one is the planner slope, where the plane of rock is falling down. Second one is wedge slope, where the wedges is formed by virtue of the different discontinuity planes. And then the whatever rock mass is coming within that wedge that is sliding down. Toppling failure is one kind of planner failure only, where the two sets of plane two two sets of two joint sets, or discontinuity planes are created; and the one by one, the columns are doubled down.

And circular failure is the failure, where the rock mass is slided down in soil in general. Or, very very highly fractured rock mass it is observed, where it is completely failed. The material is failed, because it is a soft material and it is not following any discontinuity planes; it is slided down as the material is highly fractured.

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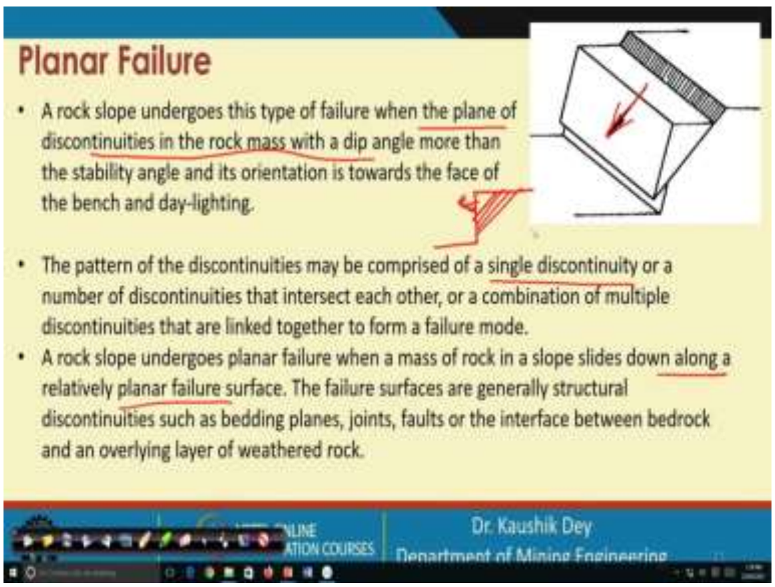

Now, in this lecture, we will end with the planar failure; so, let us look what is planar failure. Basically, planner failure is a type of failure when the plane of discontinuities in the rock mass with a deep angle more than the stability angle. Or, you can say the angle of repose, or friction angle, and its orientation is towards the face of the bench and delighting. Then, the chances of failure of this rock mass are there; and that is called a planar failure.

So, here the important part is the discontinuity plane, its pattern is very very important. It may be continuing a single discontinuity, or it may be a set of discontinuities. Or, it may be a set of discontinuities, it may link together also. And the rock mass is slided down along this plane. And it occurs in most of the cases, if we are failed to control the direction of our benching.

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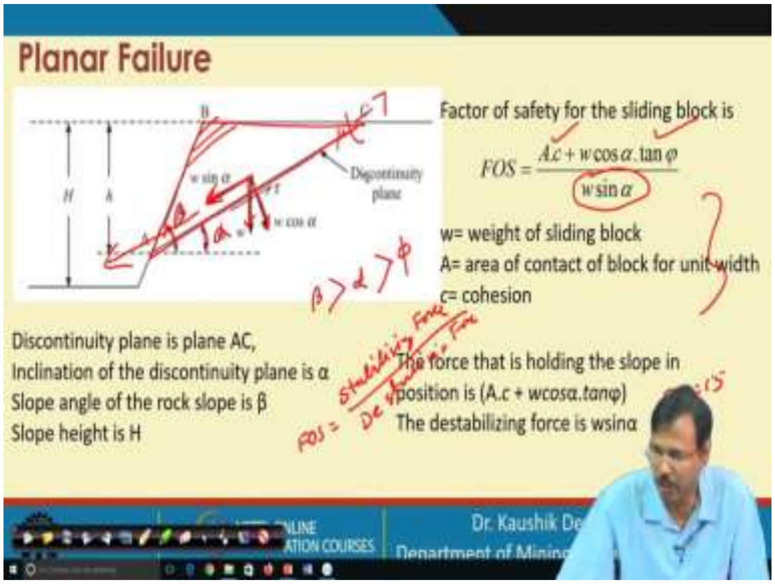

So, now, if we are looking into this, if we are considering this rock mass, or in word; say this rock mass weight is w acting here. And then there are two components, sin alpha and cos alpha; this alpha is the angle of discontinuity plane with the horizontal. And it is acting at a depth of h, while the bench height is H. So, this bench angle beta is greater than the alpha, and this alpha is greater than the friction angle phi. So, if this is the considerations occurs, we are trying to find out what is the destabilizing force, and what is a stabilizing force. So, this destabilizing forces this one, which is trying to send this rock mass at this position.

