Surface Mining Technology
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Lecture 58
Stability of Bench Slopes - III

Let me welcome you to the 58th lecture of Surface Mining Technology, online NPTEL online certification course, this is the third lecture on Stability of Bench Slopes. This is third and final lecture of this stability analysis and in this lecture, we will discuss about the circular failure.

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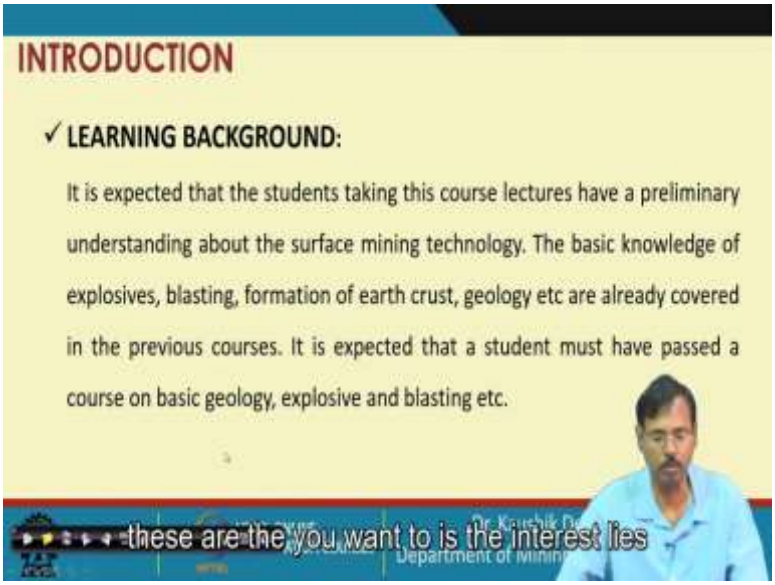

But before that as we do in every class, let us retrospect once again, what are the learning background required for Surface Mining Technology course.

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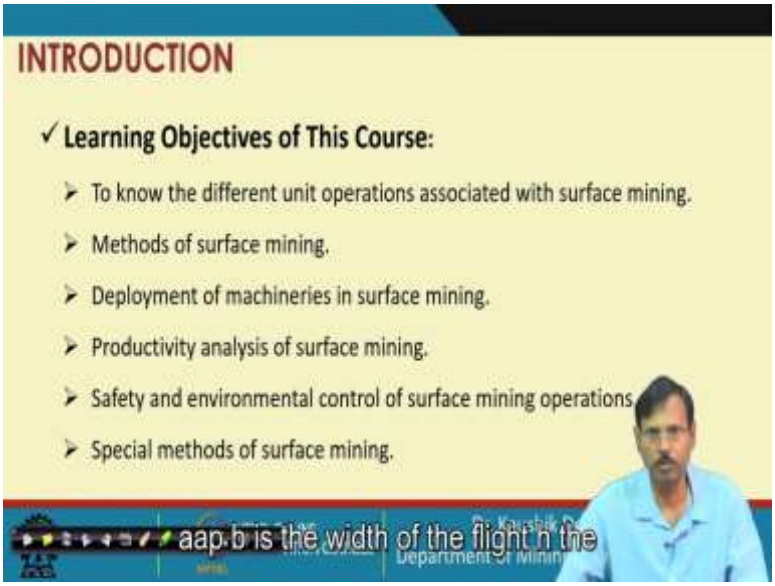

The learning objective set for the Surface Mining Technology course.

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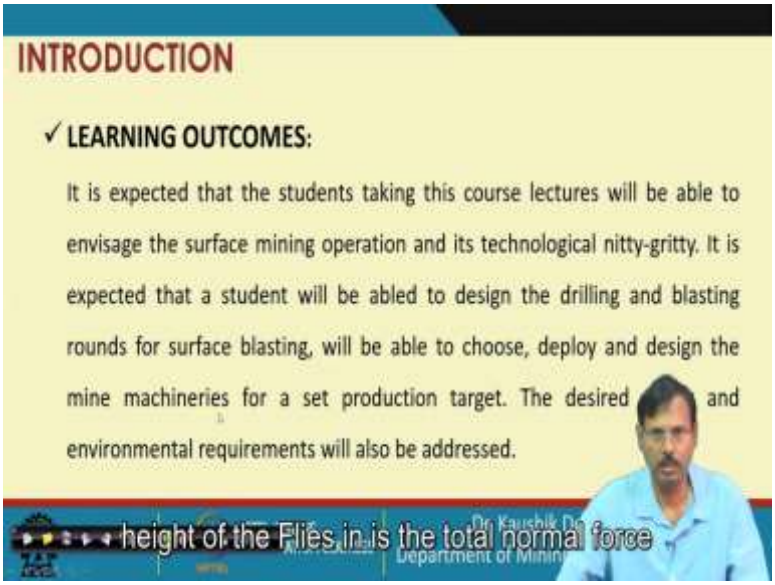

And the expected learning outcomes from the participants of the Surface Mining Technology course.

