Soil Mechanics/ Geotechnical Engineering I
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Lecture – 58
Slope Stability

Good morning friends, once again I welcome you to this course and today the last lecture I have covered Slope Stability analysis, some introductory methods. And first one was infinite slope and second one different type of a slopes of c with c phi soil and based on assumption of a particular slip surface and or methods are already is explained and I will take a problem now to explain or illustrate how to use this method.

So, the problem was the this is the problem the embankment in the figure made up of soil with phi equal to 30 degree and c equal to 20 kilo Newton per meter square. And soil on which the embankment sits has a phi of 7 degrees and c equal to 75 kilo Newton per meter square and for this for both soils unit weight is 19.3 kilo Newton per meter cube and determine the factor of safety for the slip circle shown; that means, next figure I will just show.

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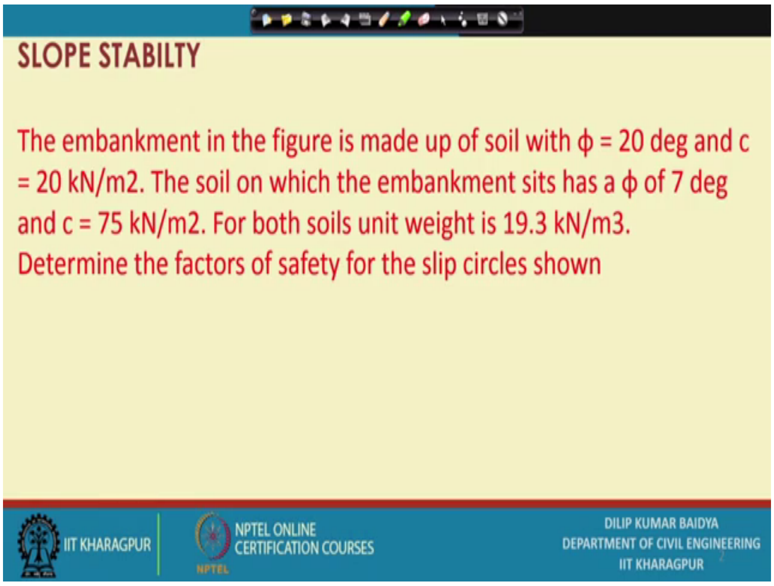

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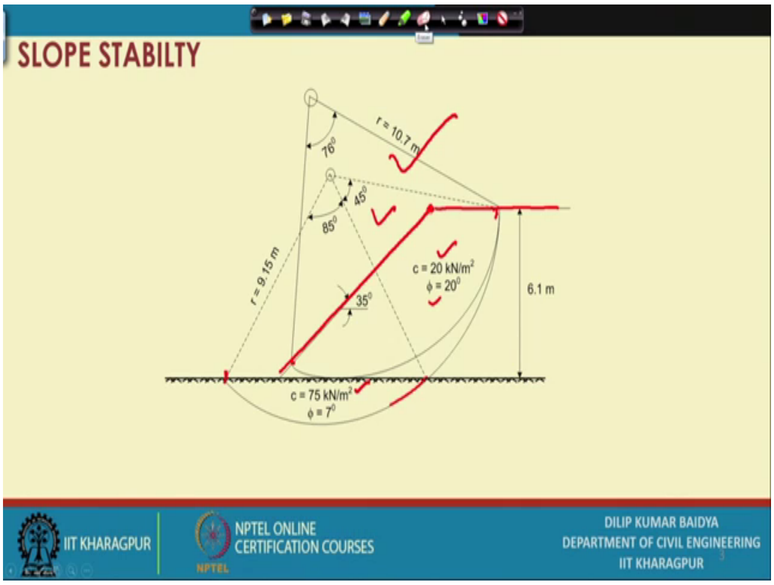

These are the things, this is this is the slope basically from a started from here to started from here to here this is the slope surface and this is the sloping surface and this is a level surface and this is the a one a one level ground and this is the original ground level some of this is embankment is made.

Now, for the embankment soil c is 20 and phi is sorry also 20 degrees and c also 20 kpa and this slope angle is 35 degrees and this embankment was built over a soil that having c equal to 75 kilo kpa and phi is 7 degrees. Now to find out the factor of safety as a as I have explained before that you need to assume a slip surface different slip surface and finally, you have to find out where your factor of safety become critical and that will be the actual slip surface.

