Soil Mechanics/ Geotechnical Engineering I
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Lecture – 60
Concluding Remarks

Good morning, once again I will welcome you to this course and we have reached towards the end. In fact, I have completed the entire content what I wanted to cover. Only this last half an hour I kept to summarize the entire thing and also just give you that some tips so, that you do you do not do mistake in calculation

And so, with this I will just summarize what we have covered. In fact, in the last class last lecture we have completed the our slope stability analysis and in that I have shown one problem which was very quickly I have done.

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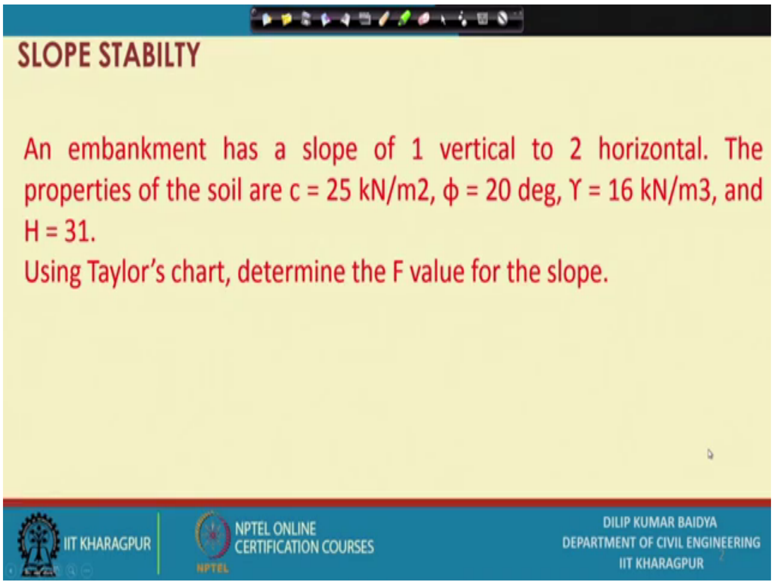

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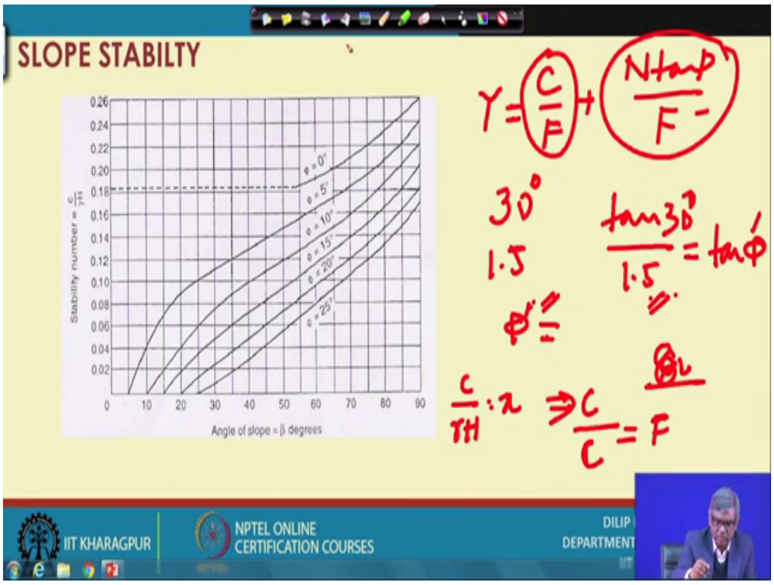

The problem was the slope is given with a particular angle and height and also it is soil properties also given and we need to find out the factor of safety using Taylors chart and Taylors chart was something like this and you can see that if you that which problem I have solved very quickly last class and. In fact, you can see that if you know the angle and of the slope suppose 30 degrees or 40 degrees and if you know the angle of the internal angle of friction then I can project on to that and then I can get the value of stability number.

And from there stability number I can find out the C and then factor of safety against C that can be because I what I ordered the determine C for the soil I can find out. But in this if I do directly like this then it is assumed that that factor of safety for phi is taken 1 and we are getting a different factor of safety for C that is not correct.

Actually shear strength generally will be equal to whatever I will finally suggested Shear Strength that will be C by F plus N tan phi by F. So, we need to provide the factor of safety in two places.

So, if I directly based on phi project on this and then get the stability number from there if you find out C and then we are getting a factor of safety which is different and we have assumed already factor of safety for phi is 1 they are different.

So, because of that procedure actually is that you have to first that take a factor of safety for phi, sum of phi is 30 degrees. Then what I will do, I will take a factor of safety suppose 1.5 then I will do I will calculate tan 30 degrees divided by 1.5 that value will come and whatever value will come that I will be converting into again tan suppose phi dash. And from there I will get a phi dash value and I will now look this table corresponding to this phi and then corresponding to the given angle and then finally, I will find out the C a stability number from the stability.

Number C over gamma H from if there is a value, suppose x then from there I will get a value of C then you have the C obtained for the lab C test. And then C from here that is actually or C available here C whatever we are getting C divided by the lab C that gives you a factor of safety. Now, we are getting one factor of safety here and we have started with the factor of safety of this 1.5 and these 2 to be compared.

So, initially what are based on your first assumption it may not match in that case what I have to do as it is not equal then I can change this factor of safety to another value and repeat this process. And then I will get another factor then I will again compare and I will see how close it is if they are diverging then I will change may I will make the change in other direction and.

