Soil Mechanics/ Geotechnical Engineering I
Prof. Dilip Kumar Baidya
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture – 59
Slope Stability (Contd.)

Well, let me continue what I have done in the previous lecture; that in the previous lecture I have discussed about the stability chart method which can be used the chart can use to find out the factor of safety quickly. In fact, there are a number of methods are available we have discussed only a few and. In fact, at present since earlier when there is no computer people used to do by hand calculation, all rigorous calculation people used to do by hand.

But now and when I do when we do by hand also we had a restriction; that means, we cannot handle too many complicated slope or irregular slope only homogeneous and plain slope only you could handle. So, because of this, but actual slope in nature a particularly natural slope and all they are quite complex.

And because of that people actually try to use more advanced method and of course, there are few methods several methods are available and finally, those methods are computerized; that means, it is a programmed and if you give the proper input; that means, shape geometry of the slope and the soil property and it will calculate and give you the factor of safety.

These are actually rigorous method, before going to that I will just take one problem which I had just completed in the previous lecture that is using Taylor's stability chart.

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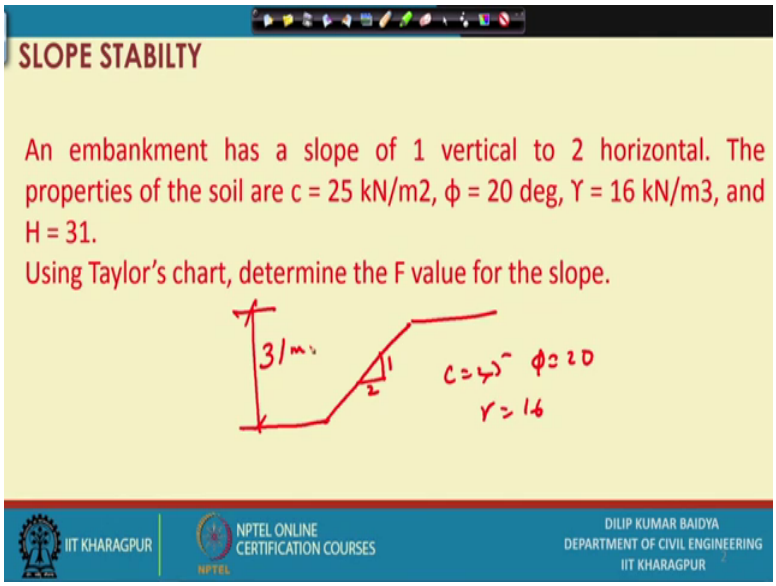

So, this problem is something like this and embankment has a slope of 1 vertical to 2 horizontal and the prop properties of the soil c equal to 25 and phi is 20 degrees and gamma equal to 16 kilo Newton per meter cube and H equal to 31; that means, your slope 1 vertical 1 vertical 2 horizontal.

So, something like this so, this is 1 and this is 2, 1 vertical, 2 horizontal the slope was like this and this property of the slope material embankment where C equal to 25 and phi equal to 20 and gamma equal to 16 and this height of the slope is 31 meter 31 meter.

Now, using Taylor's chart I have to find out what is the value of factor of safety for the slope. So, let me ah start that and of course, I have not included in this chart better I will do I will bring the chart or I will open another file stability number N equal to C by gamma H and that will be your so, no.