So, here on that pros suppose we are so, assume that on that process we have reached or assumed one slip surface which is started from here and become tangential and reached here and this is one and another slip surface we assume suppose you started from here and it gone below deep and then reached here. So, this is one slip and this is another slip.

So, if you have this is the slip surface what is the factor of safety you have to find out. If this is the slip surface what is the factor of safety you have to find out. So, these two actually while solving the problem or to find out the factor of safety for a particular slope we assume different slip.

So, two such slips taken as a example and I am showing the calculation procedure to how to find out finally, the value of c sorry value of factor of safety.

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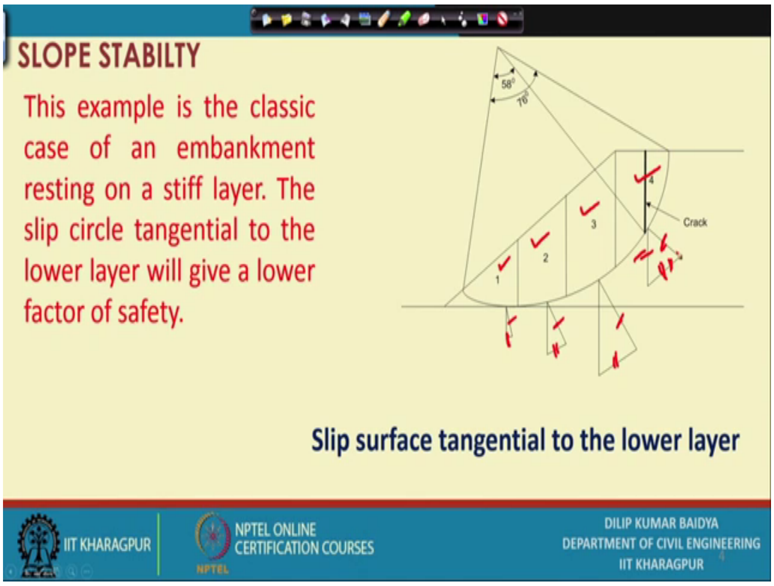

So, next slide so, this is the one of first I will the embankment resting on a stiff layer and the slip circle tangential to the lower layer will give you a lower factor of safety so; that means, finally, we will show you that. So, we are assuming the first one it is the given like that and we have already explained that when this type of problem we solve and typically we need to divide into number of slices.

So, here suppose the angle was 76 degrees and then this top portion of the circular arc and it is surround it is surrounded by this slip slope line and this level line and we approximately divide into 4 different parts top part 1, part 2, part 3 and part 4. Now, in these actually we need to if you put in a graph sheet and in a particular scale and then if I finally, if I the in the graph sheet if I do by num, counting the number of blocks approximately you can find out the area of this similarly area of this, area of this, area of this.

And if I find out the area of this particular portion of the slope and then if I multiply by unit width suppose the slope is perpendicular to this one meter then if I multiply by one then we will get the volume and then unit weight of soil you multiply then you will get the soil weights. So, soil weight will act vertically so, that you have to show with a particular scale and then you have to draw tangent and normal to this point to get the reaction and tangential force. So, for each slice so, that is the one graphically can be done; So, first calculate the weight of each and draw a vertical line and then from there in scale you draw a normal from here and from here you draw a tangential to this.

So, then you will get the this is T component and this is N component, this is N component , these are all N, N and these are actually T, this is T , T, this is T like that. So, if I do in the graph paper then this easily can be done. So, I will show this table form the calculation of these in the tabular form suppose the first one sorry.