So, that the finally, the assumed phi value factor of safety and the finally, obtained factor of safety for C they are same and then based on that I can say that is the final factor so; that means, factor of safety for both here and here should be equal.

So, I will assume initially here and find out here and based on the from the chart and they should equal if they are not equal I will change my assumption. And then I will get the new value and then assumed value and new value I will compare and finally, decide if they are close enough I will assume that there is the factor of safety. So, this is the way to be done. So, this I have done quickly. So, just because of that I will summarized once again how to utilize this stability chart.

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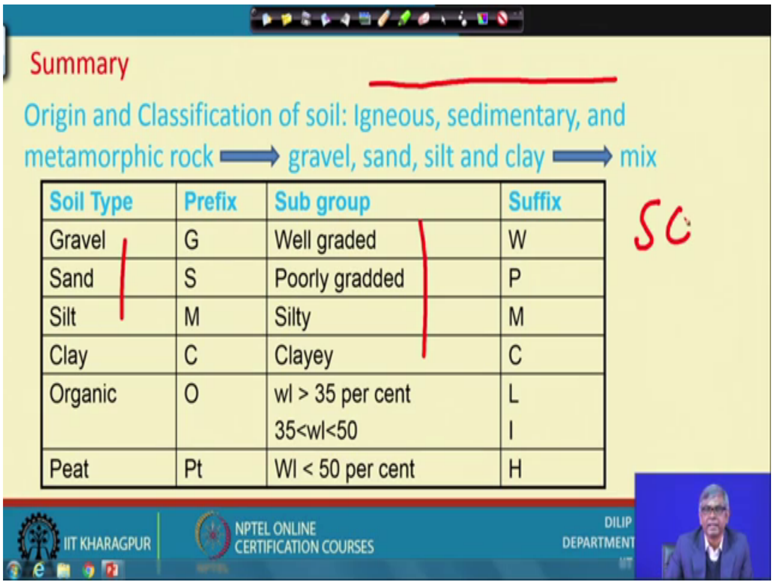

Next, I will go to right from beginning what we have covered I have initially given the origin of the and classification of the soil. Origin originally soil actually formed from the molten magma and through cooling it has converted to rocks and different types of rocks we have seen.

Igneous, my sedimentary, metamorphic with time this with the time and the different physical processes this rock converted from one to other and then finally, this would from rock to again with physical processes it convert to gravel, sand, silt, clay etcetera.

And in the nature actually we will find it in the form of mix and when we find this mix soil mix then we will try to if it is a granular mix we try to do grosgrain size analysis. And based on that we classify the soil using 2 letters one actually first letter and second letter what is first letter actually.

Generally gives you the soil type and second letter gives you the sub group for example, if I get a soil named is C; that means, clayey sand. So, like that will do and at the same time if the soil is contains too much of fine that they are plastic soil then what we do.

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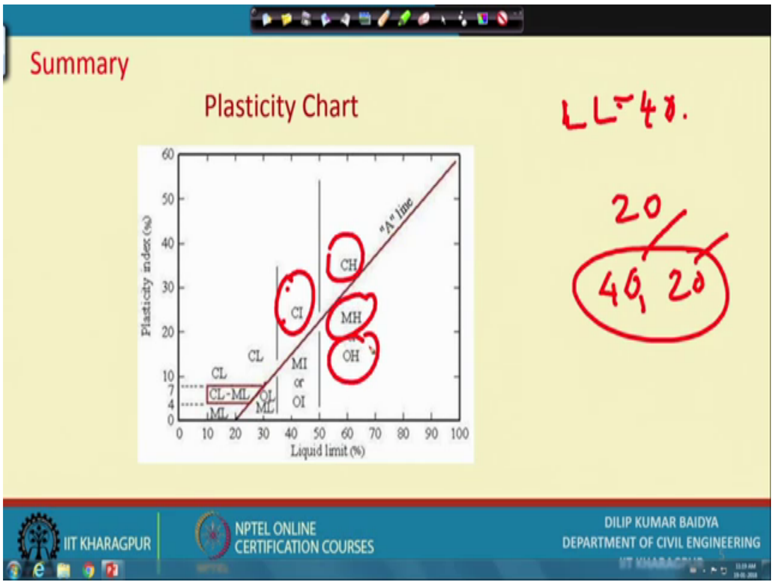

We use plasticity chart that we will find out liquid limit and plastic limit and based on that I do, I find out the plasticity index and other side I put liquid limit and then this is the plasticity standard chart. If this chart actually the if a particular soil is having liquid limit is suppose 30 liquid limit is 40 equal to 40 and your plasticity index suppose 20 pi is equal to 20. Then this 40 and 20 I will put 40 and 20 then 40 s here and 20 is here.

So, it will come somewhere here so; that means, that based on the plasticity test of the soil I will put that point in this chart and depending upon the position of the point I can classify the soil you can see there are three different zone this is a one zone, this is another.

So, liquid limit up to 35 to 50 and 50 to 100. So, these 3 zones are there and again there is a line if above a line soil be treated as high plasticity and in the below line this is low plasticity. So, the soil suppose if liquid limit is 40 and plasticity index is 20 then it is coming here it is above a line and between these 35 to 40 liquid limit then soil will be classified as clay with intermediate plasticity. Like that it can be a clay of high plasticity.

