Advanced Foundation Engineering
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Lecture - 3
Soil Exploration: Penetration Tests

Hello. In our last class I have discussed about the various soil exploration techniques like direct indirect, direct methods and semi direct methods. Indirect methods over tests or toll plates, then semi direct methods; it was boring. Now, today I will discuss about the direct indirect method to determine the soil properties or in-situ soil properties.

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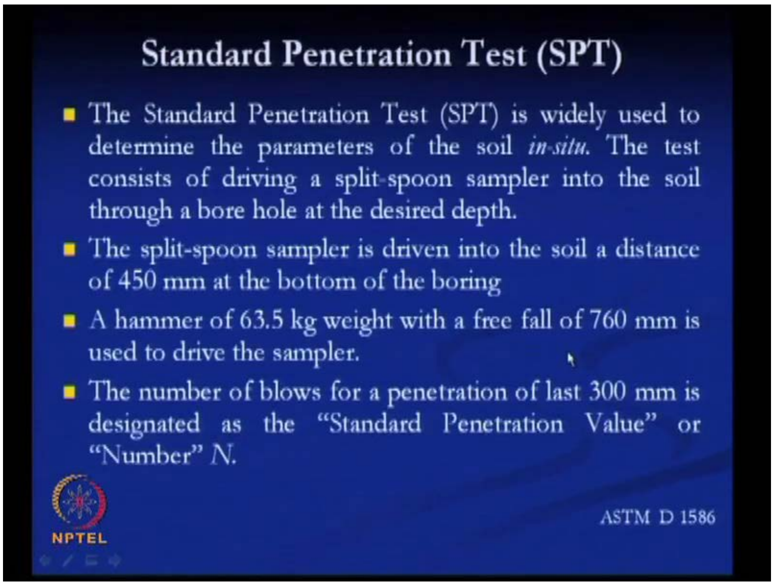

Now, first that penetration test that I will discuss in this section is standard penetration test. Now, this standard penetration test is widely used to determine the parameters of soil in-situ. The test consists of driving a split-spoon sampler into the soil through a borehole at the desired depth. So, up to required depth, you have to drill the borehole and then you have to conduct the test at that level and you have to drive the split-spoon sampler into that level.

The split-spoon sampler is driven into the soil; a distance of 450 millimeter at the bottom of the boring. Now, hammer of 63.5 kilogram was used and with a free fall of 760 millimeters to drive the soil, to drive the sampler. The number of blows for penetration at least 300 millimeter is designated at Standard Penetration Value.

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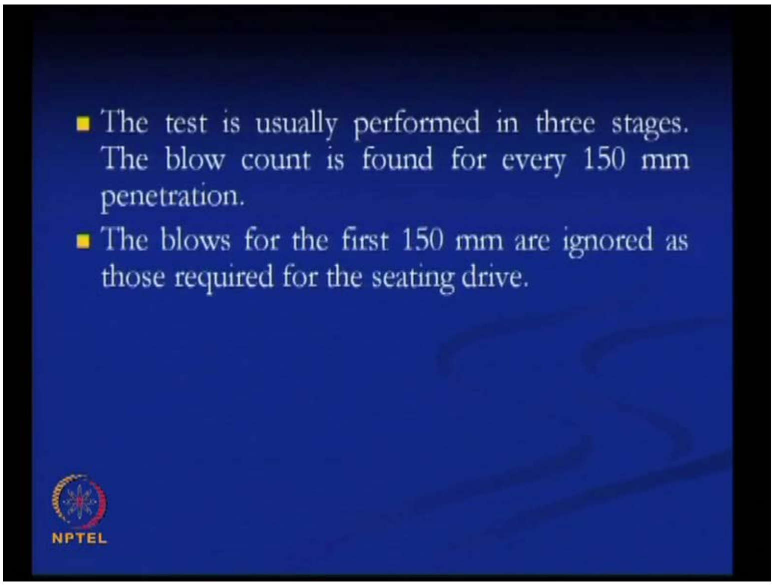

That means this test is conducted in three stages. In each stage, you have to penetrate the sample by 150 millimeter. So, first stage you have to penetrate the sample by 150 millimeter. Then you have to count the number of blows required to penetrate that soil sample sampler into the soil by 150 millimeter.

Then next stage, you have to penetrate that sampler into the soil again by 150 millimeter. And, in the third stage we have to again penetrate the soil sampler into the soil by 150 millimeter. So, in three stages, total 450 millimeter penetration is required. And at each stage, you have to count the number of blows that is required to penetrate that 150 millimeter.

Now, first 150 millimeter penetration number is generally ignored. And, the summation of last 300 millimeter penetration number is designated at as standard penetration number. And, this first 150 millimeter is ignored, as these required for the seating drive. Or it is ignored under next two stages penetration value; that is 150, 150 each or 300 millimeter penetration is called as penetration number.