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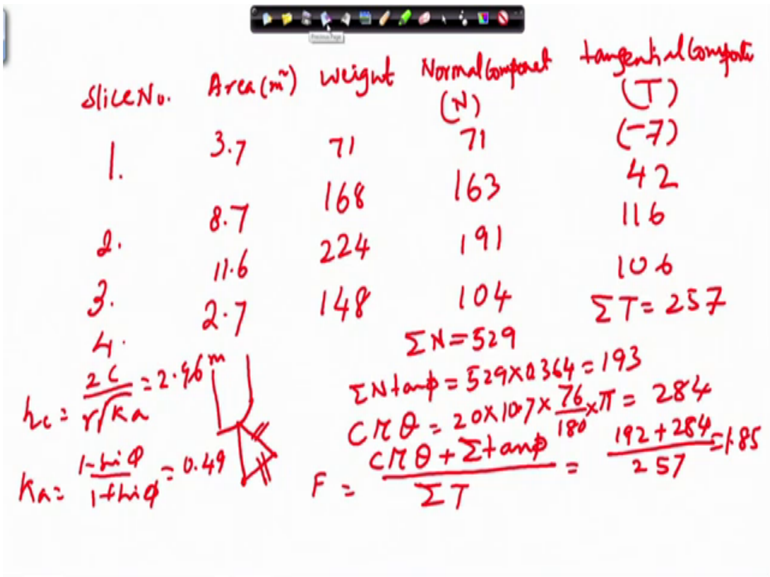

So, for this I will suppose take a new sheet, slice number and then area suppose in meter squares, then weight and then normal component normal component and that is that is N and tangential component that is T, that is in factor of safety equation N and T is there.

So, slice number 1, 2, 3, 4, slice number 1 area become 3.7 meter square and these become 8.7 and it is 11.6 and this is 2.7. And then if I multiply by simply the unit weight you will get the weight because it is unit length is taken. So, this becomes 71, 19 into 3.7, 19.3 into 3.7, these become 168, these become 224, these become 148.

And now graphically when I get a bottom of the slice suppose something like this and I get weight here then I will draw a tangent and then this so, this become your T, this become your N. So, from there graphically I can draw that and then I will get this is 71 itself because it is a varies minor difference will come, this is 163, this is 191 and this one 104 and whereas, this one will come minus 7 and this one will be 42, this one is coming 116 and this one is coming 106.

Now, sigma N equal to 529 and sigma T equal to 257. Now, your sigma N tan phi will be equal to 529 multiplied by 0.364 equal to 193 and cr theta that will be equal to c is 20 multiplied by r is 10.7 is given multiplied by 76 degree was the angle divided by 180 into multiplied by pi to convert into radian. So, this gives you total 284 kilo Newton.

So, your factor of safety equation will be equal to cr theta plus sigma tan phi divided by sigma T these are the expression. So, if I now put all the values that is 192 plus 284 divided by 257 so, that gives you factor of safety equal to 1.85. So, this problem is done without taking any your a tension crack. So, as I have told I have discussed before that that is a c phi soil, there can be a tension crack and depth of tension crack we can find out hc expression hc depth obtained tension crack will be 2c into gamma root ka.

And here your ka 1 minus sin phi by 1 plus sin phi if I do it gives you the value 0.49. So, if I put all those value here this comes 2.96 meter and so; that means, if I take from the your right side so, I can go back sorry. So, this is the one, now if I take a tension crack here if I take tension crack here this tension crack depth actually you have got now 2.96 and; that means, beyond that actually this portion will not consider any shearing resistance. So, you have now your slip surface become this length, but entire weight has to be considered.

So, this angle become now 58 degrees and if the angle become 58 degrees then your cr theta become cr theta become 20 multiplied by 10.7 multiplied by 58 divided by 180 multiplied by pi.

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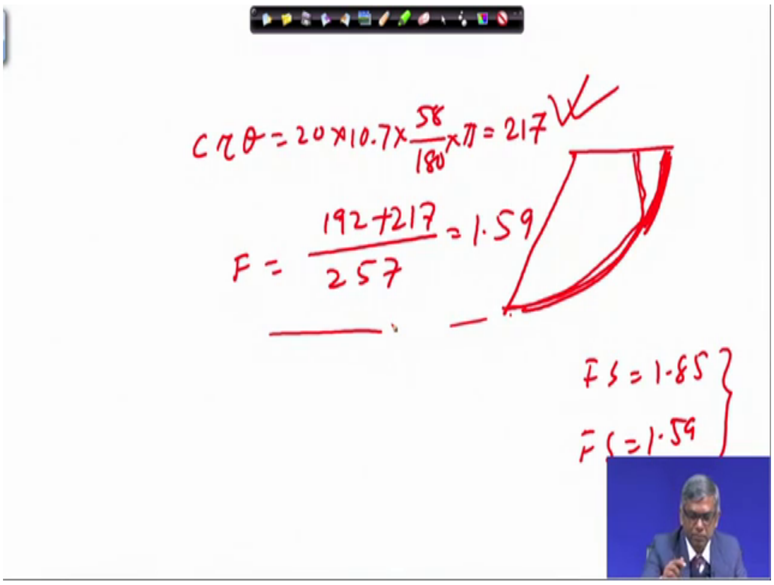