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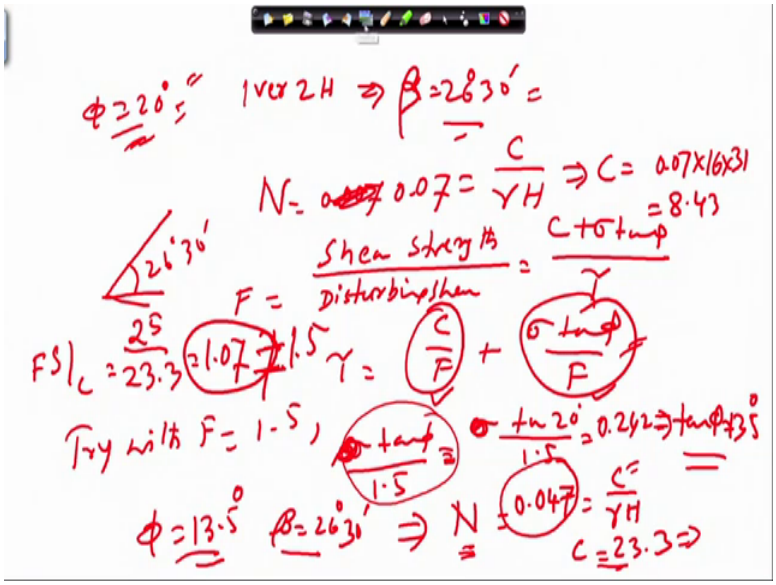

So, I will not do that, what I will do I will do for phi equal to 20 degrees. And slope angle actually 1 vertical, 1 vertical, 2 horizontal corresponding to it gives you alpha equal to 26 degrees 30 minutes so; that means, the slope at the slope 26 degrees 30 minutes.

So, this is actually I think it is written as beta. So, this beta equal to these and phi equal to these and if I refer chart then I will get N equal to value actually 0.007. And sorry not 0.007 this perhaps 0.07 if I go I will go back to that chart once again and then and I know this is equal to C by gamma H. Then from here I get C equal to C equal to I get 0.07 multiplied by 16 multiplied by 31. So, that is equal to 8.43 kilo Newton per meter square.

But, this is not the factor of safety mainly because when the if it is the value of phi also when you calculate factor of safety both in the phi component and in the C component factor safety should be there. But, when it is phi is assumed to go 1 factor of safety is as 1, then only it is value is coming like this, but this is not the actual calculation. Our calculation was F equal to Shear Strength divided by Disturbing Shears and that is actually Shear Strength is C plus sigma tan phi and this is actually.

Student: Tau.

Tau ok; so, your tau will be equal to C by F plus sigma tan phi by F so; that means, you have to and this F and this F should be same.

So, if I do this way then what I will do I can do I can assume a factor of safety and then I can find out this one and then correspondingly I can find out value of C and then find out the factor of safety. If I do that, now I will try with F equal to suppose 1.5 and then I can find out sigma tan phi by 1.5; that means, sigma sorry not sigma tan, tan phi tan phi by tan phi by 1.5.

If I reduce then it become a tan 20 degrees by 1.5 and that gives you 0.242 and which can be equal to which gives you tan phi equal to 13.5 degrees.

Now, this tan as I have tell you by introducing factor of safety I am reducing the value of phi. Now, with this value of phi; phi equal to 13.5 degrees and beta equal to 26 degrees 30 minutes and then I defer refer the chart and then I will get a value of N and that time you will get a N value equal to 0.047.

So, if I get the N value this that is again C by gamma H and from there I will get C value will be equal to 23.3 and then your factor of safety for C will be actual value available is 25 and here actually mobile is 23.3. So, factor of safety is 1.07 and these 1.7 factor of safety we are getting for C and you have assume factor of safety for phi as 1.5.

So, one point this is not equal to 1.5, this is not equal to 1.5. So, hour actually if based on this assumption of phi factor of safety in phi 1.5 you have reduced value of phi and then that reduced value of phi and beta you refer the chart and then get the value of N. That is getting 0.047 and then that value if I refer to these then if I refer to equate you C by gamma H then you get you get a C value of this. From this C value and actual C value available is 25 then I am getting a factor of safety of 1.07.

But, which is different from the assumption 1.5; that means, our my assumption is not correct the factor of safety actual available is something different than that. So, because of that so; that means, this calculation will not correct. So, what I will do again I will be doing again I will be doing another assumption; that means, I can change the factor of safety now factor of safety I will change to 1.35 suppose or.

