Foundation Engineering
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Lecture - 07
Core Penetration Test and Other In - Situ Tests

So in the say 7th lecture we will discuss about the remaining part of cone penetration test and then I will discuss about the other in situ test. So, in the last class in the 6th lecture I have already discussed about the some part of the cone penetration test, I have discussed the static cone penetration test.

And now today, I will discuss about the static cone penetration test, the remaining part of the static cone penetration test and as well as I will discuss about the dynamic cone penetration test.

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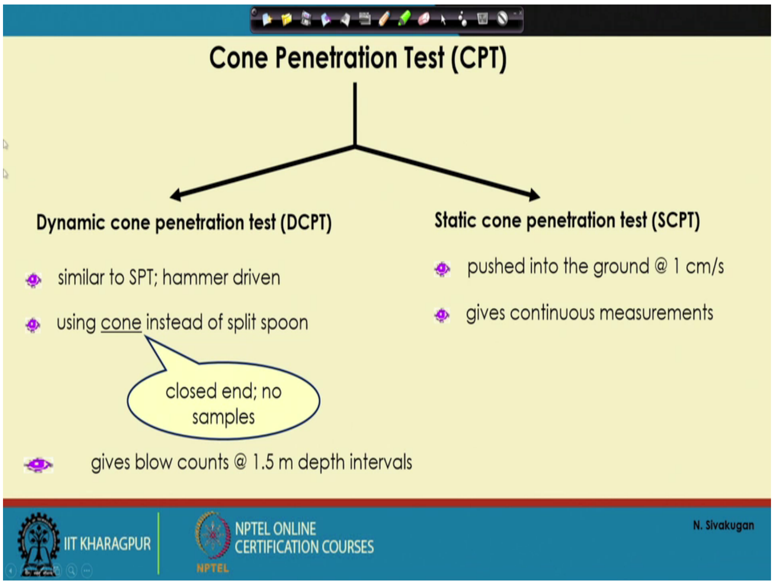

So, I have already discussed these things that in the dynamic cone penetration test, which is similar to the SPT where we are applying hammer blows or blows to drive the cone into the soil.

Like SPT that we are applying the blows to drive the sample a tube into the soil and, but in a static cone penetration test we are not driving the cone, we are basically pushing the cone into the soil at a particular rate and that rate is given generally one centimeter per second.

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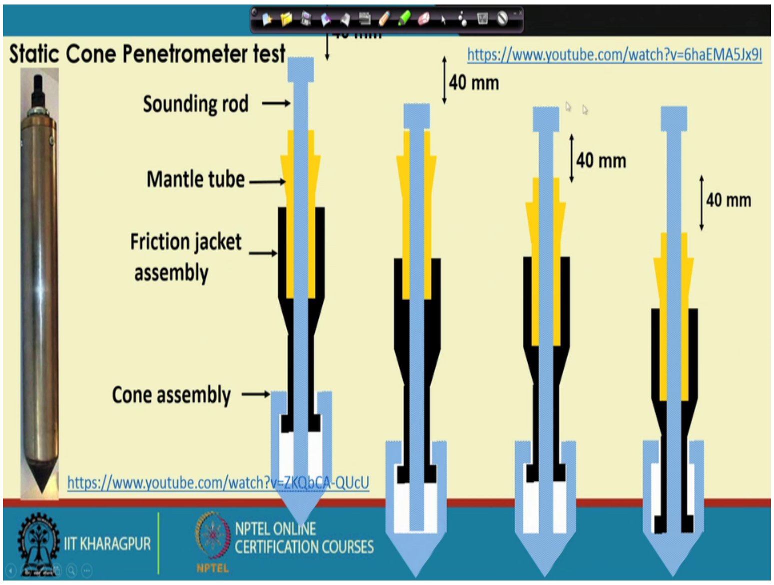

But in the SCPT Static Cone Penetration Test we are getting continuous measurement but in the dynamic cone or the SPT, where the hammer blows is required.

So, we are getting the data with certain interval and that is generally one point not more than 1.5 meter depth interval and, but in the difference between the SPT and the cone penetration test that in the SPT we can collect the soil sample, but in cone penetration test whether it SCPT or DCPT or dynamic or static we cannot collect the soil sample. And another difference in between the SPT and the DCPT or Dynamic Cone Penetration Test that in the SPT the borehole is required.

But in the dynamic cone penetration test or any cone penetration test the that borehole is not required. So, next one I have discussed already this part, that is the four major parts in that a cone that sounding rod mental tube friction jacket assembly and cone assembly.

First the cone assembly with sounding rod is pushed with 40 millimeter and then we will get the cone resistance and then this is a second position then the sounding rod friction jacket assembly and cone assembly these three all are pushed into the soil further 40 millimeters.

So, here we will get the total resistance; so, from the total resistance if I subtract the friction cone resistance. So, we will get the friction resistance. So, that is why we can separately calculate the cone resistance and the friction resistance. In the next part we will push the mental tube by 40 millimeter and in the fourth stage we will push mental tube, and the friction jacket assembly for the 40 millimeter so, that we can bring it to the original condition.

So, I can show you one particular YouTube video and the link is already displaying the screen that here this is the first stage where it is pushed by 40 and the further the total one is boost by further 40 and then the total system is taken into original position.

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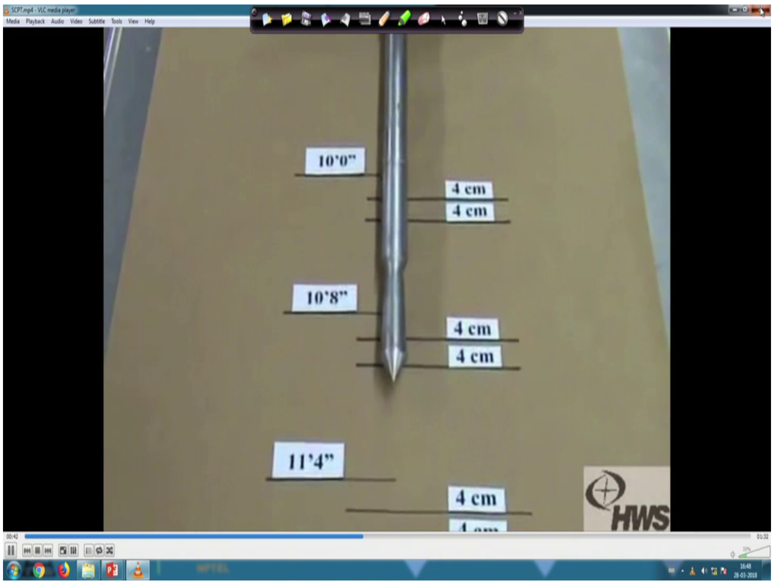

Then the next one we will go for the next a depth, where we want to take the data. So, first 40 millimeter for the cone resistance then the next 40 millimeter for the total resistance, then we will bring the total system again in its original position. So, this way these things will continue.

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And the same thing we can do in the field I have the video the same one, first the cone resistance we measured then the total resistance then finally, if you subtract the friction at cone resistance from the total resistance, we will get the friction resistance.