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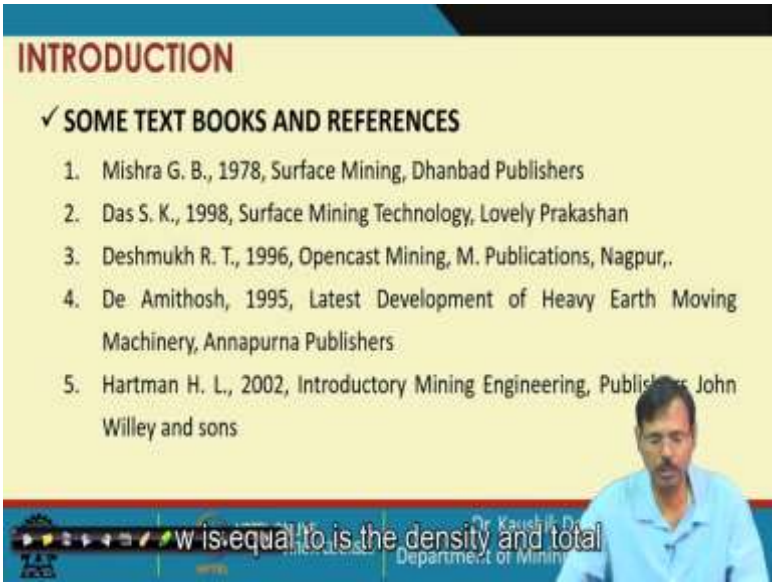

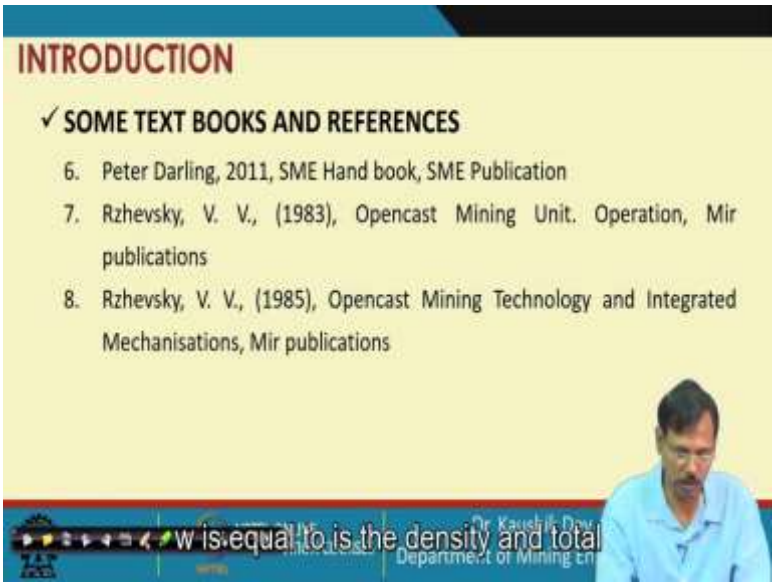

And these are some of the textbooks and reference books. As in the last two class also have discussed for slope stability, recommended books is the book written by Bradley and Brown, another book is available which is written by Brown only. There are many more books are available, pit slope manuals are also available, slope stability software's are also available, apart from that free Matlab codes. Matlab codes are also available for analysing the slope stability.

It is very important for an engineer who is assigned with the slope stability analysis job to understand the geological disturbance that is very important because slope stability largely depends on the geological disturbances, their orientation, their deep angles, deep directions

these are very important, so that part is of a significant, knowledge in that area, should be there for a slope stability engineer.

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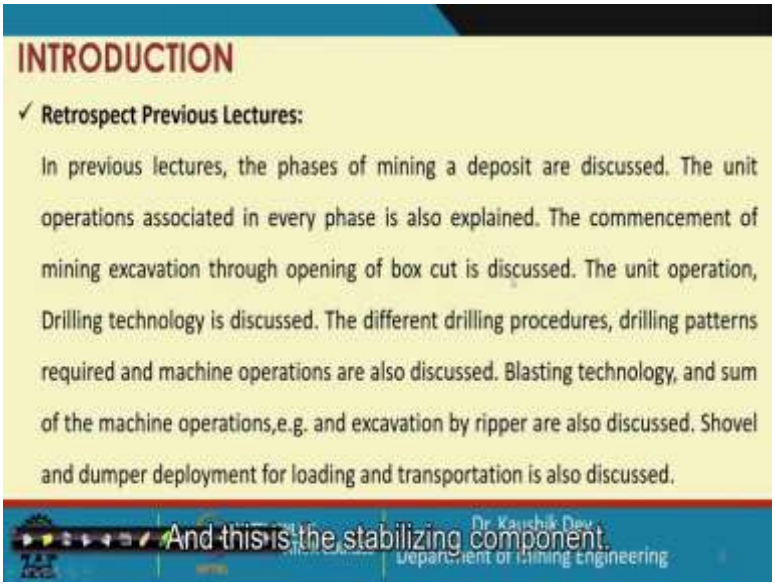

Now, let us retrospect the, whatever we have covered so far in Surface Mining Technology course, we have started with the current status of surface mining in the world. We have completed the phases of mining a deposit and every unit operation associated to each phase. We have completed the commencement of surface mining with box cut. We have discussed in detail the drilling technology, drilling patterns, their machine details, machine and machine deployment details, all these are discussed.

We have discussed the blasting technology; we have discussed the blast design techniques for surface mine and to how to assess the results of a blast. We have discussed the last three mining techniques, that is the excavation of ripper, the capability of ripper, the performance of ripper are discussed.