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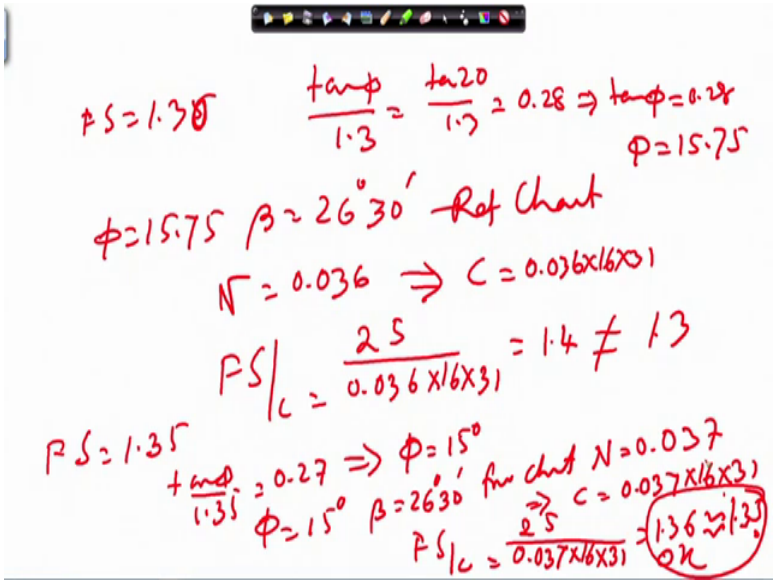

So, suppose 1. 1.3 factor of safety suppose 1.3 I assume and then yeah your tan phi by 1.3 equal to tan 20 by 1.3 that comes 0.28. And that gives you tan phi equal to or that gives you tan phi equal to 0.28 if I do then phi you get and actually 15.75.

Now, phi equal to 15.75 and beta equal to 26 degree 30 minutes and refer chart then I will get a N value equal to I will get a N value equal to 0.036. And this gives you C equal to C will be equal to 0.036 multiplied by 16 multiplied by 31 and your then factor of safety for C will be equal to value available is 25 divided by 0.036 multiplied by 16 multiplied by 31. So, that gives you a value equal to 1.4.

So, which is not equal to again 1.3; So, I will then you I will assume another factor of safety equal to 1.35 then your tan phi by 1.35 that gives you 0.27 from there I will get phi equal to 15 degrees. Now, phi equal to 15 degrees and beta equal to 26 degree 30 minutes and from chart I will get N equal to 0.037 037. Then your that from this one will give you C equal to 0.037 multiplied by 16 multiplied by 31.

Then factor of safety for cohesion will be value available 25 divided by 0.037 multiplied by 16 multiplied by 31 and that gives you 1.36. It is quite close to 1.35 since so; that means, for the particular slope which you have used that slope for that slope your factor of safety that that is slope with 1 vertical, 2 horizontal and with value of phi equal to 20 degrees and gamma equal to 16 and height 31, the factor of safety comes out to be 1.35.

So, this is the problem asked actually so, you have to do a trial and error method; that means, you assume certain value of factor of safety and then if it is does if does not match with a factor of safety finally, then you have to modify it and do the process until you get a convergent result. So, this is the way so, 1.36 and 1.35 they are quite close, you are assuming that you have raised to a value which is acceptable.

So, the finally, we can say the factor of safety for this slope is 1.35. So, and this stability chart actually I will refer back once again if necessary.

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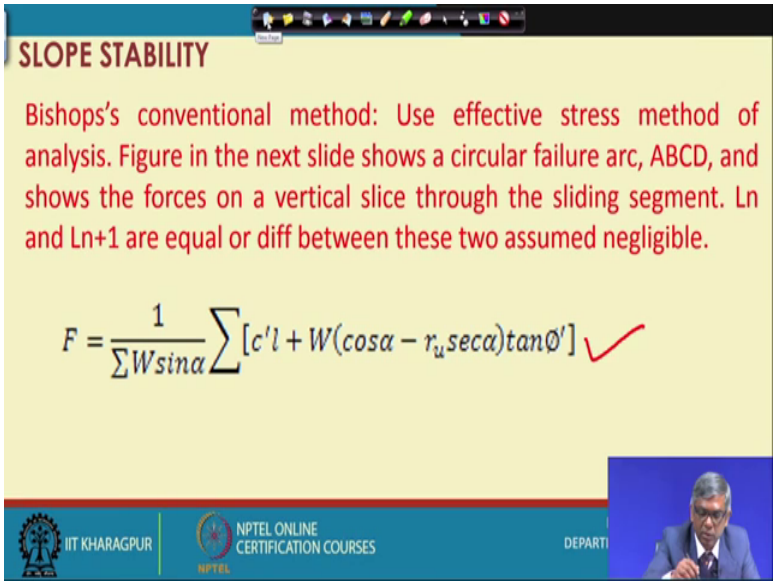