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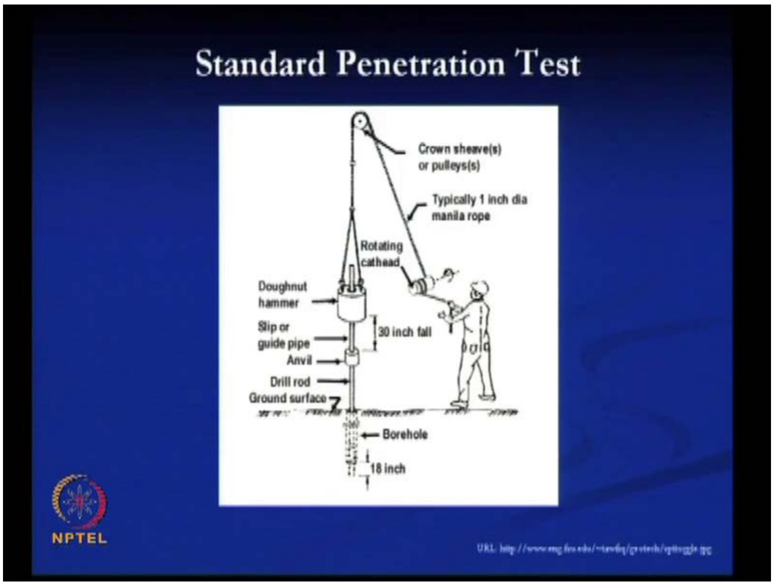

Now, this is the test setup. This is the hammer which is used. The weight of hammer is 63.5 kilogram and free fall is 760 millimeter. And, it is used to drive the soil sample into the soil within that borehole up to the desired depth for three different stages.

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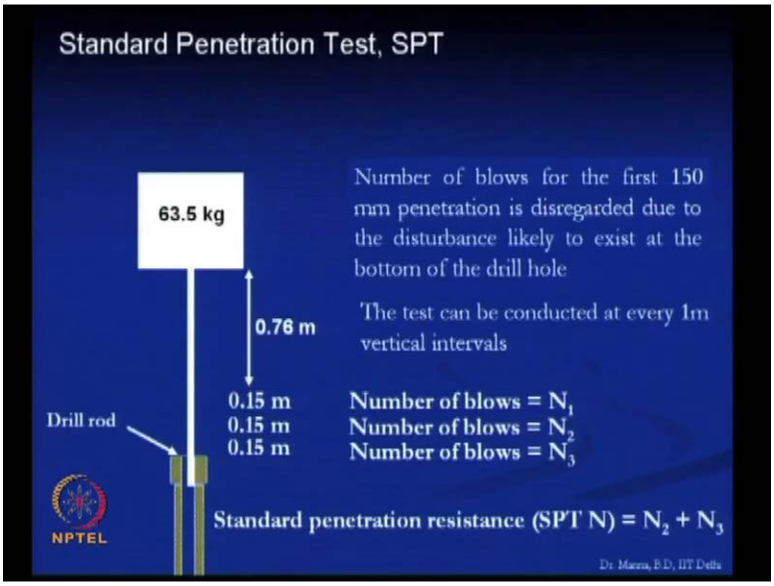

So, now if I go for this penetration value, so you can see that this hammer is driven and the soil sampler is penetrated for 150 millimeter, 150 millimeter, 150 millimeter in three stages. And, this free fall is 76 millimeter. And, each time this blows number is counted; that is N 1, N 2 and N 3. And then the standard penetration resistance or SPT value N is the summation of these last two blows number; that is N 2 plus N 3. Now, this number of blows for the first one hundred and fifty penetration is neglected due to the disturbance like the exist at the bottom of the drill hole. So, because of this reason first one hundred and fifty penetration number is neglected.

The next is… this test can be conducted at every one meter interval. Sometimes it is conducted for 0.75 meter interval. Or later on that interval can be increased of a up to one 1.5 meter interval.

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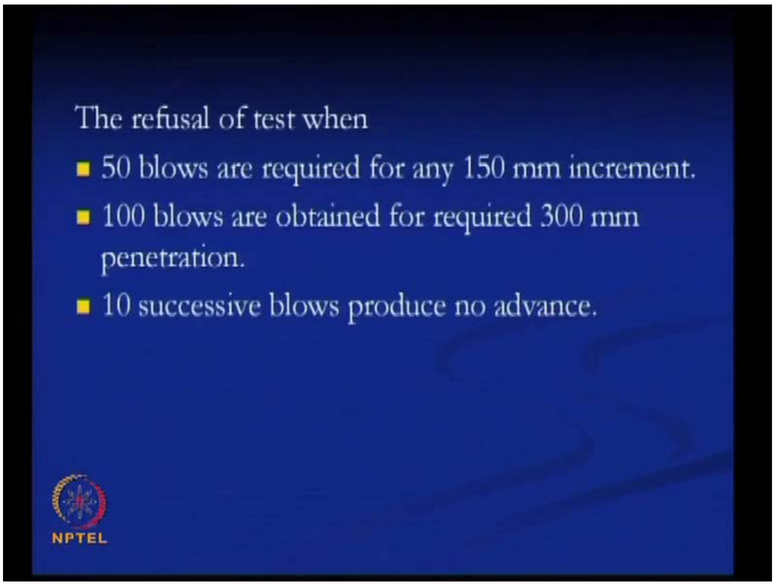

Now this, when this test is called as a refusal, then there are three conditions; one is that fifty blows are required for any 150 millimeter increment. If there is 50 blows are required for any 150 meter increment, then it is called the refusal.

Next condition, if hundred blows are required for, required, obtain for required 300 millimeter penetration. And, the last one; that ten successive blows produces no advances. And, if there are any three conditions observed in the field, then we can say this is the refusal of test.