After that we have discussed the excavation carried out by the shovel especially for the lose Rock marks or the segmented Rock mass and their performance, their cost analysis are discussed. The transportation system is also discussed with special reference to the shovel Dumper combinations. The allocation of dumpers with the shovels, their performance analysis, their cost analysis are discussed in detail.

We have covered the operation of surface miner, their methodology pit layouts, performance analysis, cost analysis are discussed. We have discussed the operation of dragline for direct casting of material, we have discussed the three mode of operation of dragline, the extended

bench method, direct casting method, side cutting method, extended bench method, all these are discussed and along with their performance and cost analysis.

We have discussed the highwall mining technique, we have discussed the designing of highwall mining technique. We have discussed the bucket wheel excavator, the different mode of operations, performance analysis and cost analysis of the bucket wheel excavator. We have discussed the highwall, that haul road maintenance and haul road construction details are discussed. We have discussed the dimension of stone mining method. We have discussed the sea bed mining method and we have discussed the other auxiliary mining operations required like secondary bolt and blasting, sump pit construction, all these are discussed and this is our final topic. We are discussing about, before closing of the mine, that is the analysis of slope stability.

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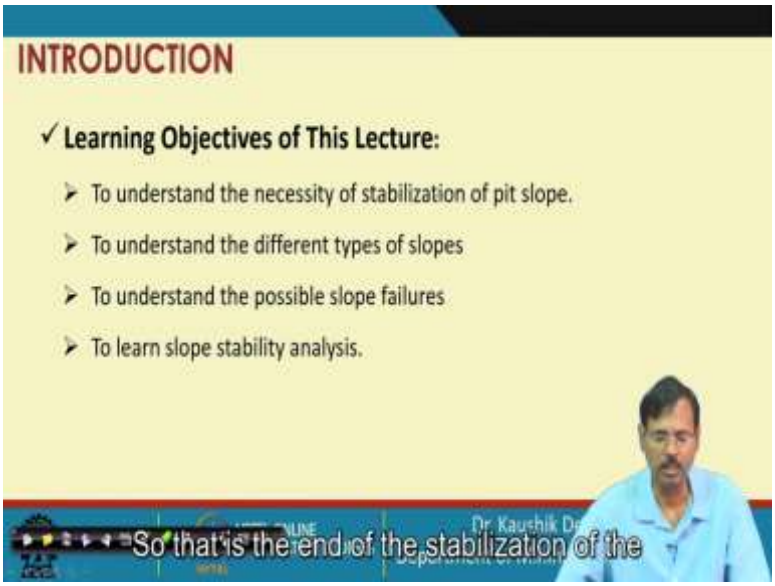

We are discussing, this is the third and final lecture of the analysis of stability of slope. The set objective for analysis of stability of slopes is to understand the necessity of stabilization of pit slope, to understand the different types of slopes, to understand the possible slow failures and to learn the slope stability analysis.

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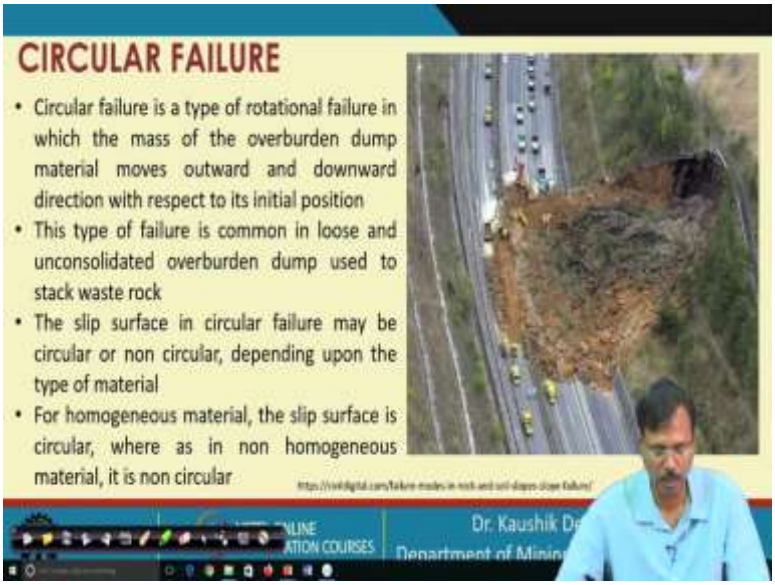

So, we are already covered, we have seen there are three types of, mainly three to four types of slope stability analysis is carried out. The plan of failure, slip failure and circular flow are the main, top link failure is also there. So, plan of failure, slip failure and top link failure, we have already covered, this is the circular failure, we are discussing about.

So, circular failure is basically a rotational failure of in which the rock mass of the overburden dump, which are basically the lose formation, failed completely following an Arc of a circle. And these slips occurs suddenly and this is, the material is come down a huge quantity of material come down in that case. So, this is one circular failure of a natural slope, which is occurred, can be seen in this picture.