So, now next thing is that a rigorous method and in the rigorous method actually first introduced by Bishop and Bishop consider conventional method actually use effective stress method and figured and the next slide that is the figure actually one particular slice should be shown.

And that slices what are the forces acting it is shown and then we will see that finally, the slope that slice is statically indeterminate and to make it statically determinate some assumption was made and based on that finally, he derived the factor of safety expression for a complicated slope something like this.

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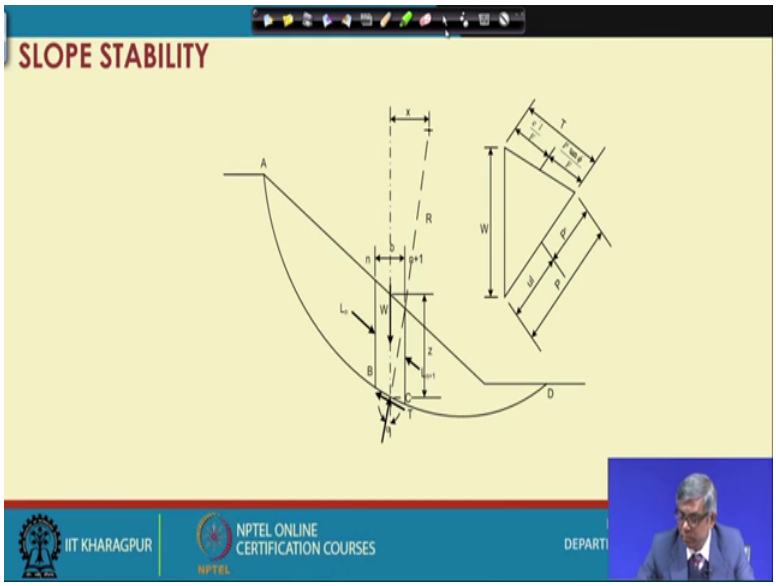

So, if you so, the better I will go to the next slide so, this is the slope suppose this is the slope and then on this slope there is a slice taken suppose one slice is taken here and on that on that slice what are the forces acting? This self weight of the slice it is acting. Then from the left side that will be force acting from the left side and from the right side there will be some force acting and there will be tangential force acting there is a normal force acting.

So, all those forces are actually until unless you assume these two; if I keep these two unknown then your problem will not be able to solve. So, Bishop actually assume this and this actually equal and based on that and then doing all those calculations stability and all he has got the expression for factor of safety factor of safety equation is like this.

So, here in this actually you can see each slice W to we calculated W sin alpha to be calculated for this slice at the end summation to be taken. And this is actually c dash the cohesion effective stress cohesion cohesive part and the l actually length of the that slice. And then again W cos alpha then you can you can find out the pore pressure at the point and this is the again there is a angle component and then tan phi dash. So, all those things then for each slice it has to be obtained and then finally, it has to be summed out a summed out ok.

So, then after these this is a total resistance and this is total disturbance and then you will get the factor of safety from this and if I use this method generally it is noted that you

will get a some difference and some errors and this error actually in favorable side actually it estimate.