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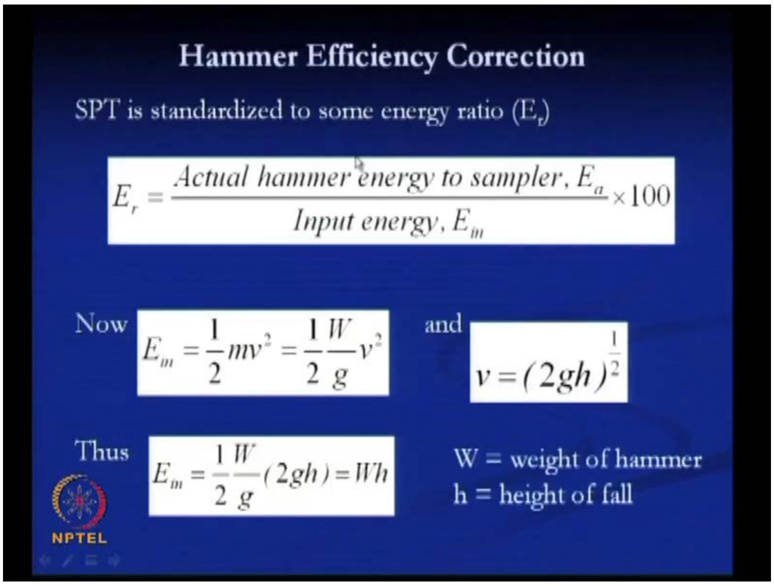

Now, when we are driving this split-spoon sampler into the soil, there is a… some corrections are required. Those corrections are basically in three types. One is for hammer efficiency correction, another is overburden correction and next one is for the drill rod, borehole diameter and then the length of borehole; all these things, some corrections are required.

So, first this hammer efficiency correction; now, this SPT is standardized to some energy ratio. Now, what is the energy ratio? This energy ratio is the ratio between the actual hammer energy to sampler that E a and input energy; that means, the input energy which is E i and the actual hammer energy required to penetrate that sampler into that soil, which is expressed in percentage.

Now, we can calculate this input energy. It is half into m v square; where m is the mass of the hammer and v is the velocity of the hammer. Now, we can write this half into W by g into v square; where W is the weight of the hammer and g is the acceleration due to gravity. Now, we can say this velocity, we can calculate by using this expression two half root over 2 g h; where h is the height of the free fall.

Now, ultimately the input energy will be the weight of the hammer into height of free fall. So, if we know the weight of the hammer, if we know the height of free fall, then we can determine what will be the input energy of that particular hammer of that particular condition. Now, actually in the field that, this input energy may not require… is not applied to driven that soil sample into that test condition. So, we have to apply some correction.

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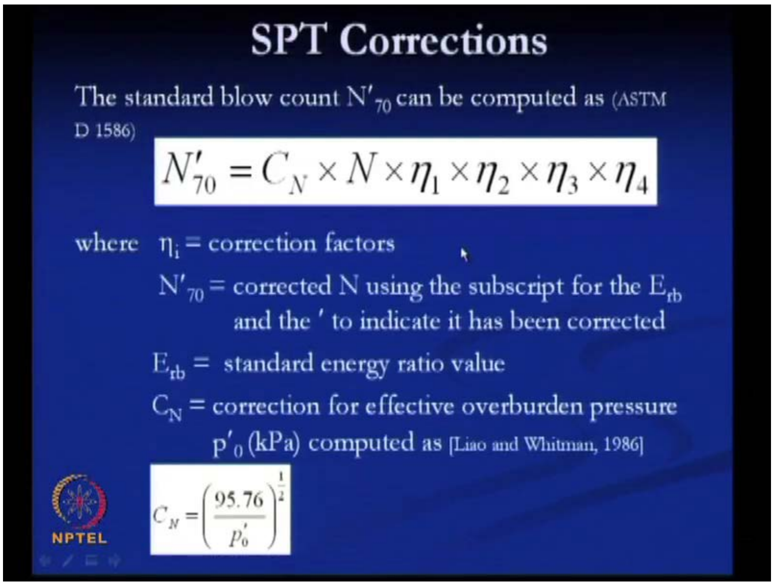

Now here, this is the correction; say suppose N dash 70, it means that corrected N using the subscribe for the E r b and the dash to indicate that it has been corrected. That means this dash indicate that this N value or the field. This is the measured N value and this dash indicated that, that is this N value has been corrected. So, it indicates that, that has been corrected. And with this, 70 indicate that with a standard energy ratio value; because as we have defined what is the energy ratio and then this 70 means this is the standard energy ratio. Now in the field, it is observed that this standard energy ratio is 70. So, here we generally express this N value as in 70 standard energy ratio.

So, now we have to apply the other correction. The C N is the correction due to effective overburden pressure. And, we can use this expression where P zero bar is the effective overburden pressure and then we will get the C N value by using this expression.

Now, this is very important for correction for the granular type of soil, where this effective overburden pressure will play a very important role when you determine this SPT value; because then near the ground surface, this effective overburden pressure is less. And, when you go into the deeper strata, then this effective overburden pressure is very high. So, that is why this, that is some correction is required due to this less and more effective overburden pressure in different soil strata.

So, now for that in this correction factor, we can correct that effective overburden pressure; correction due to effective overburden pressure. Now, this n 1; this other correction factors are due to several factors that I will explain.

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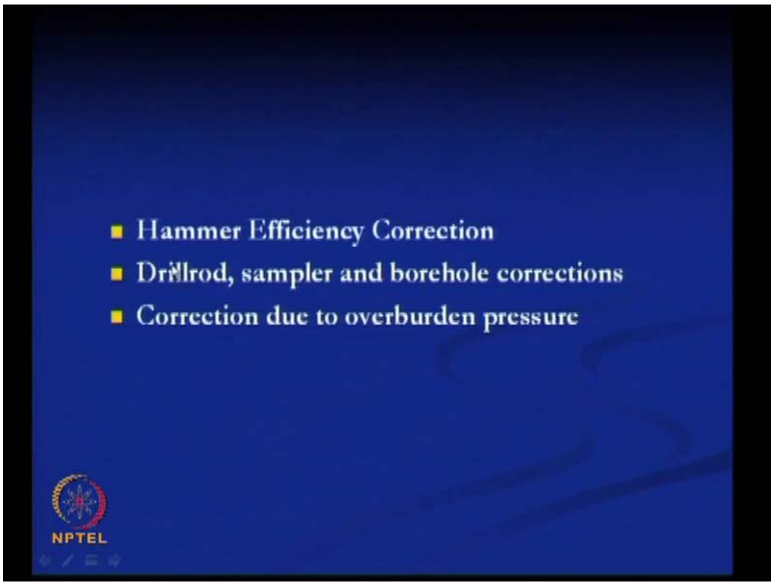

That that is this first one is the hammer efficiency correction and then the correction due to overburden pressure. And then the other corrections are correction due to drillrod, sampler and borehole.