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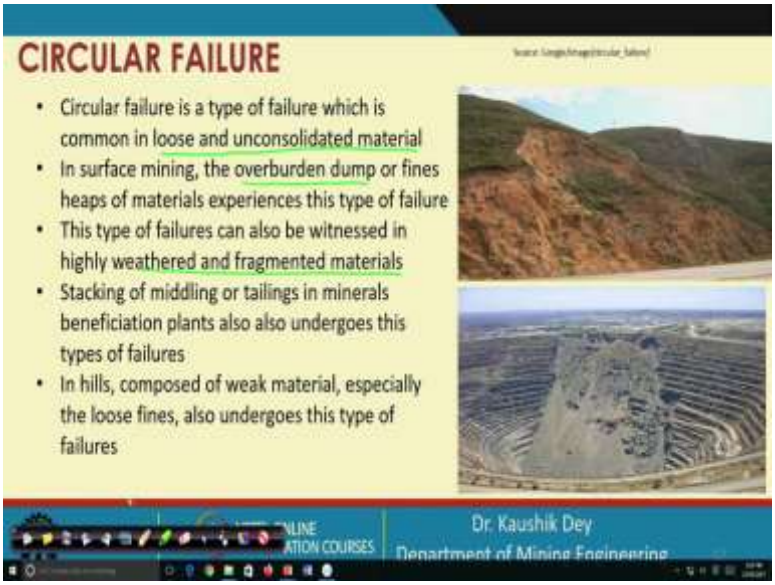

Now, these are some of the examples of the circular failure occurred in the mine. You can see the quantity of material, the quantity of material slided down here is very very high and that's why the rehandling cost any of machines which are under operations are already damaged because of these, so the consequences are very very high in this case and that is why it is very very important to control this circular failure.

So, circular failure is important one because no one knows, in the, how the Arcs are being developed inside that is prediction is very difficult and that is why this failure occurred, sufficiently analysis is carried out beforehand, it cannot be controlled. So that is why circular failure analysis is very important now a day's slope stability ladders are there to analyse the movement apart from that serving techniques are there. Formation of cracks in the surface are tried to be monitored.

So, all these technologies are adopted but circular failure is a huge devastating failure, in general the consequences are considered to be very high. So, circular failure is occurred in a common in loose and unconsolidated material, in mining generally occurred in overburden dump, but may occur in the top benches where the loose materials are there and highly weathered and fragmented materials are available in those cases. The occurrences of the circular failure may happen and that is why proper monitoring is required.

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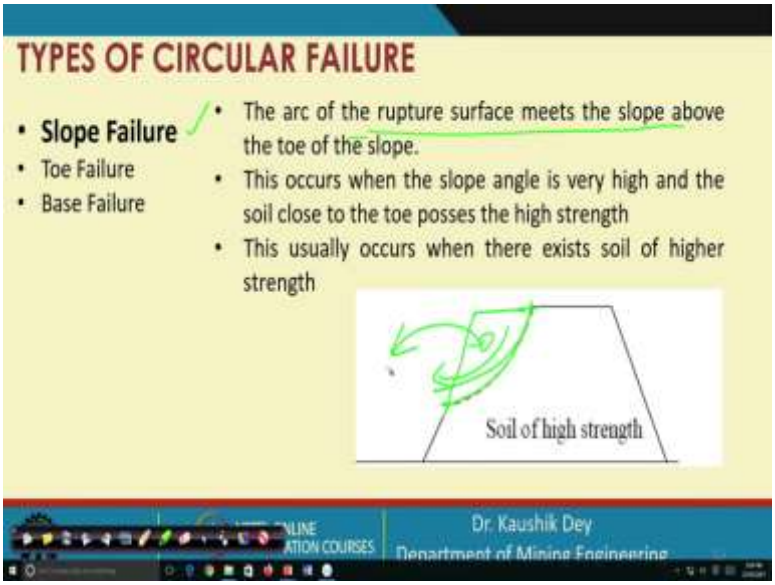

Circular failure is categorised in 3 ways, one is slope failure. In slope failure is the bench is like this, a part of this bench is fall down and you can see this Arc is formed this bench is fall down like or slide down in a form of Arc here, that is called slope failure. This Arc of rupture meets the slope, so this is formed and this made the slope, so this will become delighted and moved out, so this is the slope failure.

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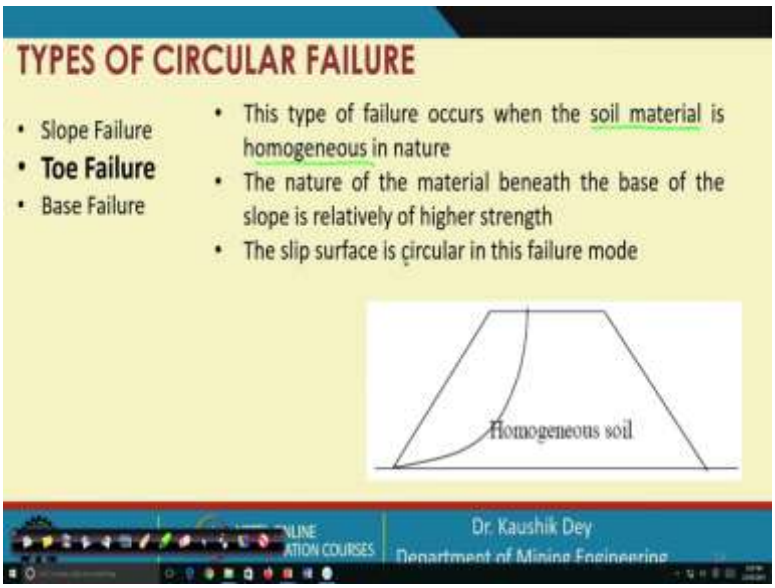

This when the Arc is meeting with the toe, this is called toe failure. This is occurred when this part, this rock is very competent and this is a homogeneous loose material. Then, this type of failure occurs because this homogeneous loose material on any condition, the this one the destabilizing force is becoming more than the stabilizing force, this material slide down

like this, so this is often occurs with increase in this weight because of the moisture content or the saturation.