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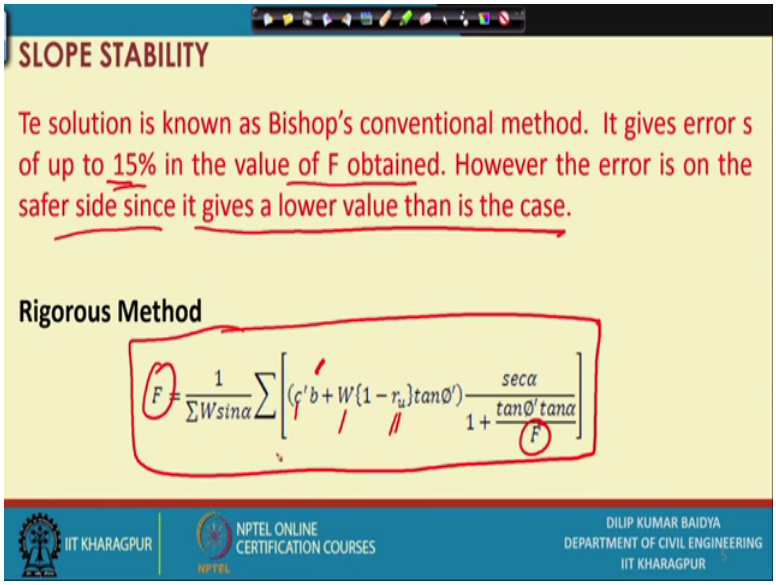

So, the solution given is known as Bishops conventional method and it gives error up to 15 percent in the value of F obtained. So, and 15 percent error in the value of F; however, the error is on the safer side, since it gives a lower value of a value than it is actual.

So, Bishops that conventional method whatever you have the recommended generally it gives you a lower value factor of safety which is actually safer. So, because of that, but always safety is not expected you have to think about the economy also.

So, because of that further investigation what carried out and then Bishop further modified his solution and he gave a final expression that is called Bishop's modified method and in this he has given an expression again you can see the this expression is a big expression and in these the surprisingly you can see both side of the equation having F, factor of safety.

So; that means, what you have to do? We cannot find out factor of safety just like that you have to trial and error. So, you have to assume value of factor of safety and then do the entire calculations then finally, find out what is the final factor of safety. So, these two finally, it has to be matched like by while doing using stability chart you have done.

Similar way here you have to start with a factor of safety and then you have to again final factor safety you have to find out and you can see the a number of things are there which are all known. These are actually width of the slice, this is equation, this is W weight of the slice, this is a pore pressure all those things for each slope has to be calculated and.

So, this calculation before coming the computer. So, easily because this is the developed in and fifties or sixties; So, that time computer was not a readily available and the performance of also was not so, fast, but people use to do by hand calculation and that hand calculation is quite rigorous.

So, that calculation to do this calculation by hand; people use to follow a particular method or steps. So, this hand calculation is quite rigorous, one has to do by using a table and then table calculation generally. So, we have several component each by one or one by one you calculate in the tabular form and finally, left side factor of safety right side factor of safety when it matched then you will satisfy that you get the factoral factor of safety.

And in fact, presently this calculation hardly people will be done will be doing by hand calculation. It is generally it not generally it is commonly it is software available actually, the whatever the steps we follow in hand calculation that is actually instructed in the program and then if you give the geometry and a certain soil parameter all soil parameters relevant soil parameters then it gives you the factor of safety.

So, this is the one method, but somehow this since I will not be able to introduce the software part and. So, this Bishop's method that is either conventional or modified method is out of the scope. So, I will not this is of course, problems they said I will not solve by this method. Already whatever possible within hand calculation by hand calculation I have already explained.

And this Bishop method only for introduction introducing that there is some method which is very accurate and reasonably accurate and also applicable to all situation; that means, any slope whether it is natural or manmade, any irregular, non homogeneous, with pore water, without pore water, with water table, no water table. Any combination actually the slope is there this calculation can be done by program and so, this is actually

a method available and in a commercially software's available. So, people can use it and other than that there are other methods also.

So, I will not discuss that, I will stop here only thing I could not show the table on this; somehow let me see whether in a in the last one I can show that, otherwise I will stop here and.

Thank you.