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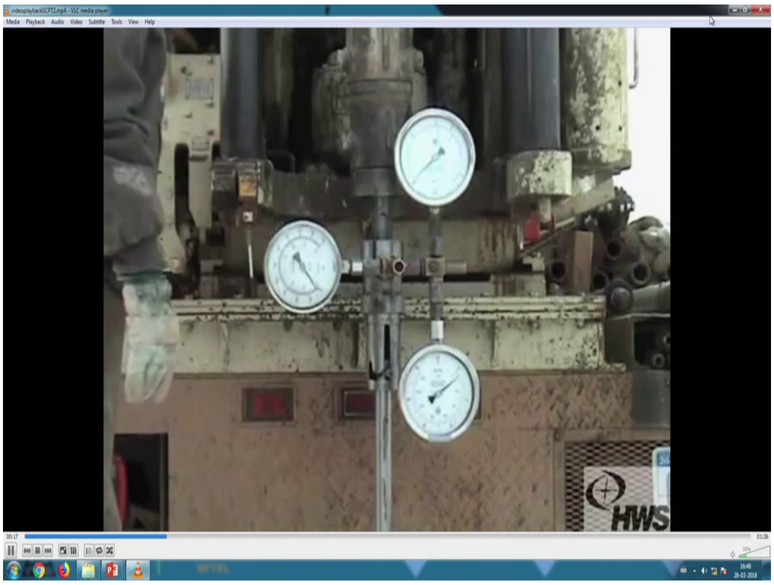

So, these are the testing methodology, here we are measuring the resistance that this is the estimate and this is it is pushed into the soil. So, once we get the resistance, then the next step we have to determine the soil properties, we those properties will be required for our foundation design.

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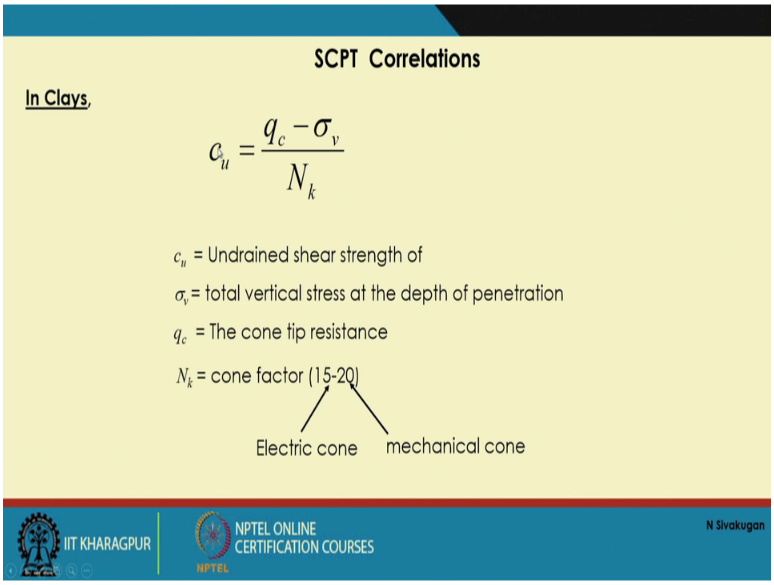

So, for the clays the C u value undrained shear strength or undrained cohesion of the soil, this undrained shear strength of soil. So, here the C u value is given qc is the cone tip resistance or cone resistance or sometimes we call it tip resistance, and sigma v remember that it is total vertical stress at a depth of penetration and N k is the cone factor. So, if I use the electrical cone then it is 15 if I use the mechanical cone then it is 20. So, N k value is in between 15 and 20. So, these value we can take any value in between this range depending upon which cone we are using.

So, but remember that it is the total vertical stress, it is not the effective vertical stress. So, this way this correlation is given.

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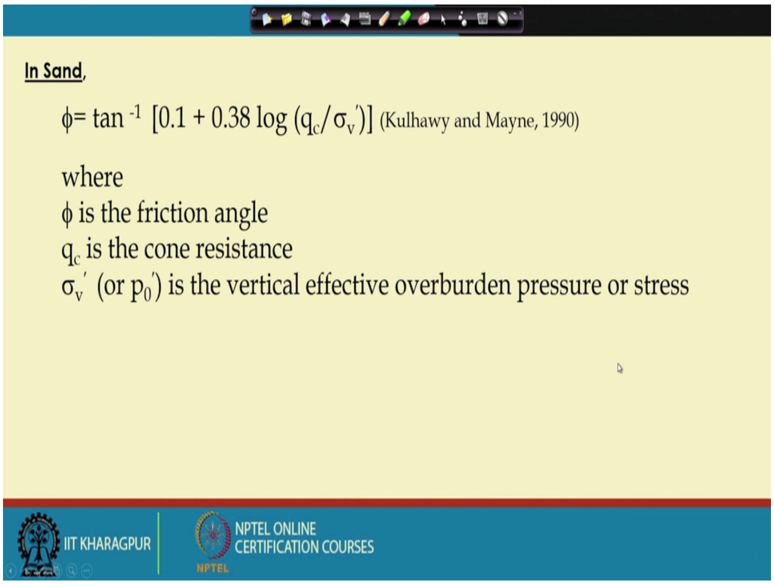

So, but for the for the sandy soil, if it is a sandy soil then the friction value or the friction angle the phi is the friction angle we can get with these a relation. So, here it is log qc is the cone resistance and sigma v dash; So, here sigma v dash. So, sometime as I mentioned we can we put it as a p 0 dash it is the vertical effective overburden pressure or stress.

So, initial one in case of clay it was the in initial it was the total stress, but now it is the effective stress. So, and I have already discussed that how we will calculate the effective stress how will calculate the total stress. Total stress suppose if it is saturated soils, total stress will be the unit weight saturated unit weight into the height, but if it is the effective stress, then you have to subtract the pore water pressure so; that means, the we take the submerged unit weight of the soil into the depth.

So, these two correlations we can use to get the cohesion value and friction value of the soil based on the cone resistance.

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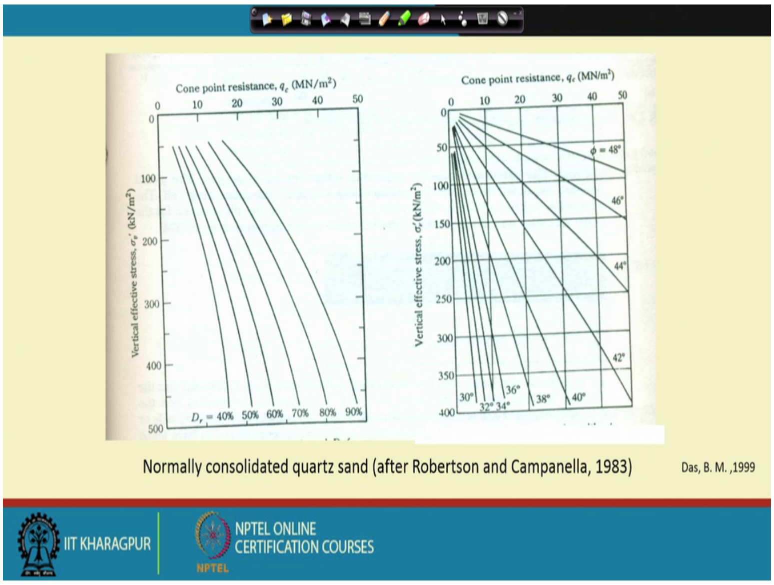

So, and we have a charts also, by which also we can determine the what would be the relative density of a soil. If I know the cone resistance suppose if I know the cone resistance and 30 and if I know the vertical effective stress. So, we can get what will be particular relative density. So, that will be the 80 percent relative density of a soil.