So, that is why in loose soil, in rainy season, this type of failure occurs. Sometimes, this is also occurred because of some high pressure working at this place, sometimes because of their weight it may occur also. So, this type of failures are often found in case of soil material in mostly in homogeneous cases and this analysis must be carried out considering the, this type of formation in that case.

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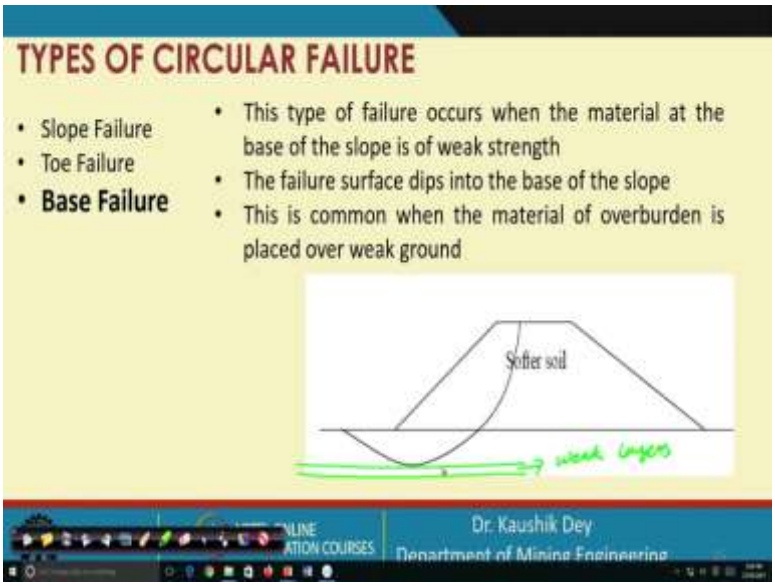

And third one is Base failure, Base failure occurs when the floor material is very weak. So, if this material is very weak in that case this cannot withstand the load of this one. So, this try to hit at this position and by this way, this complete Rock mass is slided down towards this is also called Base failure. Base Failure is often occur if these are slow, this portion is very soft or there is some very weak layer. Weak layers are existing in below ground, then often this type of failure may occur that is called Base failure.

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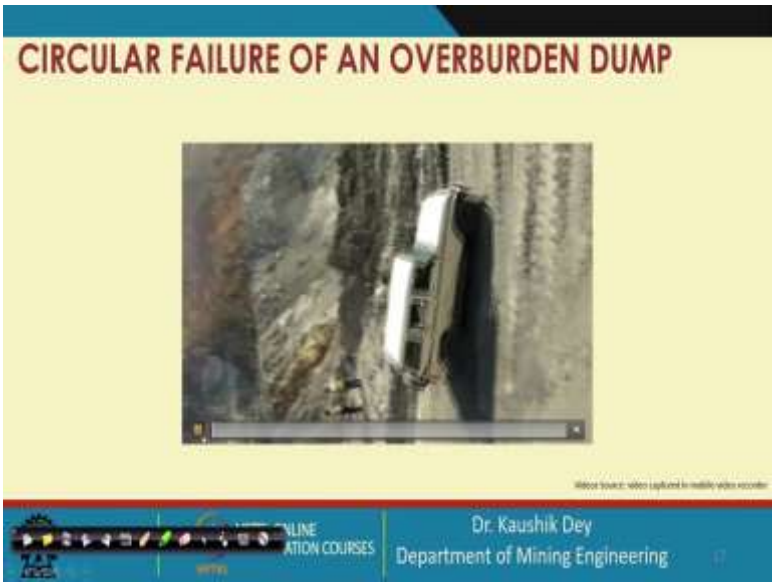

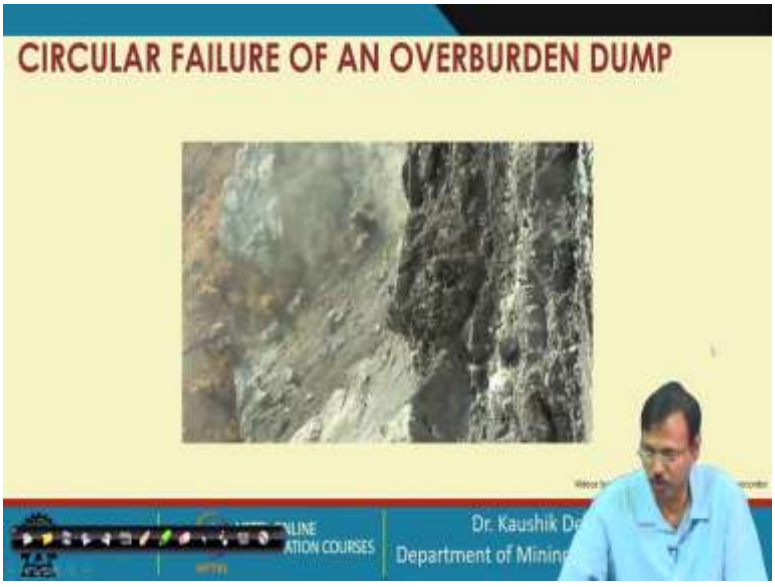

Now, let us look into some of the slope, circular failure of the slope. So, this can be seen, how the material is being slided down in a circular failure. This is one circular failure video of a of the two-drill machine, as already told to you. These are the two-drill machine and this see circular failure of the material is still coming down.