And stabilizing force is that the frictional component which is coming; that is the mu into w sin alpha whatever is coming, that is the frictional component. So, if we are considering this along with the cohesion, then the factor of safety which is the stabilizing force, stabilizing force by the destabilizing force; or we can say the strength by the stress also. So, the stabilizing force is the cohesion plus, frictional component frictional force; and destabilizing force is the weight component of the rock mass. So, if we are considering this one, then whatever value you are getting that is considered as the; that is considered as the factor of safety.

So, for our open cast slop benches, we have to find out that this for a factor of safety should be 1.5 for a long term stability; and more than 1.2 for the short term stability we can consider. And depending on that we have to carry out the analysis. So, planar failure analysis required the holistic joint survey, and we have to find out the material properties.

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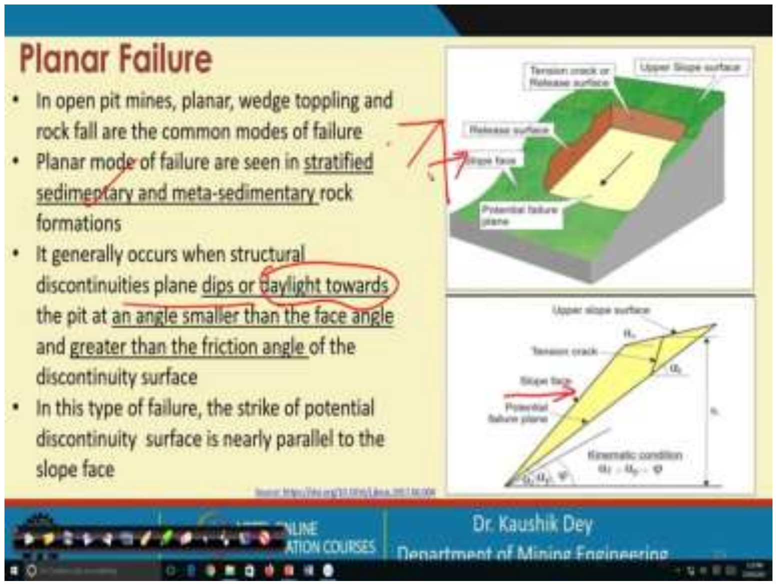

Generally, planar failure is observed in mostly the sedimentary deposit; because the sedimentary deposits are having clear joint sets. And the discontinuity plane dips or daylight towards the pit at an angle smaller than the face angle, and greater than the friction angle. So, the important part is that greater than the friction angle, smaller than the slope angle is well understood. But, this material will fall down, only when it is daylighting towards the face.

So that means, if we are having this joint set, this will fall down if it is open towards this side. But, instead this joint set will remain same, but instead of having the bench direction at this side, if we are changed our bench direction to this side. This same joint will not pose any threat to the failure of this planar failure of this rock mass. So, that is why this daylighting is very very important, if the direction is daylighting towards that one; and then only it will fail, otherwise it is not failing at this side. So, the orientation and delighting is very very important one in the slope failure analysis.

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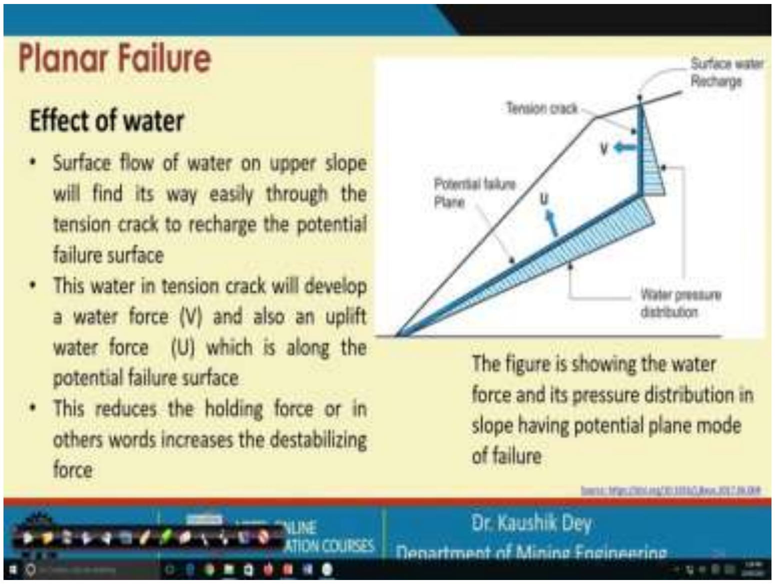