Similarly, if I know the cone resistance if I know the vertical effective stress, then we can get that suppose it is 30 is the cone resistance and vertical effective stress is 150 kilo Newton per meter square so; that means, the phi value will be 44 degree. So, this way also we can use this chart and get the phi value and the relative density of a particular soil.

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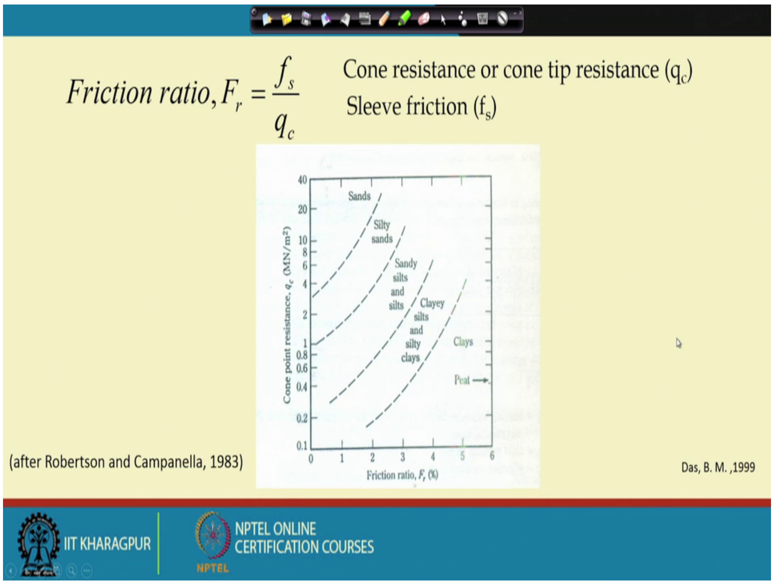

Next one, we can calculate the friction ratio, this friction ratio is the sleeve friction or the friction resistance divided by the cone resistance.

So, if I know the friction ratio, then we can use this chart where the friction factor this is friction factor and this is the cone point resistance or cone resistance it is in meganewton per meter. So, if I know the friction factor, if I know the cone resistance.

So, suppose the friction factor a friction ratio is 3. So, if the friction ratio is three and we have the cone resistance is 0.4 meganewton per meter square. So, and this is 3. So, soil will be the clay is silt or the silty clay. So, the type of soil also we can determine based on by using this chart if I know the friction ratio and if I know the cone resistance.

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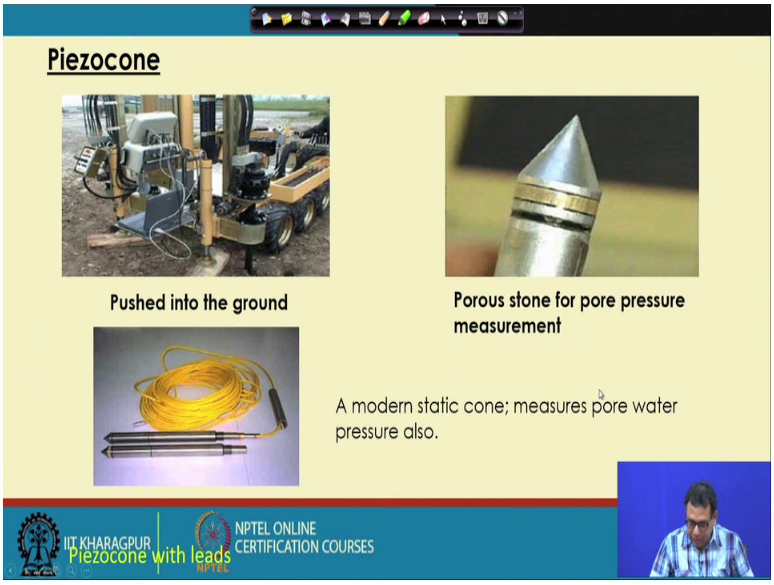

Next one is a Piezocone. So, nowadays the with the static cone we measure the pore water pressure also because here the pore water porous stone, for the pore water pressure measurement unit is attached. So, we can measure the cone resistance, we can measure friction resistance, we can measure pore water pressure and we can re measure the friction ratio.

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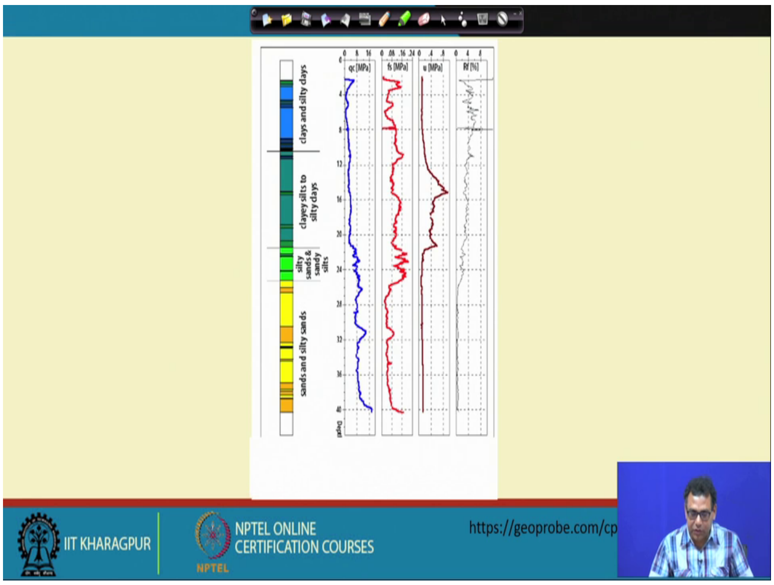

So, this is a particular typical example. So, this the reference is given. So, where we can get say particular depth, that this is the variation of cone resistance with depth the blue one. Red one is the variation of the friction resistance with the depth u is the pore water pressure variation with the depth and Rf is the friction ratio variation with the depth

And these are the different types of soil. So, we can get the continuous data and then from this data we can get this plot. Finally, we will get these plots and then from this plot particular type of soil we can get, if we know the values we can get the our required soil properties for the design that can be cohesion, that can be friction or we can identify the soil we can get the different properties based on the is the charge or the correlations that I have shown.