The main power has been hidden because of this failure, but drill machine could not be withdrawn, because the stock master are already stocked, drill rods are already inside the hole. So, this complete material is now slided down, gradually it is moving out in this direction and the, all this material is coming down. So, complete top benches all the top benches, overburden benches fall down.

So, this is another view of the same failure. See, still the drill machine can be seen and the Base rock, this completely falling down. This bulldozer was also under operation there, but this is fortunately withdrawn. This is the complete top benches; has come out, slided down in a circular failure, from the top all the material is coming out.

So, this is a huge sliding, more than 1.5 million metre cube of material has come out and three drill machines are stuck in this circular failure. So, right time observation and monitoring is very important in this case otherwise the withdrawal of the men, machines to save their life is, will not be possible if the proper monitoring cannot be carried out. There is a little bit problem with the monitoring system that is why it could not be done but fortunately manpower service with sufficient time ahead before the failure are reach at the position of work.

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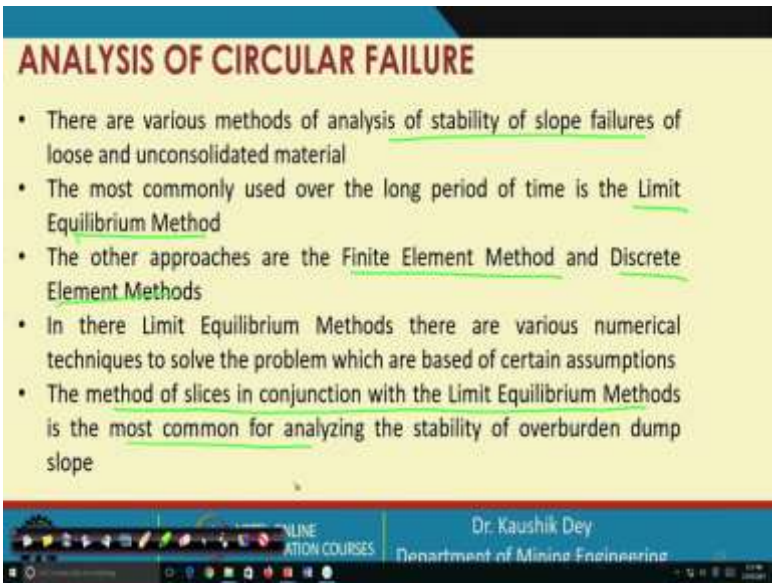

So, now look into the details of this circular failure, circular there are various method to analyse the stability of a slope failure under further circular failure analysis. One is the Limit equilibrium method, apart from that Finite element methods are also there, Discrete element methods are also there, the bishop's analysis are also there. So, there are different methods. The method of slices in conjunction with the Limit equilibrium method is the most common method for analysing the stability of overburden dump slopes.

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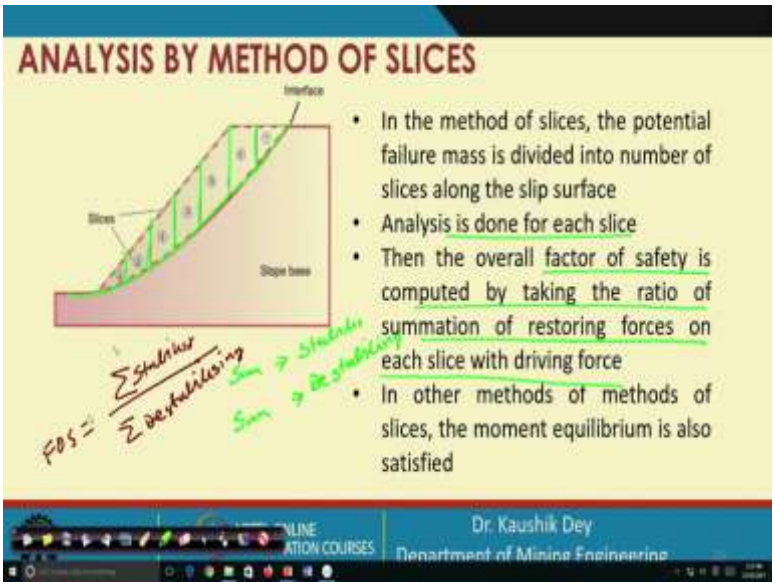

So, let us have one look into this, so generally the method of analysis of slices are carried out, the complete slope is divided into a number of slices. So, now this is 1, 2, 3, 4, 5, 6, 7, 8 slices, so now in these slices, the potential failure mass is divided into a number of slices and analysis is done for its life. The overall factor of safety is computed by taking the ratio of summation of restoring force and the driving force, so for its life, the sum of the stabilizing force and some of the destabilizing force is considered. So, as this is considered, so overall stabilising force is coming and overall destabilizing force is considered and that is considered the factor of safety.