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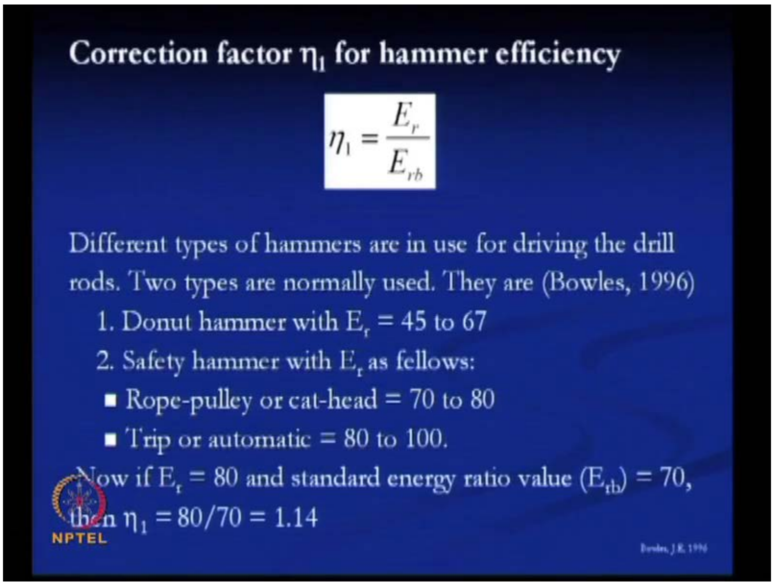

Now here, how we will get this correction due to hammer efficiency? Now one is; this first correction factor is represented as the ratio of E r and E r b; where E r is the energy ratio and E r b is the any standard energy ratio. Now depending upon the type of hammer, this E r value varies. Now, generally these two types of hammers are used. One is, this first one is safety hammer and this is the donut hammer.

Now, for this first type of hammers, this donut hammer, this E r value varies from 45 to 67. And, for safety hammer this E r value, if it is the rope pulley or cat head system; then it is 70 to 80 and if it is a trip or automatic, then this E r value is 80 to 100. So, how we will calculate this first correction factor or correction due to the hammer efficiency?

Suppose if energy ratio at any condition is 80 and the standard energy ratio value is 70, then the efficiency, correction due to hammer efficiency will be 80 divided by 70; that will be 1.15. If this E r value is say 70 and this standard one is 70, then this correction factor value will be simply one. So, in this fashion we can correct this n value at any energy ratio condition depending upon the type of hammer we are using.

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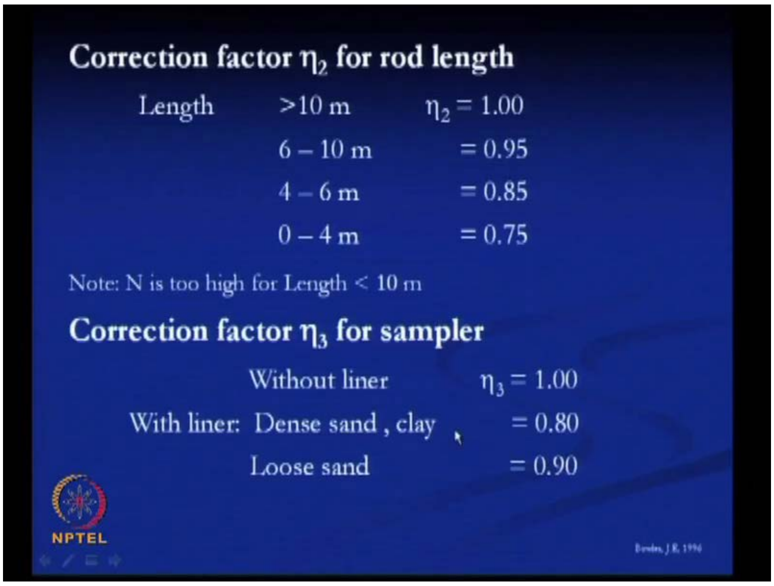

Now the second correction factor or this correction factor due to rod length, if this rod length is greater than 10 meter, then this correction factor is 1; if it is within between 6 to 10 meter, this correction factor is 0.95; if it is within 4 to 6 meter, this correction factor is 0.85; if it is 0 to 4 meter, then correction factor is 0.75. Now if N is too high for length less than 10 meter; so if we use this length of this rod is less than 10 meter, then this N value is too high.

Now, the correction factor for this sampler is if it is without liner, the sampler tube, then this correction factor is one. If with liner and we are measuring this n value for dense sand and clay, this value is 0.8; for the loose sand this value is 0.9.