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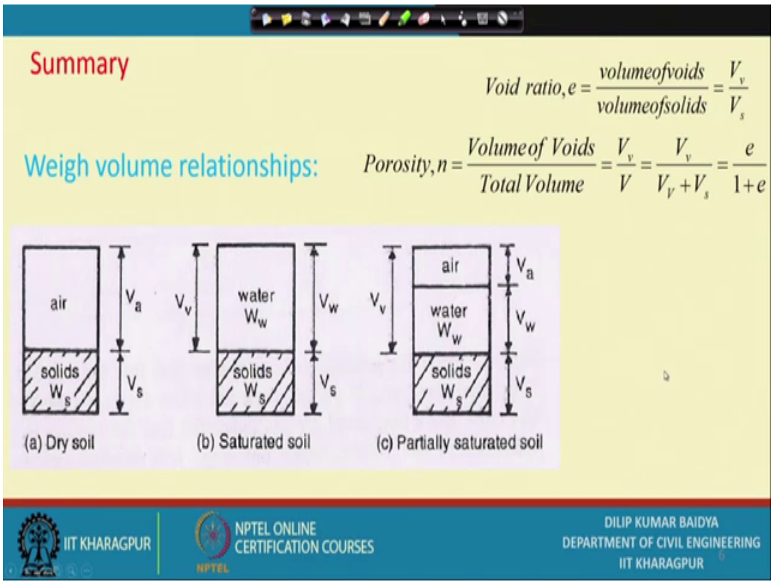

So, will it can be of silt of high plasticity or organic high plasticity like that this can be classified. So, this is about classification and next actually we covered several aspect of soil mechanics that well while reducing the relationship. This is also always you have to keep 2-3 definition in mind very clearly those definitions are basically you can see that void ratio this is volume of void by total volume if solid. Porosity is volume of void by total volume and their relationship we have to remember based on this 3 phase diagram what they are you have to know to because these are required actually in calculation of even every chapters. So, you need to wait sometimes.

You have to calculate and sometimes some parameters are given based on the formula you have to use. So, if you do not remember this thing then it will be difficult to apply those in actual practice.

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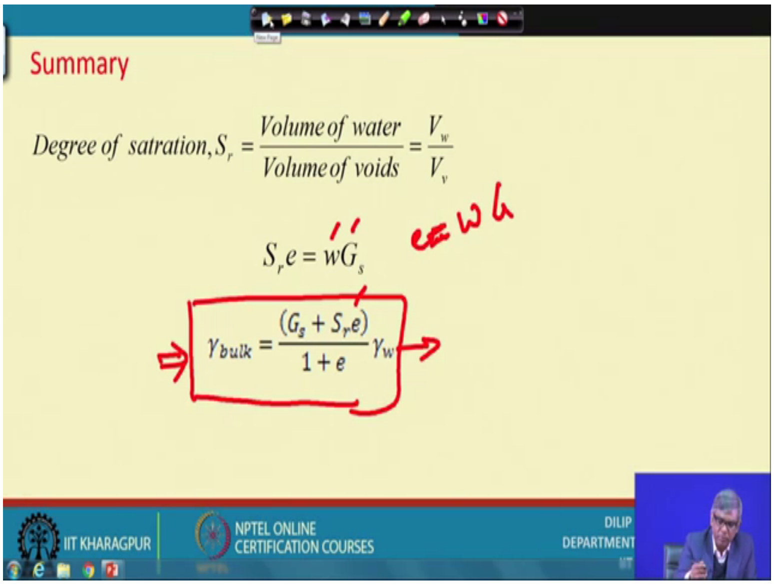

So, next is; the next thing was that degree of saturation on porosity, void ratio at degree of saturation and certain relationship between them like degree of saturation then porosity then water content and specific gravity. This is also a very standard relationship and the soil is fully saturated then e equal to w into G because fully saturated means at w equal to w equal to actually S equal to 1.

And similarly if it is a dry then S equal to 0 so, that sometime we will put it somewhere and then using those specific gravity, degree of saturation, void ratio there is a equation for unit weight and if you remember this unit weight bulk unit weight.

This can be utilized for different cases like S r equal to saturated then I can put what is the saturated unit weight? If it is dry S r equal to 0 then that can be also modified; What is the dry unit weight? Similarly I can find out what is the submerge unit weight? All can be if I remember this one properly and correctly then suitably changing those parameter I can get dry saturated all unit weight.

So, this is one thing at least to be remembered correctly so, that by substituting appropriate values or parameter I can get the other one. So, this is also very very important because in everywhere from soil mechanics is beginning to end any topic if you do there may be some unit weight calculation and if you do not remember this then we will be will be will be in we will not be able to proceed.

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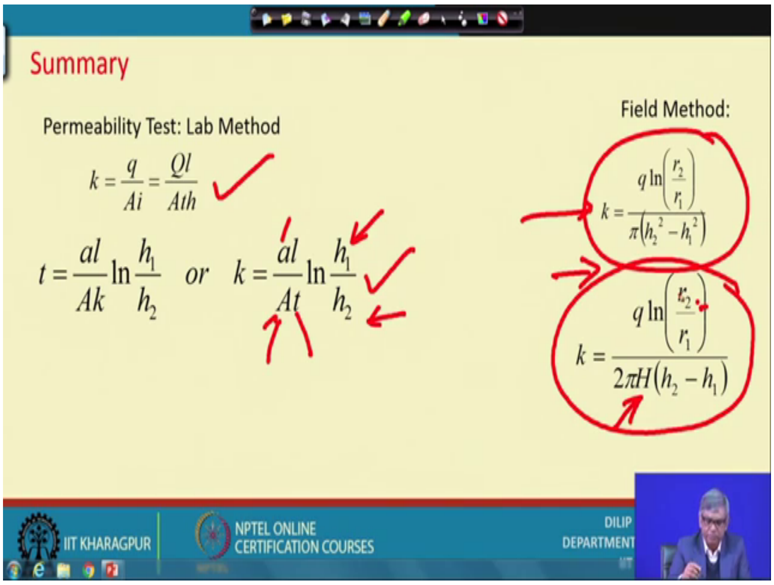

So, next is suppose there is a permeability also another important characteristics of soil. So, you need to know the value of permeability available because it is a important properties for soil. And soil permeability can be determined in different ways either in lab or in field.