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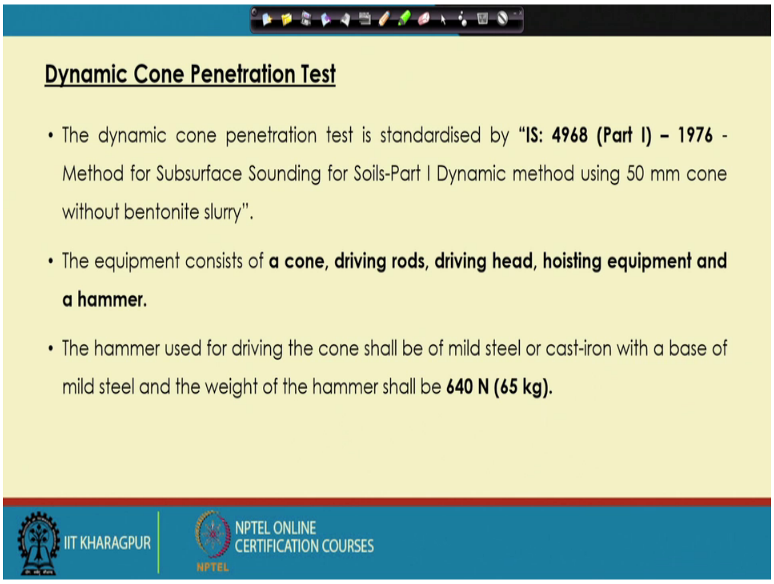

So, next one is the dynamic cone penetration test. So, as I mentioned. So, this is the IS 4968 part 1, 1976 where we have to apply the hammer blow. So, the equipment consists of a cone driving rod, driving head then whose equipments and the hammer to drive the cone into the soil.

So, the hammer used here, which is the weight of 65 kg.

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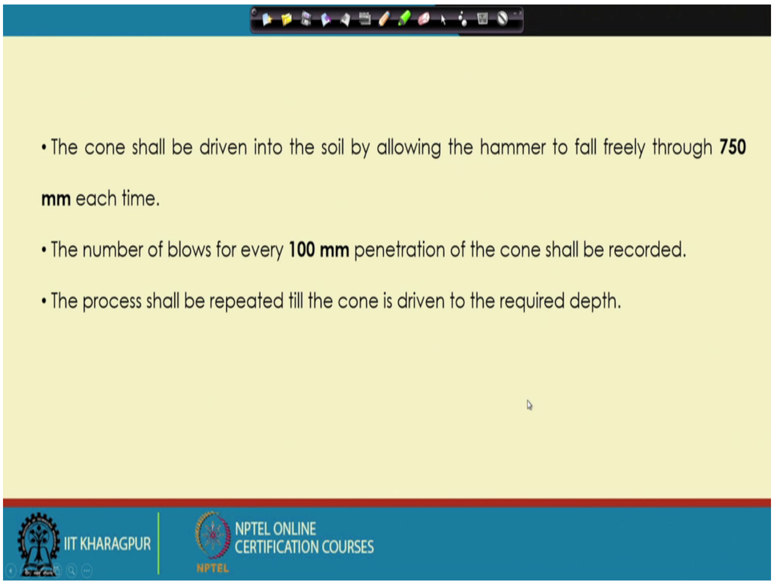

And is a free fall is 75 millimeter or 77 50 millimeter or 75 centimeter. So, the height of fall is 75 centimeter or 750 millimeter and the weight of hammer is 65 kg. And the number of blows for every 100 millimeter penetration of cone is recorded and the process shall be repeated till the cone is driven to the required depth.

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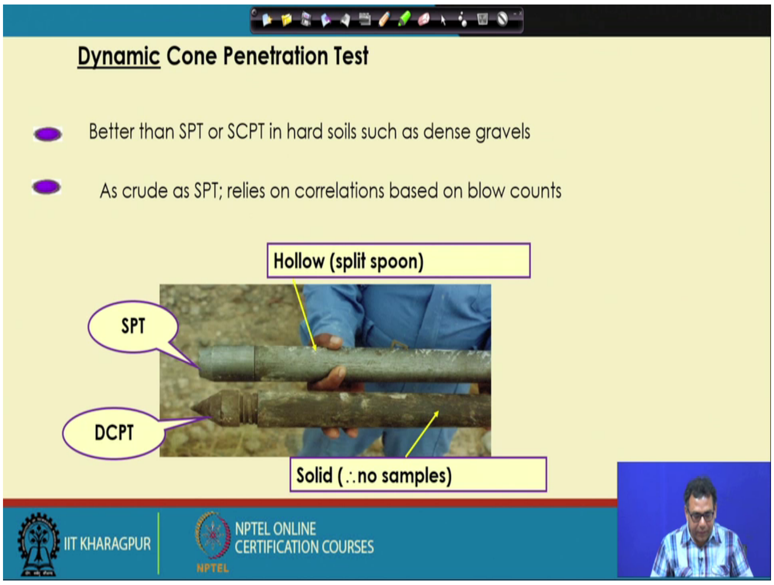

So, and better than the SPT the dynamic cone penetration test which is better than the SPT or SCPT in hard soil such as dense gravel and so, here also we have to use a available correlation to like SPT to with the number of blows to get the soil property. So, you can see these are the two SPT and the DCPT dynamic cone penetration this is the cone of the dynamic cone penetration, which is solid and this is the SPT sample which is hollow. So, here we can collect the soil sample and here we cannot collect the soil sample.

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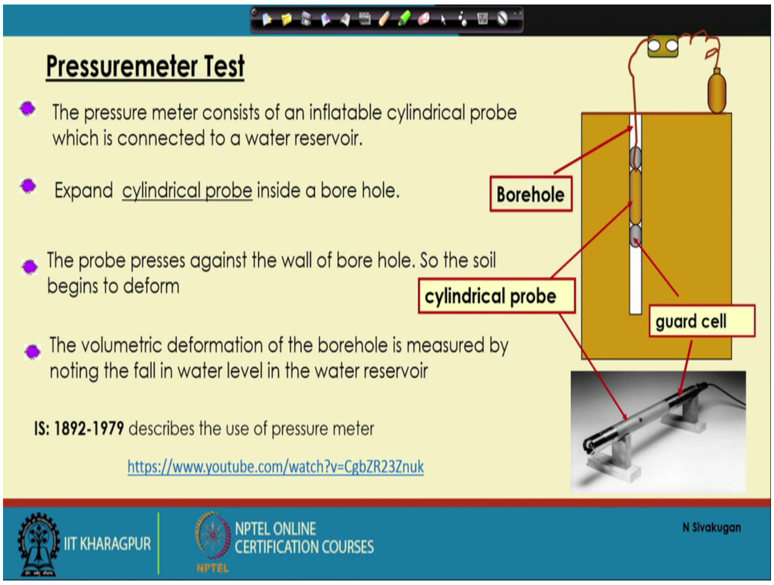

So, next so, the next test. So, the that was the cone penetration test SPT SCPT and DCPT. The next one that I will discuss about the pressure meter test which is also very useful to determine the soil properties. It is also a in situ test where the pressure meter consists of a cylindrical probe. So, this is a cylindrical probe or this is actually the pressure meter you can see, I will show you a video where also you can see the pressure meter.

So, where there is a cylindrical probe and which is connected with a water reservoir and the expand cylindrical probe inside a borehole and then probe press presses the wall of the borehole. So, that soil began to deform.