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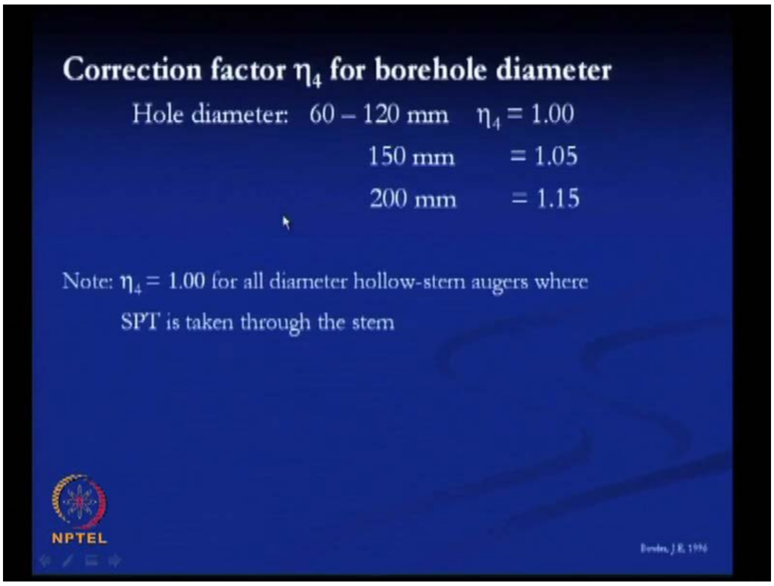

Now, similarly for the correction for the borehole diameter; so here we can use a different borehole diameter, then we have to apply some correction for different borehole diameter. Now, if this diameter varies from 60 to 120 millimeter, then this correction factor is one. And if this diameter is 150 millimeter, then this correction factor is 1.05; for 200 millimeter this is 1.15. Now, n four is equal to 1.00 for all diameters, hollow stem augers, where the SPT is taken through the stem. So, this is another note.

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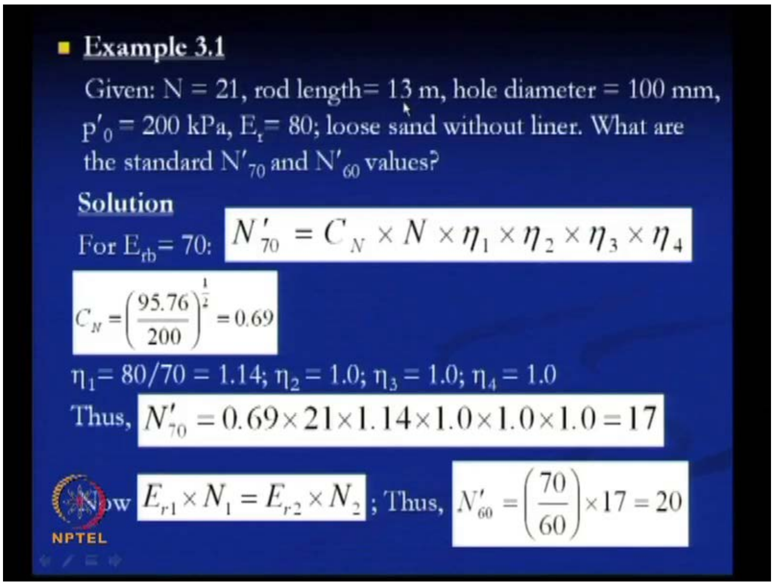

So, now if we want to solve one example, then we will, we can understand how to apply this correction and how to calculate the corrected N value from the measured N value. Now, suppose this measured N value, the field N value is 21 and the rod length is 13 meter and this borehole diameter is 100 millimeter and the effective overburden pressure is 200 kilo Pascal and the energy ratio is 80 and the sand is loose sand and without liner. So, the sampler type is without liner, then what will be the standard N value or the corrected N value under the standard energy ratio 70 and standard energy ratio value 60.

First, we will calculate this standard or corrected N value under the standard energy ratio 70. Now, for the… under this energy ratio standard energy ratio 70, now this is the expression for standard N value or the corrected N value under standard energy ratio value 70.

Now, as this P zero dash is 200, so by using this expression 95.76 root over 95.76 divided by P zero bar. In place of p zero bar, we can put 200. So, this value is coming 0.69. Now as this first energy, the first correction due to the hammer efficiency that the energy ratio, actual energy ratio in the field is 80 and the standard energy ratio is value of the 70, so the correction factor will be 1.14. And, if the rod length used is 13 meter, now from this chart we can see if this rod length is greater than 10, then this correction value factor value will be1.0. So our, this correction factor value due to the rod length is 1.0.

Now again this sampler correction factor, it is without liner. So, we can see thus this correction factor without liner is 1.0. So, we can write this correction factor for the sampler is 1.0; even this diameter of the borehole is used as 100 millimeter. So, from this chart we can say if it is 60 to 120 millimeter, then this correction factor is also 1.0. So, we will use this value is 1.0.

So, ultimately the corrected N value under the standard energy ratio is 17. However, this measured one in the field is 21. So, after applying the all the corrections and we are expressed, we are expressing this N value under a standard energy ratio that is 70. So, corrected N value will be 17.

Now, it is observed that if this energy ratio is increase increased, then this N value decreases linearly. So, by using this concept, we can use that that any energy ratio 1 and N 1 will be equal to energy ratio two into N 2. So, so this, if we use this expression, then the corrected N value for 60 standard energy ratio value will be 70 divided by 60 into 17. This 70 is this energy ratio value for the standard energy ratio value 70 and we are converting this 7 standard energy ratio value 70 to N value for standard energy ratio value 60. So, this will be 70 by 60 into 17. So, this value is 20. We are expressing this N value in an integer form.