If you do lab that if the two method, constant head method and falling head method they are the relevant formula this has to be remembered. And this what are what is what actually an appropriately you can see similar parameter cross section of the standpipe, cross section of the sample, time then head 1 to head 2 all are there.

So, many things are there and you have to use a consistent unit somewhere it is meter, somewhere it is centimetre, somewhere in millimetre and if you do not convert it then finally, their result supposed to be erroneous. So, if there is the different parameters has given in different units finally, you have to consist convert in to consistent in either in meter or in millimetre everywhere. Then only your solution will be correct.

Similarly, if it is a permeability can be done in field test and if there is a unconfined aquifer based on that we can get the k value like this. If it is a confined aquifer this is the formula to be used and you can see when the confined aquifer thickness of the aquifer is given here. And two heads observation wells and location of two observation wells from the centre of the well and then we can find out this permeability of the soil.

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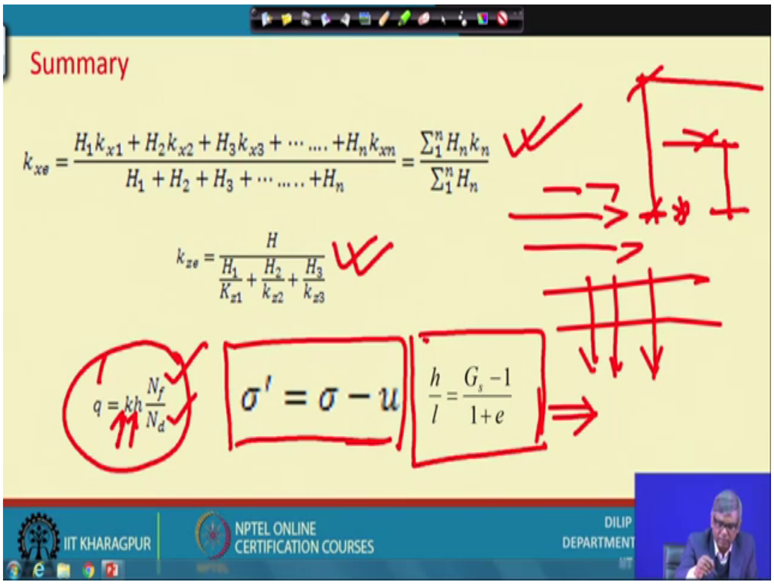

Then next was if the soil will be most likely it is stratified then the it is homogeneous, if you find the horizontal stratification then approximately one can to show handling layered soiled in the analysis is little difficult we said it is.

So, doing that we generally convert the equivalent layer into a layered soil into a single equivalent layer and then we will proceed with homogeneous analysis and. So, if the flow takes place in the parallel to with the planes then like this then equivalent permeability can be obtained from this equation. And when flow is taking perpendicular to the layering; that means, in these layers are in this direction and flow is taking place this direction then you can find out the equivalent permeability from this equation.

And when flow through when that when flow is taking place through some body which is generally not permeated generally. But if it is taking place then sometimes we need to find out the quantity of flow.

And one of the most well known method to find out the quantity of flow by drawing flow net and if you know the draw if you know if you draw the flow net then from there number of flow nets and number of potential drop if you know and if you know the upstream head and downstream head from there I can find a quantity of cpa is equal to permeability into head difference between upstream potential, number of flow nets and number of potential drop.

So, based on that I can find out the coefficient the this is also another important formula to be remembered. And then next step was a effective stress and effective stress is a very very important term in trial mechanics because strength is a function of effective stress only. And effective stress will be a is actually total stress minus pore water pressure and of course, if there is no water table effective stress is nothing, but same as the total unit weight a total pressure.

So, this is the way we generally express the effective stress; that means, if you have a soil here and if your water table is here and if I want to find out the effective stress here then at this depth what is the total stress because of this self weight of the soil I will find out. And what is the pore pressure because of these height of water up to this much and then I will subtract from the total pressure to pore pressure then I will get the effective.

So, these are the number of problems I have solve I have already solved, you can go through those and then we will understand. And then if the sometime if the flow takes place then sometime based on the gradient hydraulic gradient sometimes it is a if the hydraulic gradient beyond certain value then generally it is not stable.

So, that critical hydraulic gradient the expression on h by l is G minus 1 by 1 plus e, this is also a very very important relationship one has to remember many times it comes as a after multiple choice questions sometime you need to use for some calculation. So, this also has to be remembered properly.