So, basically here we are inserting a cylindrical probe into the borehole and the cylindrical probe in attached with a water is over and we apply the pressure. So, that the cylindrical probe inside the borehole can expand and it will press the soil wall in the borehole and the wall soil will start deform. The volume of deformation of the borehole is measured by the fall of the water because we have attached it is the reservoir. So, the borehole deformation is measured by the waterfall water level difference of the water reservoir.

So, it is the typical description of this pressure meter. So, I can. So, this is the I s code is describe the use of pressure meter. So, here the we apply the pressure through the probe onto the onto the soil wall. So, wall start deform and the deformation is measured. The deformation or the volume change this volumetric deformation or the volume change is measured with the help of this water pressure water level difference and I can show you on particular video for the this is the pressure meter.

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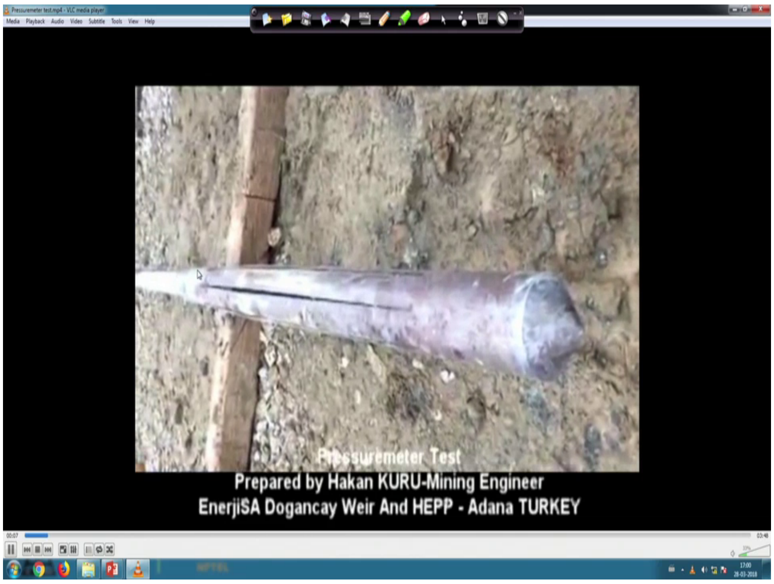

Which is this these things will expand and these are the two guard cells. So, this is the membrane that the where we will apply the pressure.

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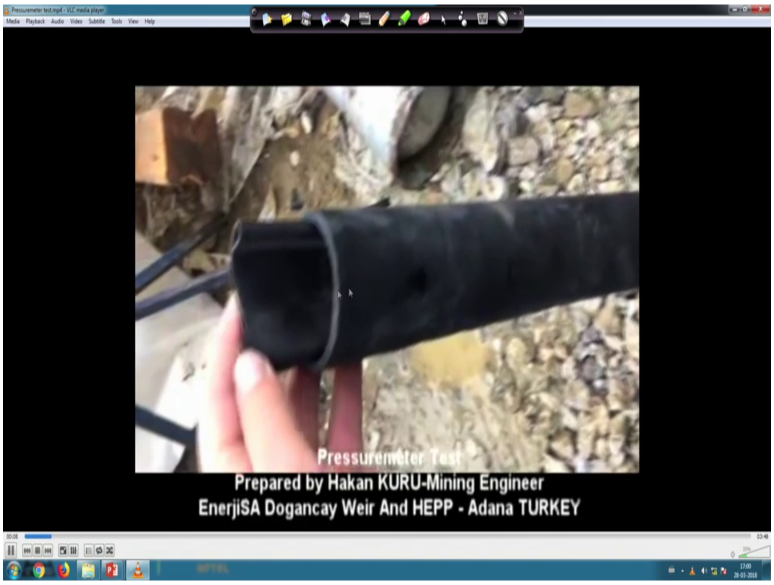

And it will expand and is the soil wall start before and we can measure the deform volumetric deformation with the help of the water level difference.

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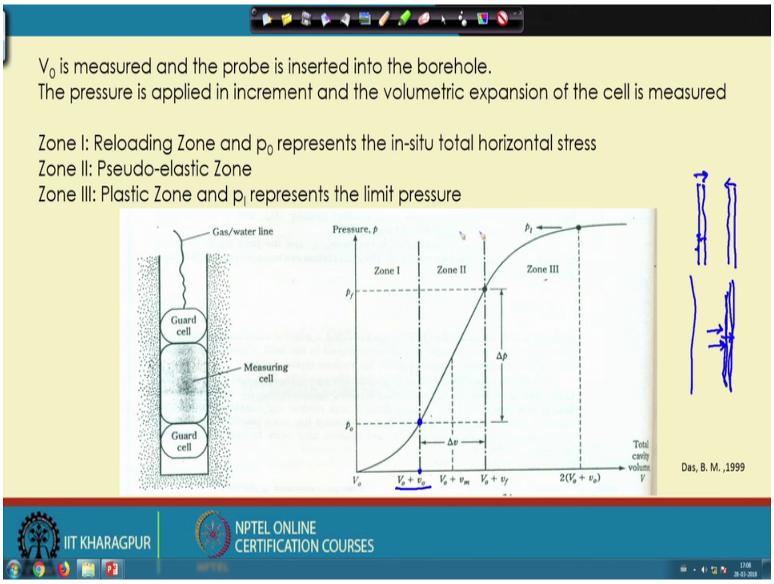

So, this is a pressure meter and this is the typical figure where this is the measuring cell or the cylindrical probe and you are apply the guard cell to protect this cell in 2 sides. So, in the video also I have shown you there is a in the in the front side and the back side you can see in the video. So, this is the protection that we are giving. So, in the and this is the your measuring cell unit. And we can see that after that we will get this type of curve finally. So, this is the total cavity value, cavity volume is the that the borehole or the cavity that is created.

So, total cavity volume because as we apply the deformation on the soil wall, the volume of the cavity will or the borehole will increase. So, this is the total cavity volume and it is the pressure that we are applying. So, we are applying the pressure and you are measuring the volumetric deformation or the volume change. So, this is the total volume of the cavity and this is the applied. So, we can see this is the typical curve. So, in here we will have three zones basically, zone 1 zone 2 and zone 3.

So, here V 0 is the initial volume of this pressure cell. So, V 0 is measured and probe into this is the volume of the measuring cell of the probes cylindrical probe V 0 capital V 0, and we insert this thing in the borehole. The pressure is applied in increment and volumetric expansion of the cell is measured. So, we apply the pressure and the volume increases and we measure the volumetric expansion. So, that is and that is why we will get the pressure versus volume curve. And this is the zone 1 which is known as the reloading zone because what is the reloading zone.

So, when the borehole is constructed. So, what will happen that, the soil will so; that means, the soil will. So, initially there is a volume of the soil wall. So, when we remove the soil from the borehole. So, there will be a expansion of this wall so; that means, the borehole when we apply the pressure so; that means, this soil again go to its original position.

So, initially when there is a soil wall. So, initially suppose this is the original actual pressure the volume of the or the side wall of the borehole. So, when we remove the soil. So, there is a these things will come in this portion so; that means, there is a expansion of the or the deformation of the wall and this soil volume or the cavity volume decreases.