So, that gives you only 217. So, cr theta is reduced actually and other things are is unchanged. So, your factor of safety will become 192 plus 217 divided by 257 so, that factor of safety 1.59.

So; that means, if I consider the factor of your slip surface was or your slope was something like this and if I consider a tension crack here, now without tension crack if your factor of safety was 1.85 and with factor with tension crack factor of safety is 1.59.

So, it is reduced; obviously, why it is reduced because the I am considering in entire disturbing for same, but while calculate the resistance I am considering I am not considering this one and that is required because when the c soil contents are possesses c value there is a chance of tension crack and tension crack depth theoretical you know 2 c by gamma root ka.

So, from there actually if I take the remaining length for resistance calculation then I can get the modified value of resistance and from there I can find the find out the value of factor of safety. So, this is a one first case and second case if I consider now which is passing through the second layer also. So, you can see now the second one, this is the one.

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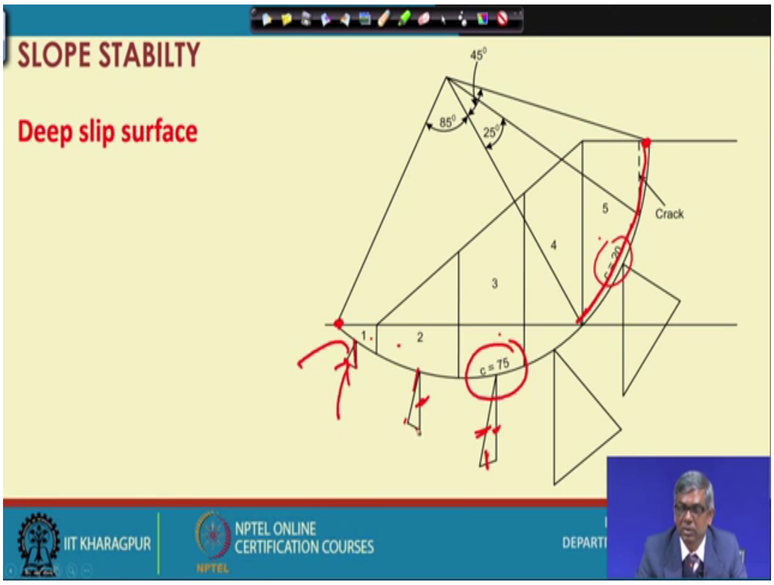

And in these you can see now the initially we are not taking tension crack. So, I am taking from here to here and this angle was a total angle was 85 plus 45.

And then your c the c for this portion is 20. So, it is divided into 2 parts because resistance is passing from these to these that is one part and resistance from here to here though total angle is 85 plus 45, then 120 and a 130, but I have to divide 2 parts. Because, while calculating resistance this portion value c value as 20 when calculating within these zone I will use c value equal to 75, the procedure is similar.

So, again I can divide into a number of slices 1, 2, 3, 4, 5, 5 slice a slices and each slice actually again I can find out the area, area multiplied by the area multiplied by the unit weight will give you the weight and from there actually I can draw a vertical line that gives you a vertical force which is in scale. And then I can draw a normal and I can draw a tangent to intersect this point then I will get a normal value, I will get the value tangential value. Similarly, for this also I get the weight this is the weight and then normal here and tangential here then again weight, this is the weight and this is the normal and this is the tangential tangent.

So, the T and N you can get so, like that for all cases like previously you have done we can find out and you can see direction of T these 2 was reverse. So, this will be minus and this will be all plus. So, now we will see the tabulation how to do this one. So, tabulation if you do similarly slice number.