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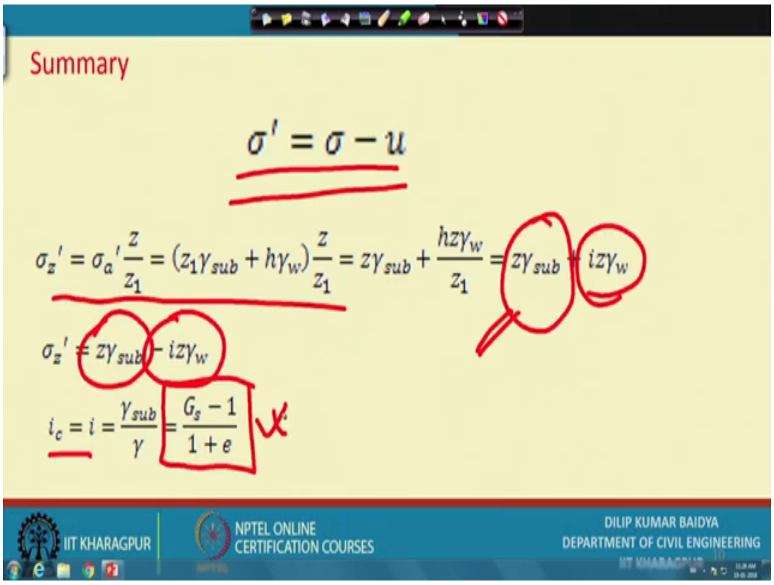

Then this is again same thing I have mentioned and this is the static conditions the effective stress is total stress minus u and when water flow through the soil again the effective stress is not be like this.

It depends on actually hydraulic gradient and you can see when the flow is taking place from downward from up to downward direction then your effective stress will be actually. Normally this is also normal effective stress when a static condition and because of this flow this is the additional stress effective stress will be increased. So, iz comma w and when the flow takes place from downward direction to upward direction then it will be again reduced.

And you can see this is actually static effective stress and because of this flow this mass will be reduced. And when the flow takes place from downward to upward direction you see the effective stress increasing; that means, there can be situation where actually effective stress may become 0 because this part becomes significantly large.

And in that case that is called critical hydraulic gradient again from this relationship I can get the relationship of critical hydraulic gradient equal to G minus 1 by 1 plus e. This is again very very important for solving problems in soil mechanics which I have shown in the appropriate places and you need to remember it properly.

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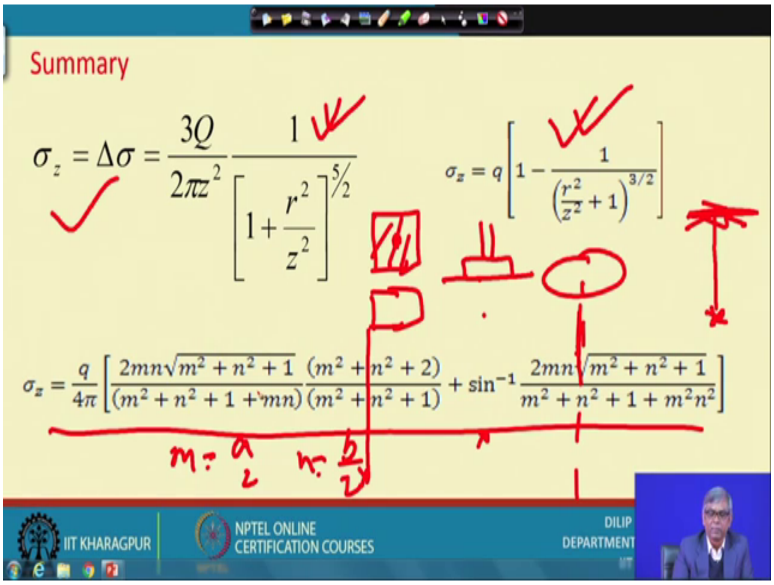

Then next is next topic was the vertical stress distribution you know. So, far whatever you have described that because of the self weight of the soil because this is the soil ground mark and you need to find out the stress here.

What I am doing? I am trying to find out the only because of the self weight of the soil here, but in the on other soil what will do we generally cost that foundation and through the structure load coming to this foundation and it is finally, transferred to the soil.

So, you need to find out different depth what is the pressure because; of this extra foundation load and that actually you can find out by different methods. That is a Boyles point out formula we have been sent though the Boyles gave the equation for point load, but in practices it not have any point load.

Hardly any have any point load, most of the time we apply load through the point through area and to how to use this point load actually if there is a area loaded with some intensity I can consider the entire load is acting at the centre and then point load formula can be utilized.

So, this same formula can be utilized and if the circular foundation is loaded then I can integrate and I can find out this is the circular foundation along the centreline of the footing at different depth. What is the pressure depth variation? I can use by integration; I can find out this expression, this expression also is important to remember and you can find out a different depth what is the pressure along the centreline of the footing.

Similarly, if the rectangular area is loaded and then different depth along the corner how to find out this corner formula is given; this corner formula again m and m is there. So, the m equal to a by z and n equal to b by jz.

So, these are the two things in this expression this expression looks lengthy and you need to do lot of calculation to find out the pressure, but in soil mechanics until unless it is specified we can generally use a quick method that is trapezoidal distribution method.