Now, there some effect of water is also there, if we are having surface water or underground water is percolating through these cracks, then the water is acting in two ways. One is that it is giving a thrust in this direction; and second is that due to the buoyancy, it is reducing the w cos alpha. So, in other turn it is reducing the frictional force; and, as well as in saturated rock mass cohesion is also becoming 0. So, basically the water in the rock slope is reducing the stability and that is why it is a threat; it is a threat to the stability of the rock mass.

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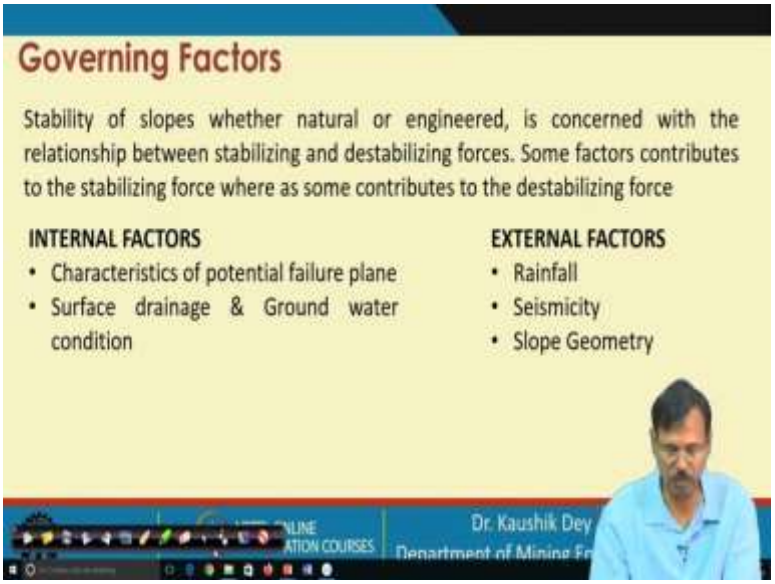

So, there are different factors which is governing the stability; these are the characteristics of the failure plane, surface drainage, ground water condition; external factor rainfall, seismicity, maybe the earthquake, slope geometries, these are some of the important factor. And the best way to control the planar failure is the change in the orientation of the bench, considered to be the best thing.

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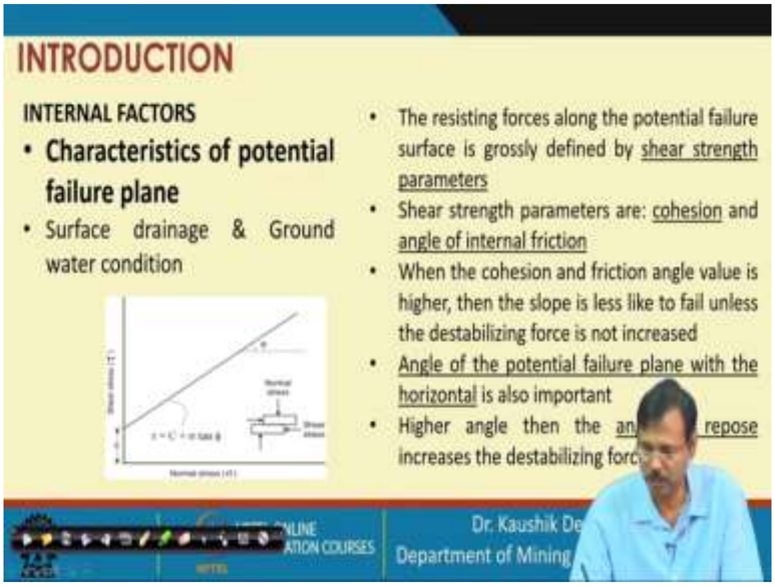

So, these are some of the characteristics of the planar failure, and these are should be controlled during this planar failure analysis. Thank you.