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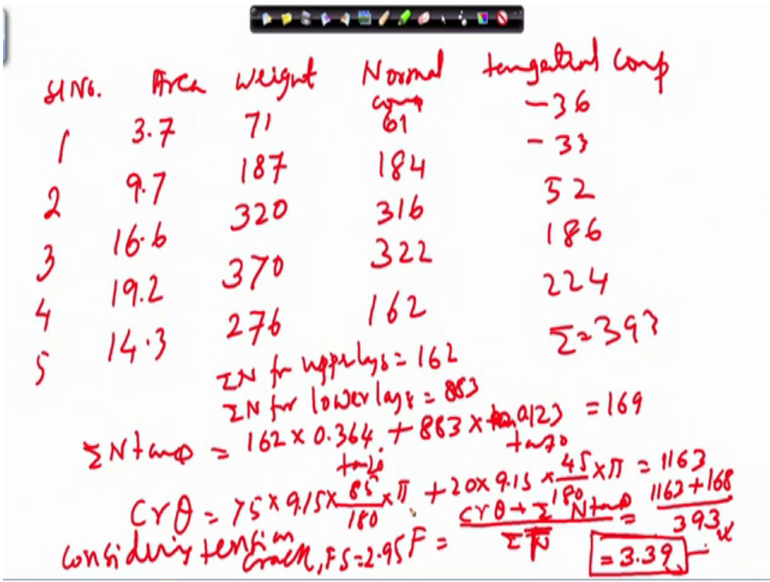

Then area, then weight, then a normal component and then tangential component; So, slice number 1, 2, 3, 4, 5 and if this is area was 3.7, this was 9.7, this is 16.6, this one or 19.2, this was 14.3 and this is a 71, this was if I multiply with 19.3 this is 187, this is 320, is 370 and this will come 276.

Now, the graphically if I draw normal and tangent from the vertical then I will get normal component the for this one is 61, 184, this 316, this one 322 and this one 162 and for this tangential component this will be minus 36, this is minus 33, this is 52, this is 186 and this is 224. So, sigma T will be equal to 393 and sigma N I will for 2 different layer I will do to sigma N for upper layer sigma N for upper layer will be equal to 162 and sigma N for lower layer will be equal to 883.

So, now sigma N tan phi; So, sigma N tan phi that is one component and since it is pass through 2 layers; So, I will do 162 multiplied by 0.364 the tan 20 degrees plus 883 multiplied by tan 7 degrees, that is a a directly I can write 0.123, this is tan 7 degrees and this is tan 20 degrees because first layer has have first layer is having phi equal to 20 degree, second layer is 7 degrees.

So, you could do this value comes 169 and cr theta if I do that is again 75 the value multiplied by 9.1 is radius multiplied by 85 because first layer or 85 degrees by 180 multiplied by pi fly pi plus 20 multiplied by radius is 9.15 multiplied the angle is 45 divided by 180 multiplied by pi. So, this all calculation if I do that comes 1163.

So, your F equal to cr theta. So, this cr theta plus sigma N tan phi divided by N sigma N. So, if I do that or sigma T then this will be equal to this is sigma T sigma T. So, this will become 1163 plus 168 divided by 393 and that gives you a factors of safety equal to 3.39 so; that means, if I take the second one which is slip surface passing through the second layer actually then it will gave the longer resistance zone and of course, this is actually one can visualize that when the slip surface is longer more will be the resistance and factor of safety will be larger.

So, that is what you have initially you commented and you can see for this case you have got a very large value of factor of safety; that means, probability of having a slip will be tangential to the when there is two layer actually it is generally the it is supposed to be or it is expected to be tangential to the bottom layer.

So, this problem again can be modified because that can be a tension crack we can also theoretically can find out what is the value of tension crack that to C by gamma and from there we can subtract the length of slip surface and then calculate recalculate the resistance and then use this formula again and you can find out considering tension crack considering tension crack same problem can be draw a done Fs equal to come there 2.95 ok.

So, these are the two problem same problem only we have solve for assuming two different slip surface and now I will continue to the next thing. So, this is the this is one method of calculating a factor of safety.