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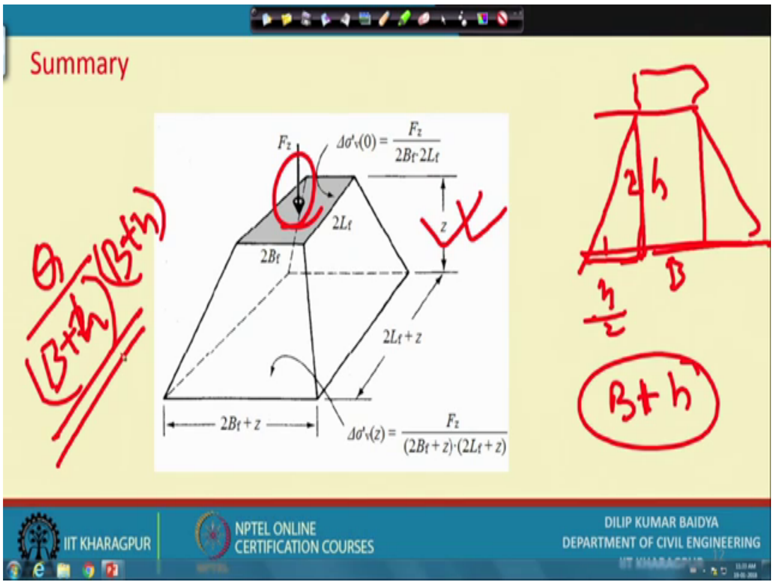

Generally we consider the 1 vertical 2 horizontal sorry 2 vertical 1 horizontal; that means, if you go down this much then you will horizontally will be half of that so, if this is this height is h then it will be this such spreading will be h by 2. So, that means, if the footing is here then I can assume the footing is widened at this depth equal to this side h by 2 and this side also h by 2. So, ultimately footing which was originally B then it will be at that depth B plus h.

So, using this enlarged footing width at the depth h I can approximately find out the pressure Q equal to B plus z or B plus h you have used B plus h if it is a square footing approximately. So, this is the method generally we use particularly for solving soil mechanics problem in the exam because, solving by the equation method it will take long time which it will not be having.

So, that much time will not be available; so, because of that we do quick method and if it is instead of square foundation if it is a rectangular foundation then B plus h l plus h. So, quickly if I know the load here, I can find out at a depth z or h. What is the widening of the footing? If I consider 1 2 vertical and 1 horizontal this distribution then I know at depth h the footing I can imagine widened by B plus h. Initial was B now it become B plus h similarly length will be increase to l plus h.

So, what will be the pressure then if the original pressure load is Q, Q divided by B by B is the footing pressure and at this depth and what is the pressure Q divided by B plus h into l plus h. So, this is the quick method generally follow to find out the pressure at any depth and that is generally recommended for examination; because examination the other method do not be able to do that much time you will not get.

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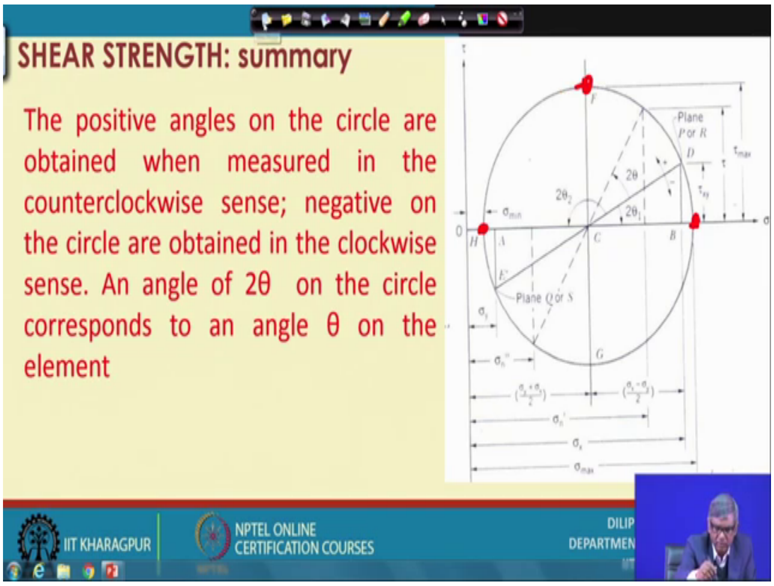

So, next to this we have actually Mohr circle and we know that from the Mohr circle we get a lot of information you can see if this is the Mohr circle if you grade then a minimum principal stress, maximum principal stress then maximum Shear Stress all we are getting.

Also when you do carry out tri axial test we apply actually we know generally two principal stresses minimum and maximum from there itself we can draw the Mohr circle and then according to the your requirement I can determined many things actually. So, this has to be properly one has to understand what is Mohr circle, how to utilize it. Next part was shear strength and shear strength.

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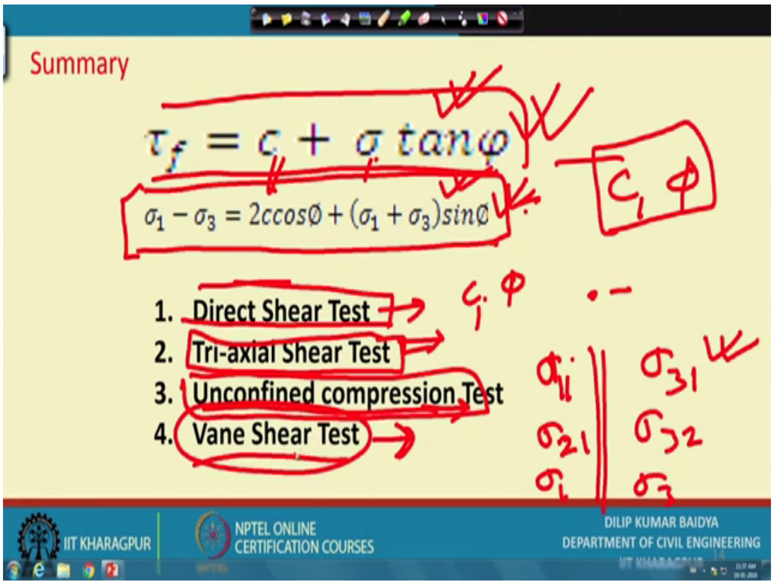

Actually by Mohr coulomb failure criteria that is given by tau equal to c plus sigma tan phi. c is the cohesion component and sigma is the effective stress and tau is the tan to phi. Actually phi is the angle of internal friction so; that means, at any point if we saw it is c phi and at any point I want to find out what the Shear Strength then I have know the c value. And if I know the phi value and then if I find out that is effective stress at this depth then I can from this equation I can find out what is the value of shear strength available from this.