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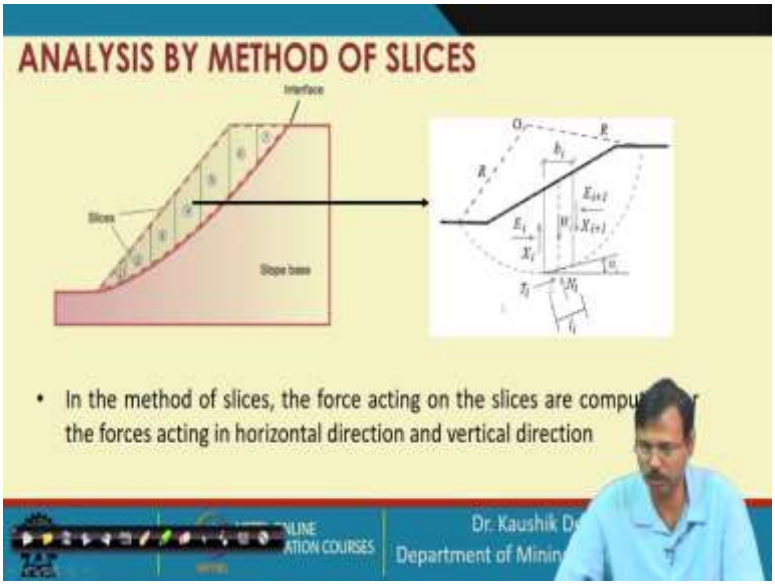

So, this is one let us have, how this slice force is considered here, so let us look into this.

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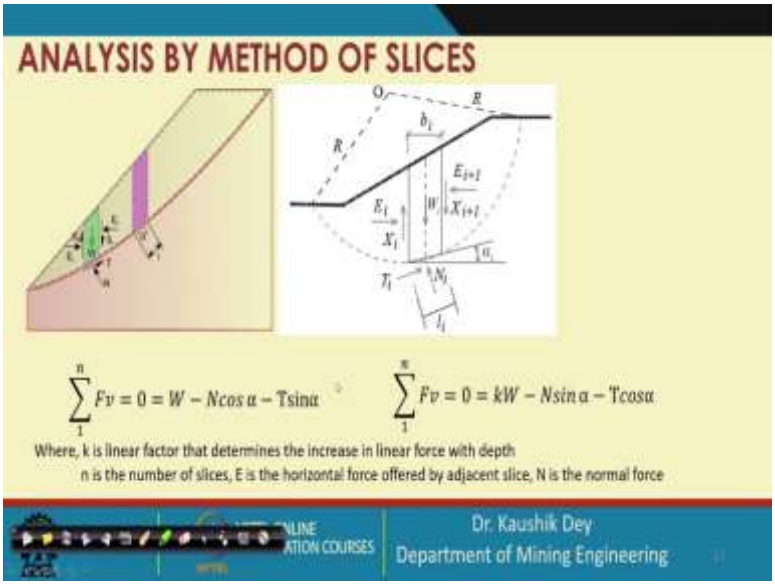

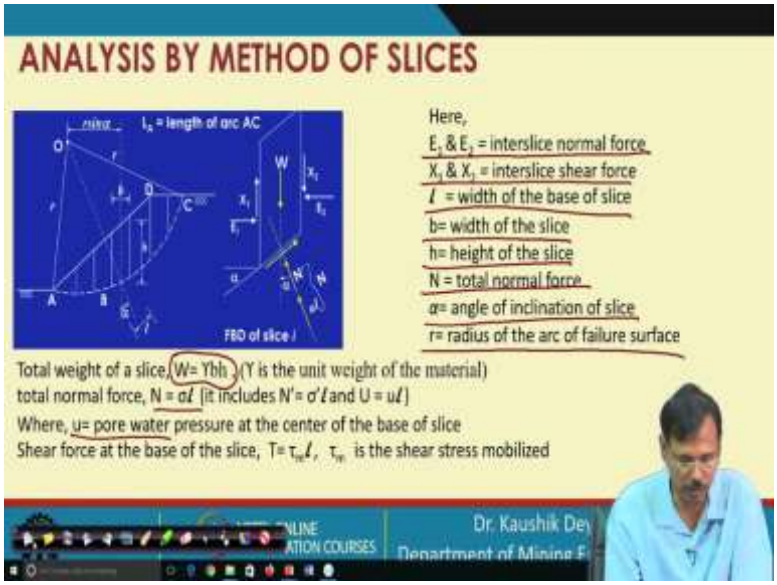

So, if we are considering this one, these are the E_1 and E_2 are the interslice normal forces, X_1 and X_2 is the shear forces, l is the width of the base slice, b is the width of the slice, h is the height of the slice, N is the total normal force, Alpha is the angle of inclination of slice and r is the radius of the arc of the surface, then the total weight of the slice is considered as W is equal to Ybh, where Y is the density and total normal force is this one, Pore water pressure is this one, if we are considering this, then this can be come out with that.