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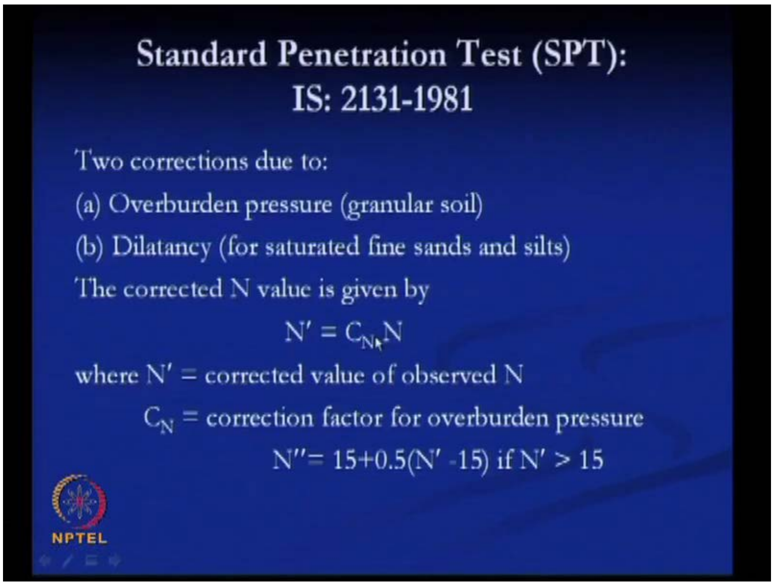

So, we can see that as the energy ratio value decreases then this n value increases or vice versa. So, in this way we can correct any measured N value under any standard energy ratio value. So, in this fashion we can correct it. It can be corrected for any standard energy ratio value. Here, it is corrected for standard ratio value 70 and 60.

Next one is, this is our IS code. It recommends that, where to apply two corrections; that, one is over due to overburden pressure; that is granular soil and another correction that IS code recommends; that is the correction due to dilatancy. That for… it is applicable for saturated fine sand and silt. So, this first, this N is the measured N value in the field and this N dash is the corrected N value after applying the overburden correction. So, C N is the overburden correction factor.

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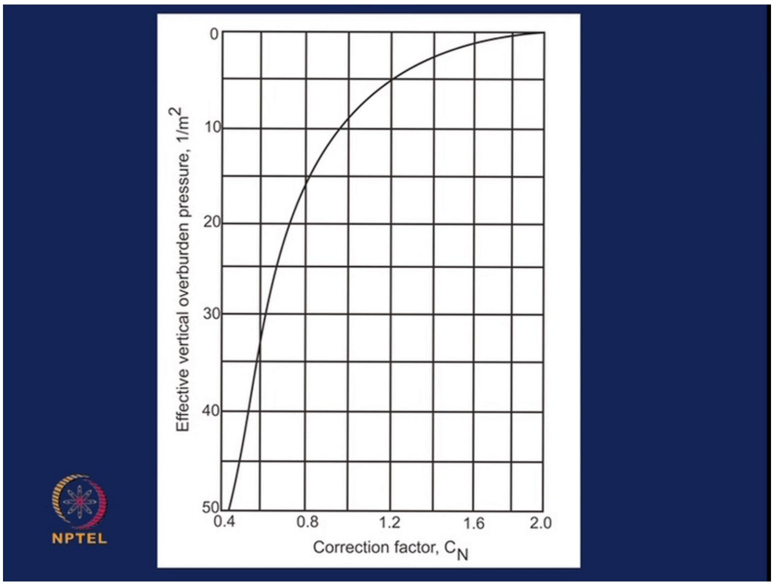

So, we will… by using this chart, this is given in this IS code that we can determine this N value C N value or correction factor due to overburden pressure in any effective overburden, corresponding to any effective overburden pressure. Suppose this effective overburden pressure is 20, then this correction factor due to overburden pressure will be around 0.78 or 0.79.

So, now if we can see thing is, if this effective overburden pressure is 10 tonnes per meter square, then this correction factor due to effective overburden pressure is 1.0. So, we can say this 10 tonnes per meter square effective overburden pressure value is the standard value; where this correction factor is 1.0. If this effective overburden pressure value increases from 10 to say 20 or 30, then this you get correction factor that will decrease. And, if this value increases, then this correction factor will increase.

So, that means we can say that this because of this overburden effect, this this the after the correction in the shallow depth, if this effective overburden pressure is less than 10 tonnes per meter square over the corrected N value, value will increase as compared to the measured one. And, as the corrected N value, if it is in… this value is greater than 10 tonnes per meter square that will increase decrease compared to the measured value.

So, in the shallow depth, this corrected value that will increase as compared to the measured value. And in the larger depth, this corrected N value that will decrease compared to the measured N value in the field. So, this is happening because of the effect of effective particle overburden pressure.

Now, the next correction is that the dilatancy correction. Now, once we gave the corrected N value after applying the effective overburden pressure correction, then that N value will use for the dilatancy correction. Now if this N dash value is greater than 15, then we will apply this dilatancy correction; if this N value is less than 15, then we will not apply this dilatancy correction. And, we can apply this dilatancy correction by using this expression.

Now, this dilatancy correction is applying because that if the N value is greater than 15, then soil is basically in dense condition. Now if the soil is saturated fine sand, all the silt in the dense condition, then if we apply this hammer load or to drive the split-spoon sampler, then this negative due to this dilatancy effect, this negative pore water pressure that will induce. And because of this negative pore water pressure, now our effective stress is the total stress minus this pore water pressure.

Now, if this pore water pressure is negative, then our total effective stress will be total stress plus pore water pressure. So, because of this dilatancy effect and the… as this negative pore water pressure is generated, so this effective overburden pressure that will increase. So, we will get a higher value of N. So, because of this reason, we have to apply this dilatancy correction to decrease or to reduce this value, N value. Although there is no such this recommendation is in this IS code; in all other code, this recommendation, this value, this correction is not generally applied. But in the IS code this, it recommends that we have to apply this dilatancy corrections also. Now this, in this standard penetration test, we are basically getting the standard penetration number N value.