Now, when we apply the pressure into the cavity; so, this soil will again go to its original position. So, that is the this zone is called the reloading zone and p 0 this point p 0 represents the in situ total horizontal stress, because that is the original condition of the borehole because of the removal of the soil. So, suppose this is the original condition of the borehole we have removed the soil. So, borehole will shift in this direction borehole. So, this is the say borehole soil will deform in this direction. So, the this is the this is the original surface, now this is the deform surface when we apply the pressure it will go to its original condition again.

So, this is the reloading zone and from here this is the zone 2 if you look at this pressure versus volume curve it is almost linear. So, that is why this zone is called pseudo elastic zone. So, that is the linear relationship between the pressure and the volume. And then the zone three which is called the plastic zone here pl represent the limit pressure. So, now, this expansion of the probe, it continue unless there is a failure in the soil or the pressure or the expansion or the pressure it will reaches its limit; So, that of the instrument.

So, generally the failure is considered when the expansion is 2 times the total volume of the cavity in its original condition; So, now, if you look at this figure. So, the actually the this original condition the volume is capital V 0 plus V 0, because V 0 is the volume of the probe and now we apply deformation. So, a volumetric expansion is small v 0. So, that the total volume of the cavity in its original condition was capital V 0 plus small V 0.

Now, we can go up to the failure is 2 times of original volume of the cavity or that is V 0 plus capital V 0 plus small v 0. So, and then we can get the pl form corresponding to this curve. So, generally this pl is calculated or determined by interposition because we know the we stop it the volume and then we get the pl or if it reaches the maximum limit of the instrument, if the pressure reaches the maximum limit of the instrument and then we stop the experiment.

So, now the how we will identify these 2 points. So, these 2 points identify these 2 points where the pressure versus volume relationship is linear and this portion is the is the left side of this linear zone or the pseudo elastic zone is the reloading zone and the right side is the plastic zone and we corresponding to this 2 point v is the small v 0 and p is the small pressure is the small p p 0 and corresponding to these points volume is the V 0 plus small vf, vf is the final and corresponding p is the pf or that is the this is noted as a pf.

So, here we have p 0 pf and pl. And here the capital V 0 is the total original volume of the cavity probe and the then there is the expansion of amount of small v 0. So, this is the total volume of the cavity capital V 0 plus small V 0 at the original condition, and the final condition we have 2 times of capital V 0 plus the small v 0. So, that is treated as a pl or the limit pressure.

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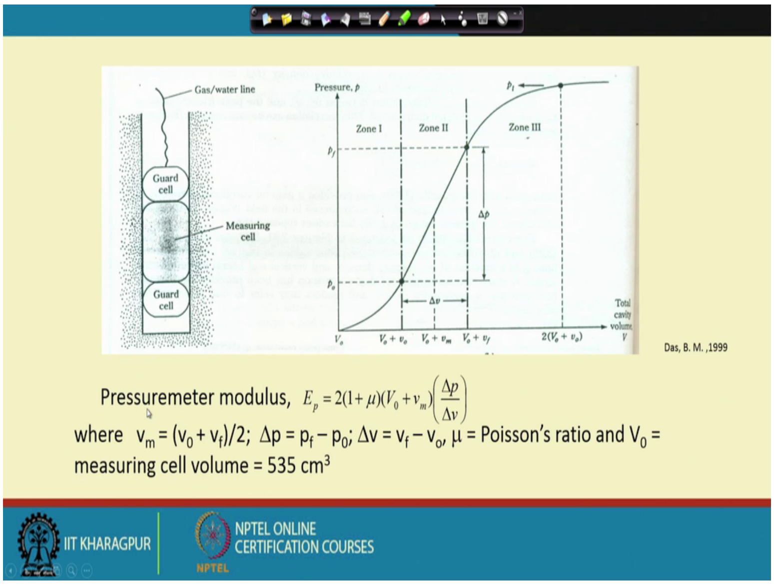

So, when I similarly again from here we can calculate the pressure meter modulus. So, this expression is given. So, where as I mentioned that capital V 0 is the volume of the a measuring cell or the probe, it is taken as 5 three 5 centimeter cube and the Poisson mu is the Poisson ratio vm is the average volume of the initial and final. So, this is the V 0 plus vf divided by 2 and del p is the difference of pressure that is pf minus p 0, and del v is the difference of the volume that is vf minus v 0.

So, and thus mu is the Poisson ratio and v capital V 0 is the measuring cell volume as I mentioned.

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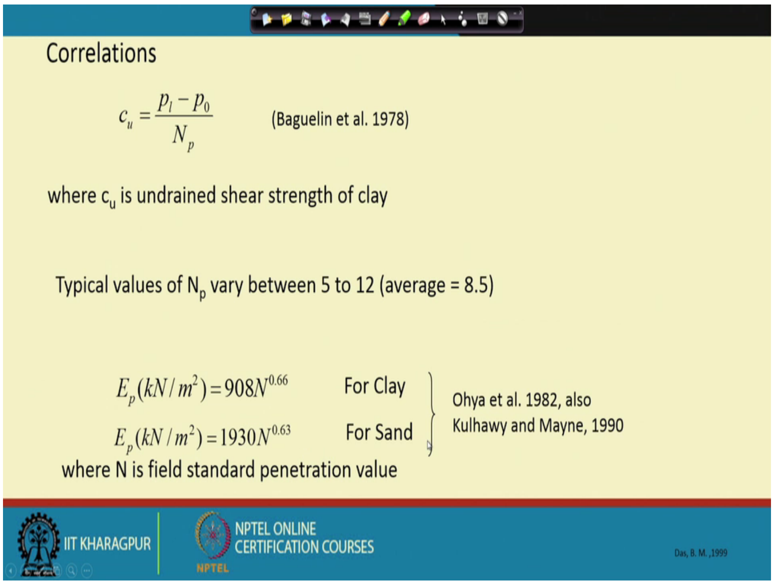

So, from here we can calculate the pressure meter modulus and then we have to applies the correlation. By these correlations we can get the soil properties like the others is in situ test we are doing. So, that is why this undrained correlation of the clay can be determined the pl minus p 0 divided by mp. As I mention pl is the this is the pl which is the limit pressure, which is the limit pressure and p 0 is the pressure that is we can get in situ horizontal stress or that we are getting corresponding to this point.

So, that is the pl minus p 0, and N p is the typical values which varies between 5 to 12 and average value 8.5 can be taken. Now this pressure meter modulus can also be correlated with the field measured SPT values and these correlations is given this is for the clay and this correlation is for the sand by which also we can determine if I know the n value we can determine also pressure meter modulus. And or otherwise we can determine the pressure meter modules with the help of these expression.