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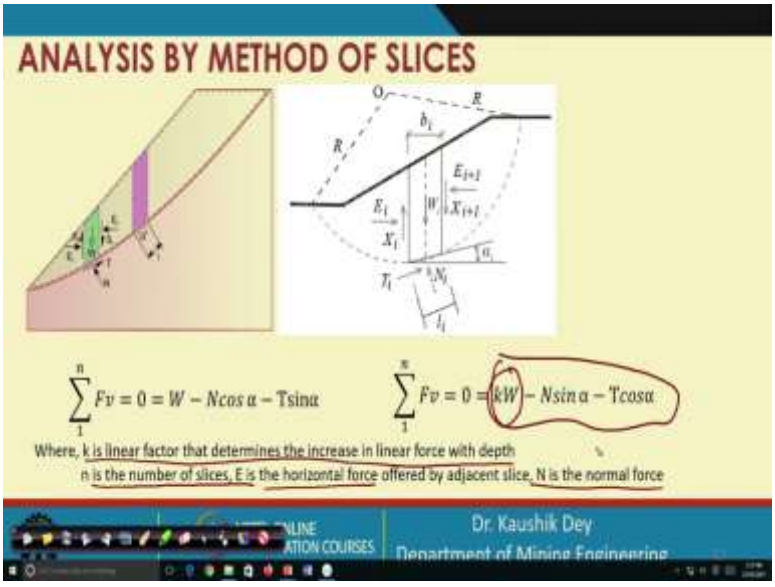

When k is the linear factor of determining the increase in the linear force with depth, n is the number of slices, E is the horizontal force acting on at offered by the adjusted slice and n is the normal force. In that case the force can be calculated using this formula. This formula is almost same for this one and this one, this is, Alpha is the angle, we are considering at this

place and n is the normal force, so that is why which is acting at this position, this is the destabilization component and this is the stabilizing component we are considering at this case.

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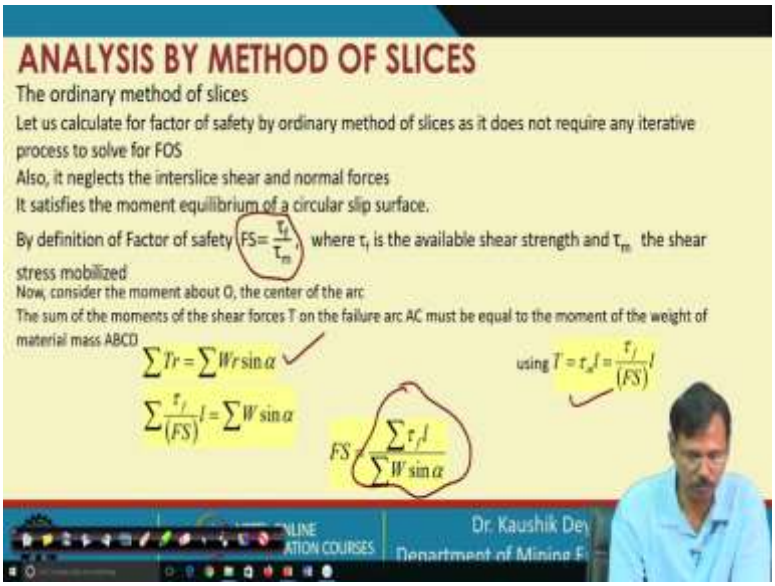

Now, this from this ordinary method of slices, the factor of safety can be considered like this. For T_r is equal to W_r sin alpha, and Tm can be computed like this, so the factor of safety is calculated using this formula.

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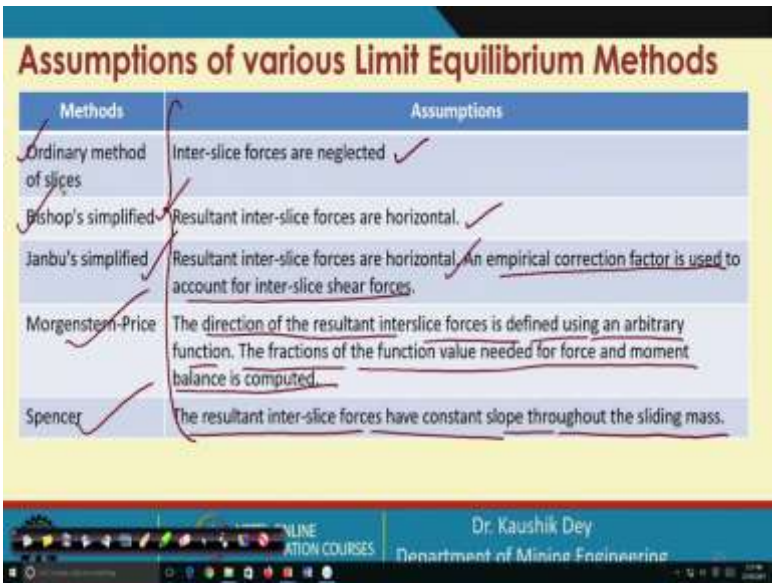

Now, in this Limit equilibrium method the assumptions are made like this, inter-slice forces are not considered here, if there is any forces are considered when the Bishop methods are

used there is resultant inter-slice forces are considered as horizontal, when Janbu's method is used the resultant inter-slice forces are considered horizontal and empirical correction factor is used to account for inter-slice shear forces.

And when the Morgenstern-price method is used, in that case the direction of the resultant inter-slice forces is defined using an arbitrary function, the fractions of the functions value needed for force and moment, balance is computed. And when this method is used, Spencer method, the resultant inter-slice forces of constant slope and throughout the slide mass is the assumption considered and with this assumption, these methods are available. These are the different methods considering the methods of Limit equilibrium method.

And by this way, generally, we go for analysing the circular failure of a slope, this ends the stability analysis of the flow for the mines. In mines, we have seen, in the pit the most common failures are plan of failure and width failure, occasionally where the loose soil benches are there not properly maintained, circular failure may occur there. But in the waste only failure which is occurred, that is the circular failure. So, for the west of circular failure analysis is very important. So, that is the end of the stabilization of the slope. Thank you.