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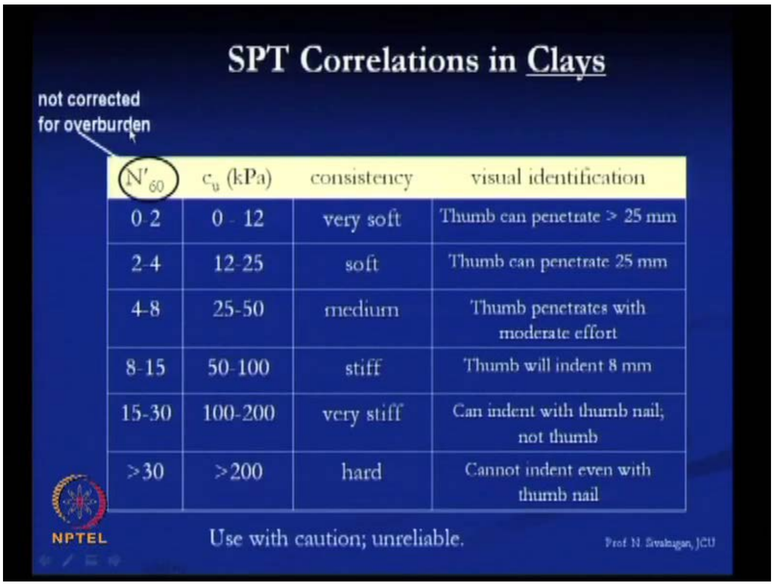

Now, by using this N value we have, based on different correlations or charts, we can determine the soil properties or that is a granular type of soil or in case of clayey soil also. Now if this N value, if it is in 60 standard energy ratio value, it is not, this overburden pressure is not applied; only these other correction due to hammer efficiency and this borehole, diameter, rod length, sampler type. So, all the corrections are applied. We are not applying any overburden corrections. So, in this value if it is 0 to 2, then this undrained correlation value is 0 to 12 kilo Pascal and this soil, we can say it is a soft soil.

So, how we will identify visual identification or how we will identify the soil? The thumb can penetrate greater than 25 millimeter. Now if this value is 2 to 4, then this c value is 12 to 25 and is the soft soil. So, your thumb can penetrate up to 25 millimeter. Now if it is 4 to 8, then this soil is medium soil and if it is 8 to 15, then soil is stiff; if it is 15 to 30, then soil is very stiff. If this N value is greater than 30, then c value is greater than 200, then soil is hard. So, and these are the condition by which we can identify this soil. Now, these correlations or these value have to use with very caution because this is not sometimes to show we have to do other perform, other tests also to verify this correlations or this values.

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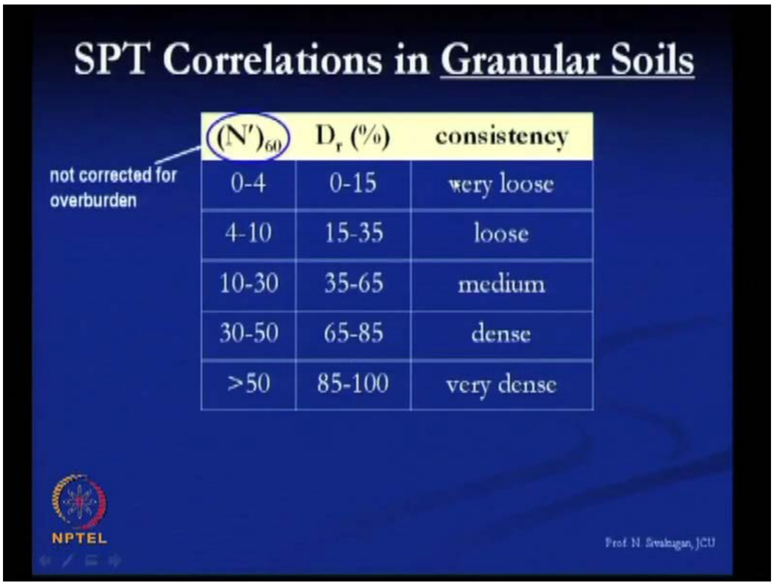

Similarly, the granular soil also. If this N value is 0 to 4, then this soil is very loose soil. And, relative density or D r is 0 to 15 percent. Now if this N value is 4 to 10, then it is a loose soil relative density 15 to 35 percent. If this N value is 10 to 30, then relative density is 35 to 65 percent and it is the medium dense. If it is 30 to 50 it is very… It is dense soil. And, if this value is greater than 50, the relative density is 85 to 100, then it is a very dense soil. So, you can also use this table to based on the N value, we can identify or you can find the relative density of the soil. And, now we can identify which type of soil it is.

Now, there are so many charts or correlations are available by which if we know this N value, either it is a field N value or corrected N value. Then by using those charts or correlation we can determine the soil properties, undrained correlation or the friction angle or any other properties of the soil.