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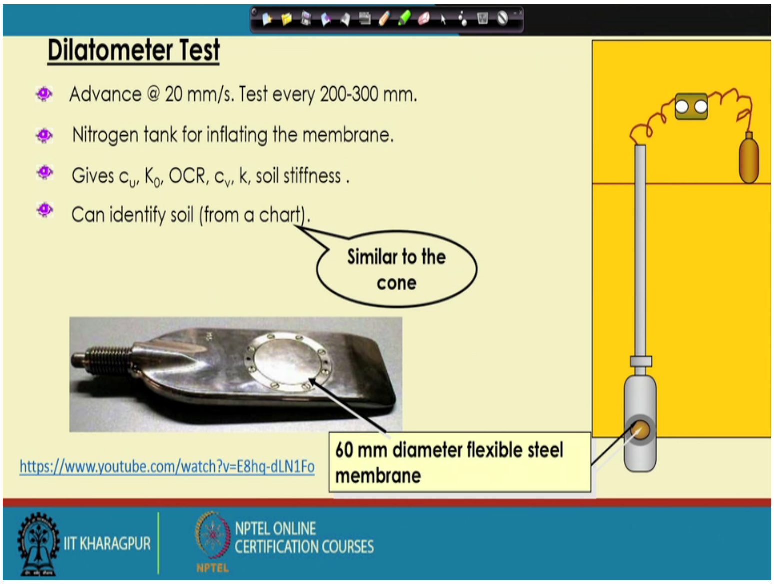

Now, the next test that I will discuss is the dilatometer test, here also this is also a another in situ test where it is advanced again it is pushed into the soil with a rate of 20 millimeter per second. So, here also you have to inflation of the membranes will the will take place, and we use the nitrogen tank to inflate this membrane.

So, this is the small membrane and this is the membrane. So, this is a 60 mm diameter flexible steel membrane. So, this with the help of these inflating the we have to inflate this membrane and then based on that, we get again here also we will get the p 0 we will get the pl this is a limit pressure, and then we can we by using the correlation we can get C u K 0 OCR all these soil properties ok.

And then we can there about also a similar to the cone resistance we have the chart, by this chart we can we can get the soil property. So, I will give you only the correlations by which we can get the values. So, I can give you the I can show you one video. So, this is the typical values. So, typical dilatometer setup yeah. So, this is the sound.

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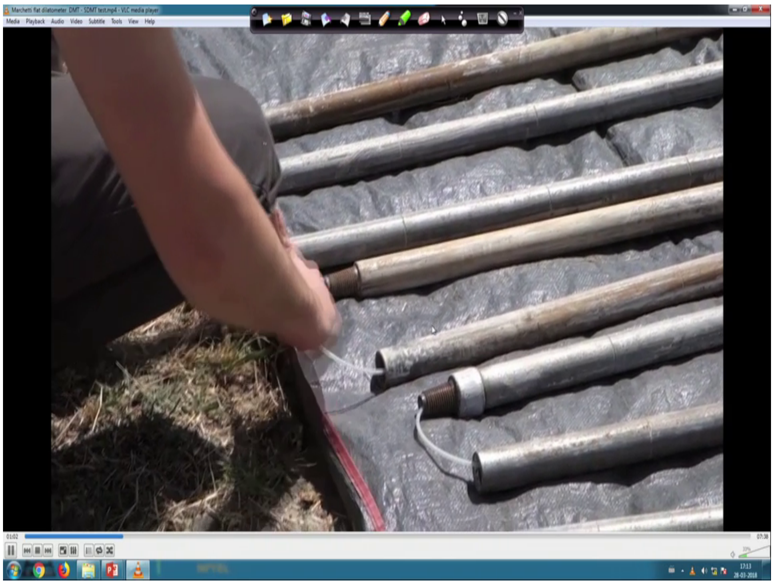

This is the rod. So, it depending upon the where you are trying to measure the properties we have to add one by one rod. So, that we can increase the this is the dilatometer and so, this one is this the if you have if you want to do the test for a higher depth, then you have to attach the more number of rods so, that these instrument can reach up to that depth.

So, and this is another rod is attached. So, this is the instrument, which is basically pushed into the soil. So, this is the three thin membrane that was. So, it is pushed into the soil.

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So, it is pushed and then the corresponding readings are and then we increase the depth of the or increase the depth of the instrument by attaching the this rod and then we can measure the data.

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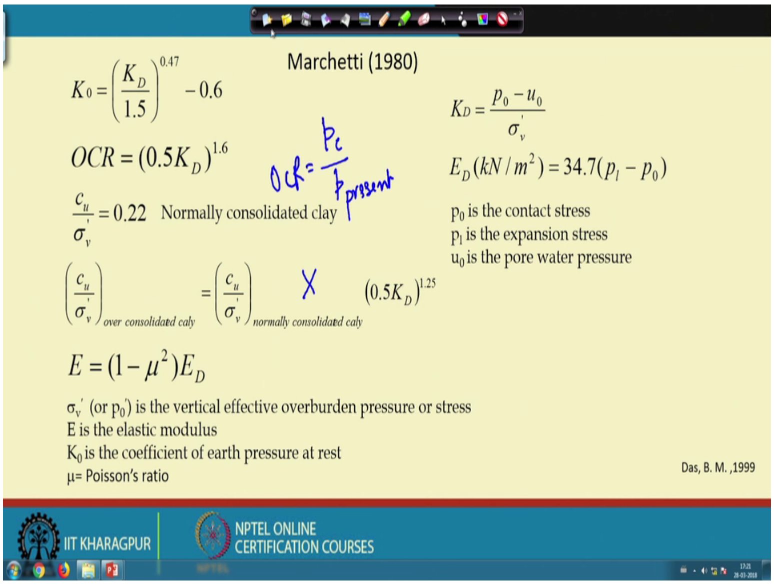

So, once we get this values. So, we can use some correlations to get the K 0 OCR C u as I mentioned that C u is the undrained cohesion of the soil and so, your K 0 is the earth pressure coefficient of the earth pressure at rest. So, here this is this is the correlation K 0 is K D by 1.5 to the power 0.47 minus 0.6. So, K D will get from here. So, here this is p 0 minus u 0. So, p 0 is the contact stress and pl here is the expansion stress.

So, here when there will be a contact that is the that portion stress, now when we apply the extension or the expansion we apply the expansion of this membrane so, that that stress is pl. And then u is the pore water pressure and from these two expressions we can get the K D and E D. See if I know the K D and E D these two parameters then we can calculate K 0 the coefficient of earth pressure at rest review the this coefficient of earth pressure are not I will discuss in detail when I will I will I will teach about the lateral earth pressure theories, where you will find there are three types of earth pressure that is active at rest and passive. So, this is the at rest.

So, this coefficient of earth pressure at rest we can determine you know that is the C u is the undrained cohesion. So, that also you can determine and e is the elastic modulus of the soil and here C v bar is the effective overburden pressure or the stress v means the vertical. So, we are talking about vertical. So, these expression we can use for the normally consolidated clay and for the over consolidated clay, we can use these correlation this is normally consolidated clay and then this is into the 0.5 K D to the power 1.25. And as we know what is the normally consolidated clay what is the over consolidated clay so, we have already discussed.

And the ever consolidated ratio is the ratio basically which is the pc divided by p present or so; that means, this is the OCR is here pc is the past maximum stress this soil is experienced and p present is the present test. Now for the over consolidated clay these value is greater than 1 and for the normally consolidated clay OCR value is taken as 1 or over considered ratio is taken as one for normally consolidated clay. So, now, these are the all expressions that we can use.