And now relating to major and minor principle stress and angle of interpretation this is a well known relationship. By using this relationship again if I have 2-3 sets of data, if I carry out tests and I can for a particular sigma 1.

I can find out particular sigma 3, then another sigma 1, then another sigma 3, another sigma 1, another sigma 3 this is your 3-4 sets. So, this is suppose sigma 1 1, sigma 3 1 and simply sigma 2 1 and sigma 3 2 suppose like that different and.

So, I can using pi and sigma I can set 2-3 equation and then taking and if the test is carried out on the same soil then in combination of 2 equation I can solve for two parameters that is phi and c like that in different combination I can find out c and phi.

So, this equation can be utilized to find out based on the test results I can set this equation 2-3 equation and then taking two equation and solving I can find out the c and phi. This is one way one can find out the phi c and phi or one can use the Mohr circle and based on that one can find out the c and phi.

So, these are the analytical things which we have to be very thorough and you have to remember this relationship, this relationship because many places you need to use this. And then to find out this test actually during test to if particular sigma 1 you apply and what is the sigma? Sigma 3 we apply and what is a sigma 1 ultimate. So, different ways this tests can be done. So, direct shear is there, tri-axial shear it is there, unconfined compression test there, the vane shear are there.

So, there are test different various tests are available and you should know which test is suitable for what type of condition and we have explained those things during the lecture class. And direct shear test and unconfined compression test actually very quick and quickly you can assess the value.

Generally for cohesive for a cohesive less soil you use direct shear test and generally for cohesive soil we do unconfined compression test. And for any tri from c phi soil and to simulate different field condition we generally conduct tri-axial test. And vane shear test generally constant, this is a very this is a this is a unique field test which is applicable for sensitive soft clay soil.

Because this type of sensitive soil when you sample it gets disturbed and you will not get the when you test you will not get the real value. So, because of that sensitive soil will generally recommended, vane shear test from where actually directly we will get the value in the test.

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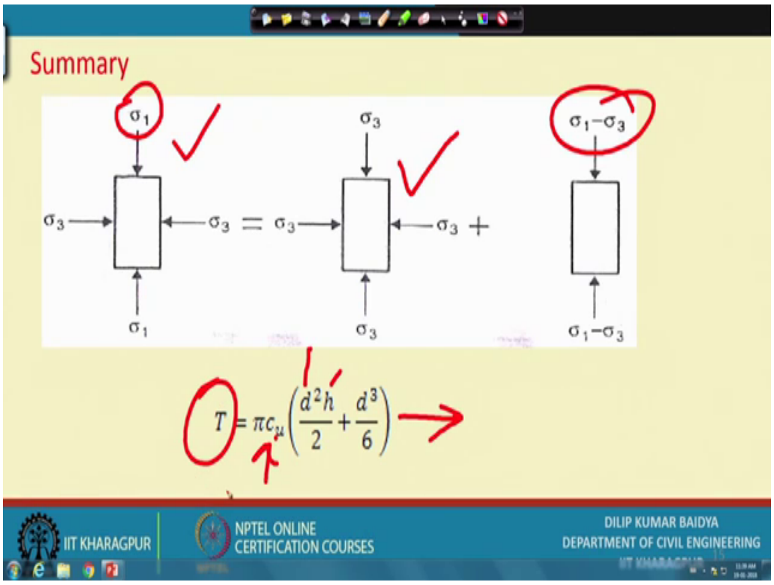

Next thing is; again during direct tri-axial test how happens absolutely apply first the sigma 1 and then this is the final. And we initially apply sigma 3 and later on we apply sigma 1 minus a.

So, these two together we create this. So, particular sigma 3 you apply and then at failure we measured the sigma 1 and based on that sigma 1 and sigma 3 and we can form the equation as we have shown previously.

And then if I have two sets of tests then two equation I get and solving two equation I can find out c and phi. And like that if you have more than two results then in combination of two, I can get again c and phi then finally, I can get the value of average value. And this is the relevant formulation for vane shear test.

Actually vane dimension that with diameter actually d and h actually height and torque applied during failure that taken during failure and it is expressed in terms of untried strength of the say soil. And from this equation one can find out the value of c.