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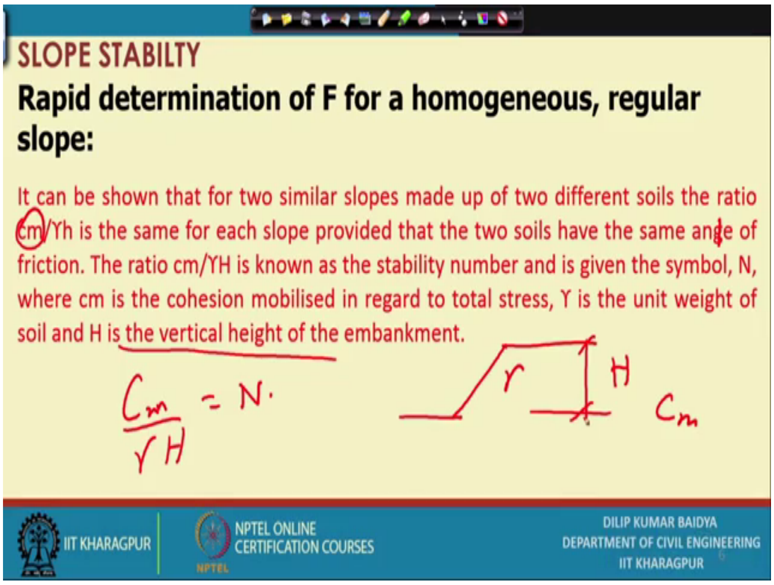

And for these this is actually basically graphical procedure you have to do lot of graphical work and finally, after doing so many assumed slip surface we will get the critical factor of safety and then corresponding to critical factor of safety we will be the actual slip surface, that is one way can be done.

There are actually a many methods in the literature and then another popular method actually rapid method by using stability chart. Actually this is given by Taylor and it can be seen so, the rapid determination of F for a homogenous regular slope.

So, if it is irregular and non homogeneous; obviously, you will not be able to do, it can be shown that for two similar slopes made up of two different soils the ratio Cm by gamma H, cm means cohesion mobilized actually it is cm by gamma H, this ratio is same for each slope provided that the two soils have the same range of friction a same angle of friction sorry angle of friction.

The ratio of cm gamma is known as the stability number and is given the symbol N. So, it is N where the cm is the cohesion mobilized in regard total stress, gamma is the unit weight of the soil and H is the vertical height. So, if the slope is something like this if the slope height is H and if the C mobilized and your unit weight is gamma then you can express the non dimensional form that is N stability number and with respect to this stability number of charts are provided. And using this chart one can find out the factor of safety quite quickly.

So, those factor of safeties are equal the chart those charts are something like this.

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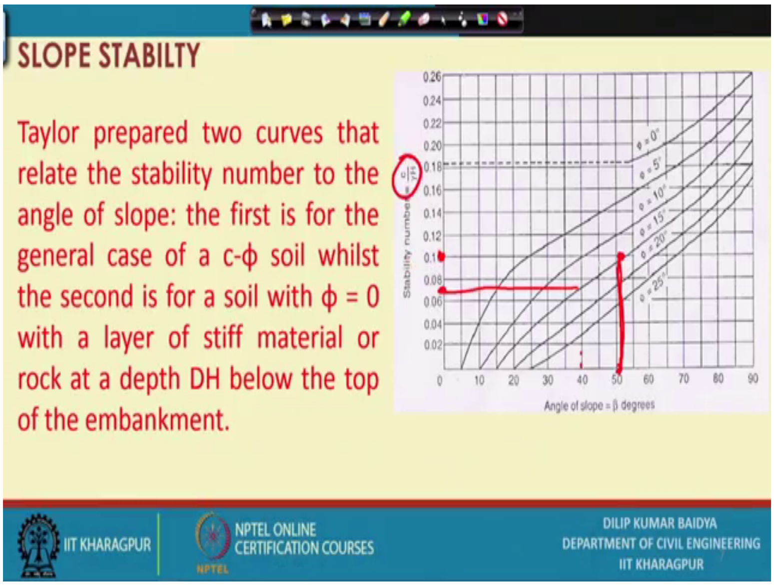

One chart is given; Taylor prepared two curves that relate the stability number to the angle of slope. The first is for the general case of a C phi soil while the second are this is the phi equal to 0 and you can see this is the chart given and either you can do two ways. Generally your phi of the soil is required, it is generally will be known and if it is known and phi and C then you have to what is the slope angle you can provide.