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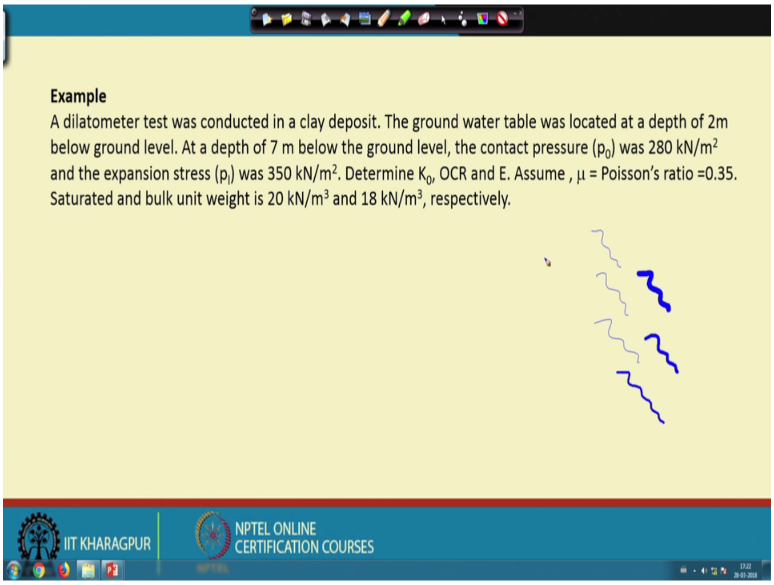

Now, we have a typical problem that we will solve here that, we have we have done a dilatometer test were conducted in a clay deposit, the ground water table was located at a depth of 2 meter below, the ground level at a depth of 7 meter below the ground level the contact pressure p 0 was 280 kilonewton per meter square and the expansion stress pl was 350 kilonewton per meter square, determined the K 0 OCR e assume mu Poisson's ratio is 0.35 and saturated and bulk unit weight is 20 kilonewton meter cube and 18 kilonewton meter cube respectively.

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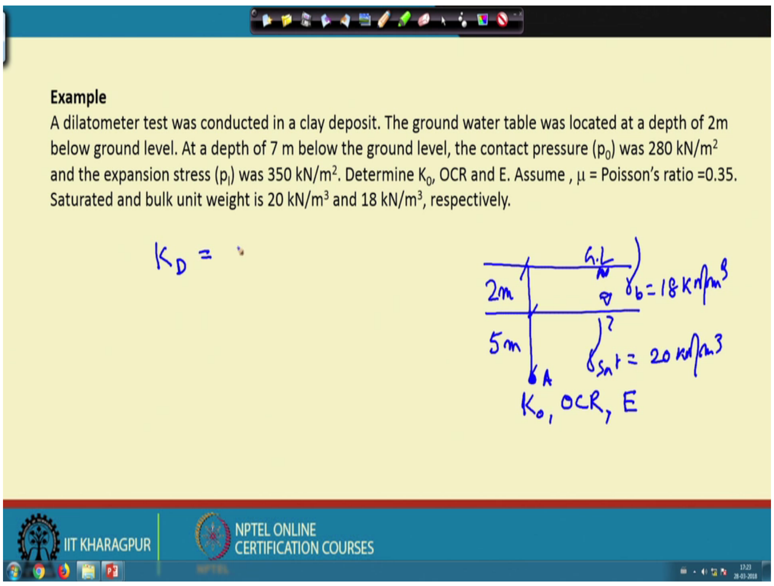

So; that means, we have a soil. So, this is the ground level or G L, and we the water table position is here which is 2 meter below the ground level, and unit bulk unit weighs it is given 18 kilonewton per meter cube and saturated unit weight is given 20 kilonewton per meter cube. So, at a depth of total 7 meter the dilatometer test was conducted and here we have to determine the K 0 OCR and E of the soil at a depth of 7 meter at a point of say a from the ground level.

So, these are the so, we know the K D expression is K D expression is given. So,. So, this is these are the expressions of K D E d. So, we will use these expressions I am just putting directly those values there. So, we have. So, that is why the K D expression.

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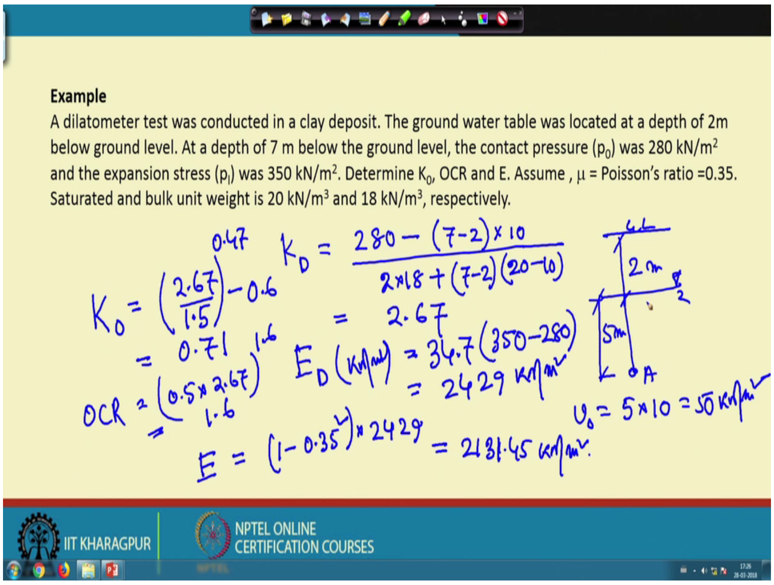

If I put the value that our this is 280 minus the pore water pressure. Pore water pressure is 7 minus 2 because and then unit weight of the water is 10. Because here the this is the ground level and this is the 2 meter below the ground level water table and we are measuring at a point of a which is 5 meter below the ground level.

So, our pore water pressure u u 0 or u will be 5 into 10 into 50 kilonewton per meter. So, this is the 10 is the unit weight of the water and then divided by this is the effectives vertical stress. So, effective vertical stress is 2 into 18 for the 2 meter plus again 7 minus 2 and you have to use the such submerged because it is below water table. So, this is this will be 20 minus 10. So, the K D value is coming out to be 2.67.

Similarly, the E D value in kilonewton per meter square, if I put these expression this will be 34.7 into 350 minus 280 and this will give you 2429 kilonewton per meter square now if I use the K 0 expression. So, K 0 is equal to 2.67 divided by 1.5 to the power 0.47 minus 0.6. So, K 0 value is coming out to be 0.71.

Similarly, the OCR value is equal to 0.5 into 2.67 into to the power 1.6. So, OCR value is coming out to be 1.6 because it is a over consolidated clay, that is why OCR value is greater than 1. So, similarly elastic modulus of the soil we can take get 1.35 that is mu square into 2429 and that is equal to 213145 kilonewton per meter square. So, while using this dilatometer test data, you have to calculate the K D and the E D and then based on that we calculate all other required parameter for the soil of a particular depth 7 meter below the ground level. And here water table is 2 meter below the ground level.

So, now, here I am finishing this lecture in the next lecture I will give you a summary of the all these test that I have discussed, and then I will go for the next part that is the sample at different kinds of sampler and to collect the soil sample for disturb or undisturbed.

Thank you.