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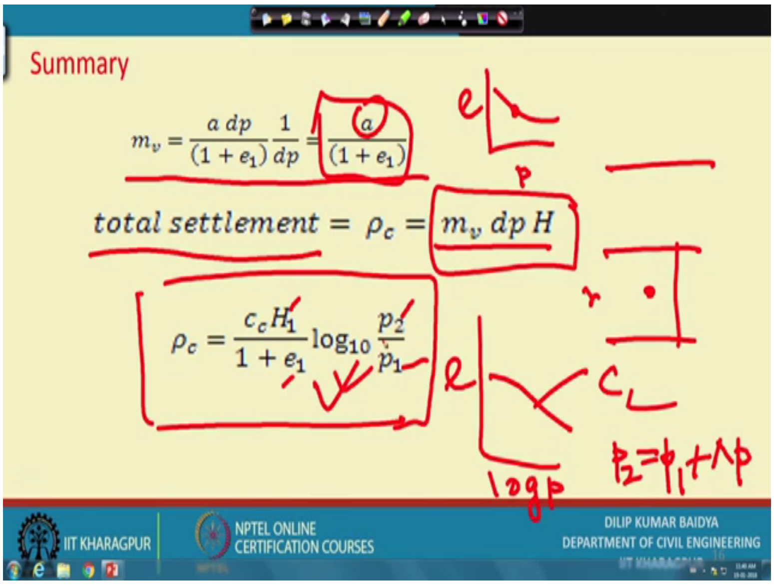

And then the there are compressibility chapter then compressibility chapter also we have done many things.

We have mentioned volume compressibility and then if you know the volume compressibility, volume complexity will be came to express a by one plus a. An a is actually slope up ep curve, e versus p and if I get that at any point what is the slope that is actually a and if I know that. And then by using this equation we can find out the coefficient of volume compressibility and total settlement can be obtained by mv dp.

If suppose there is a layer here and then at this point; What is the pressure increase? What is the mv value? And what is the thickness? If I know then by using this equation I can find out the total settlement. Then another way to find out the total settlement was the compression index method; that means, if I plot instead of e versus p if I plot e versus log p e versus log p.

Then this is become a straight line a slope of this line is called cc and then that cc and if I know the thickness of the soil and what they show and initial pressure and final pressure p2 actually equal to initial pressure p1 plus delta p. So, if I know all those thing then I can find out total settlement from this equation also.

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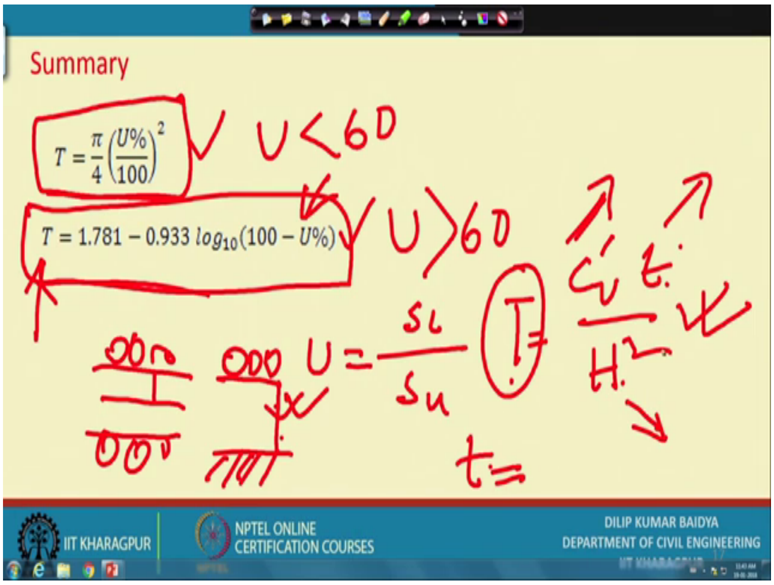

And next actually was the, if I know the total settlement then sometime question arise actually how much will be? What will be the hour? How much time it will take to consolidate these total settlements? Or to complete that total consolidation; So, for that actually we use theory we have discussed, but most important thing to be remembered that you can.

Find out the time factor and time factor can be expressed in terms of U and if that U is up to less than 60 percent, T versus U can be fitted by this equation and if the U greater than 60 percent then T versus U can be fitted by this equation. And if you know an U actually usually at settlement at any time divided by ultimate settlement.

And so, that means, if it is a 60 percent settlement how much time it will take? 80 percent settlement you can take; that means, you can different degree of consolidation and different time factors.

So, at the time factor is related to c v t by H square that c v is the coefficient of consolidation, t is the time required to reach particular degree of consolidation and H is the thickness of the drainage path. And here actually two are important to be remembered, one is the unit c v t H all units should be consistent. Sometimes it will be given meter per second and here actually you are using in hour or day then that will be a a problem. So, all a unit has to be converted in the consistent unit and then if you get them finally, you will get there.

So, generally T to be obtained from here corresponding to a particular value of degree of saturation I can find out the T say about. Then T can be expressed again with this c v is known file property, H it is the drainage path. If suppose soil layer is here drainage path is both side then your H become half of this, this is H. And if another situation this is the soil layer and drainage path is here and this is your impermeable then your H is this.

So, correspondingly if you use this from here I can get the value of T; that means, time required for a particular degree of consolidation this is actually very also important.

So, these two to be remembered, this is also remember these two cases also these different cases that consider based on that drainage condition what will be the H in this? That also to be very very carefully you have to use then only you will get the current here. So, these are the things I have repeatedly mentioned there, solved problem, once again I have shown here.

So, that is all next actually what we have after that actually we have earth pressure. Again different types of earth pressure earth pressure at raised active pressure, passive pressure all those things we have mentioned and relevant formula everything I have mentioned.

And then I have given a small introduction on slope stability and with that perhaps I hope this was have completed all those things. And I hope this will be useful to you and I will be very help happy that it becomes useful to you to for learning soil mechanics ok.

Thank you.