So, from here actually if I know the C value and unit rate and slow height then I can calculate this quantity sorry I can calculate this quantity. So, suppose this quantity is fixed above some value I got 0.1 and then if I know the phi value suppose phi value is phi value is suppose 20 degrees. So, phi value is 20 degrees suppose then our expected angle of slope this is of course, not so, straightforward. I will explain how to use this one if it is then expected from here, actually you can find out the angle of slope from here so, that is one way of using the chart.

So, if I know or otherwise if you know the angle then I can find out the knowing the friction angle and these two combination I can find out also what is the N required and once N is required is known so, H is known and gamma is known then what is the C required for the soil that also can be obtained.

So, this is different ways this problem can be solved; that means, you your either soil generally your soil parameter will be known and once you know the soil parameter what could be the shape angle of slope. And here actually when we are doing this with calculating a value of N and then projecting to that on the particular line corresponding to a phi of soil and then from there whatever angle we are getting there actually we are assuming the factor of safety as 1, but actually factor of safety will not be 1.

So, when there is a factor of safety is different than 1, then actually you have to assume factor of safety for a particular phi and then based on that you reduce the value of phi and then find out the angle and. And then from that angle you find out the C value and then whatever value of C you are getting and whatever the C value is available then find out the factor of safety and since the two soil parameter you cannot apply two different factors which is the factors which should be same.

So, whatever assumption you made initially for the factor of safety of phi and finally, after using this chart based on stability number whatever factor of safety you are getting for cohesion there should be equal. If they are not equal; that means, your assumption was not correct, then what you have to do you have to modify your assumption that will change the factor of safety what you assume for phi and then again reduce the value of phi and then find out the value of C.

And based on that C value find out again for a factor of safety for C when they are converging slowly if you if you change modify the value of factor of safety then you will see sometimes it will converge and both assumed factor of safety and the final factor of safety for C both are merging or becoming close.

And when they are becoming equal then that is the actual factor of safety for the slope. So, that is the way actually stability chart can be used so, this is one stability chart has given there is one more was there for slightly different one that is actually this is also when slope is different this type of this type then that is a another charge.

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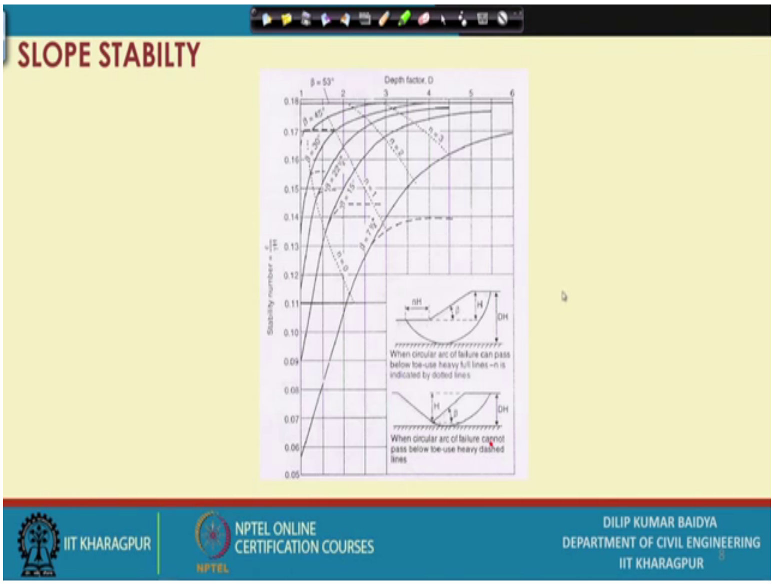

So, both can be utilized for finding out the factor of safety or if I know the; if I know all those details factor of safety everything then what will be the correspond safe slope angle that also can be determined.

So, these are the two charts given by Taylors and can be utilized for quickly determining the value of factor of safety. So, with this I will just close here and I will do in the next section rest of the things.

Thank you.