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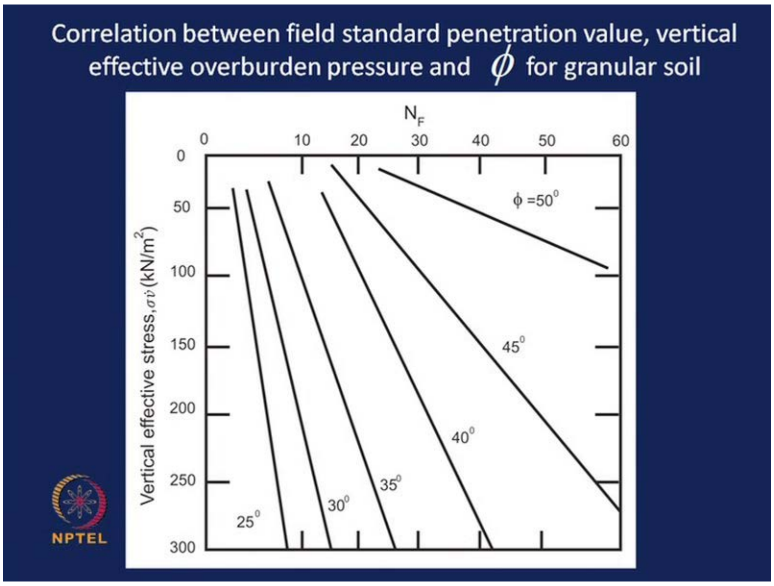

Now, here I am just explaining one chart. That this chart, by using this chart, how we can determine the phi value of the soil. So, this N f is the field value without any correction. And, if we know this N f value and if we know the any at any depth, what is the effective overburden pressure in kilo Pascal? Then by using a… suppose this N f value is 30 and effective overburden pressure is 150, so this phi value will be in between 40 degree to 45 degree. So, by interpolating also we can determine what will be the phi value. So, from here, this phi value is coming around 40 to, 40 to 43 degree. So, in this way we can, if we know the N value an effective overburden pressure, we can determine the friction angle of the granular soil; so by using this chart. So, there are other charts also and other correlations are also available.

Now, next penetration test is the cone penetration test. Now, this cone penetration test is two types. One is Dynamic Cone Penetration Test; that is DCPT or Static Cone Penetration Test; that is SCPT. Now this dynamic cone penetration test; it is similar to SPT test that is hammer driven. But this static cone penetration test, it is not hammer driven. It is it is pushed into the soil in the ground at a rate of 2 centimeter per second. That means one cone is penetrated into the soil at a rate of 2 centimeter per second, where here this cone is hammer driven.

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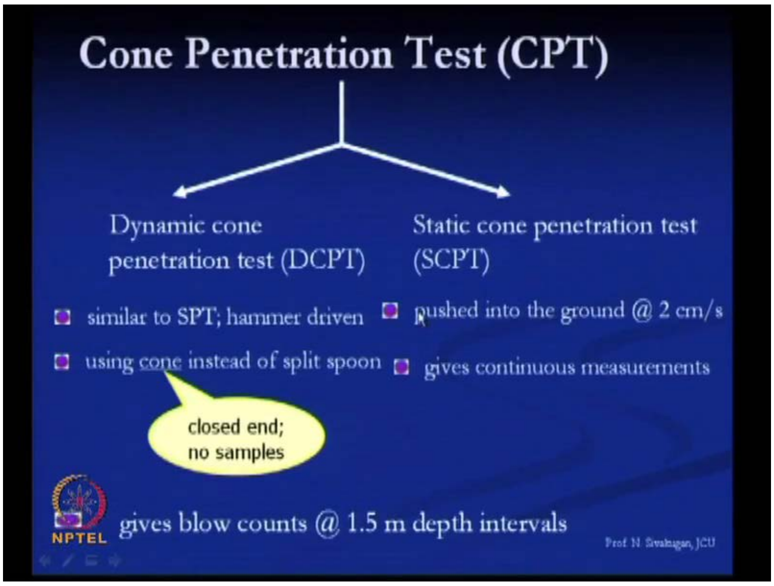

Now, using cone instead of split-spoon…, in the difference of SPT and this dynamic cone penetration test is that, in SPT we have driven split-spoon sampler. Here instead of split spoon, we are using cone and we are driving the cone into the soil. And, another difference is that in this SPT, here as we are using this split-spoon sampler, so we can collect the soil sample from the desired depth. But using the dynamic cone penetration test, this is the closed end; this cone. So, it cannot collect soil sample from this test. So, it is the basic difference that, all that these, both are hammer driven. But here in the SPT, we can collect the soil sample from the, in a desired depth. And by this dynamic cone penetration test, we cannot collect the soil sample. And here SPT, SCPT, it gives the continuous measurement of the soil resistance. So, now this give gives blow count at the rate of 1.5 meter intervals.

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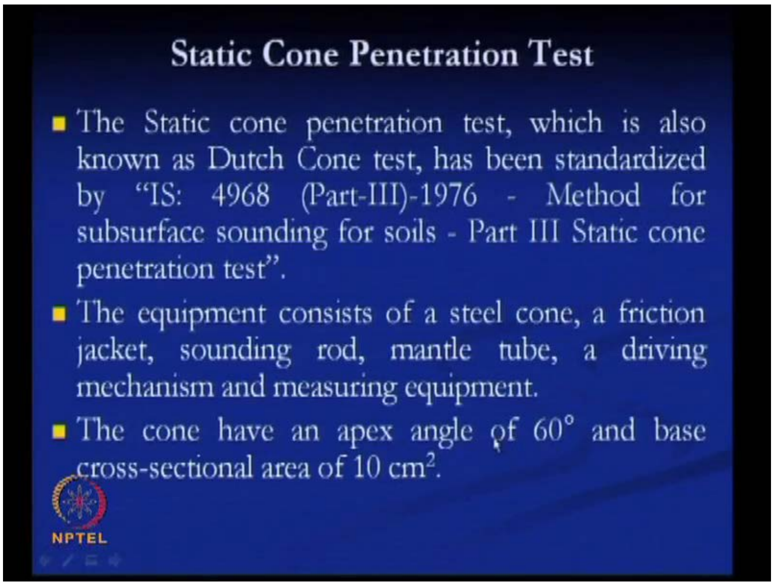

Now, first we will go for this static cone penetration test or SCPT. Now, static cone penetration test; this IS code is 4968 part III; 1976.

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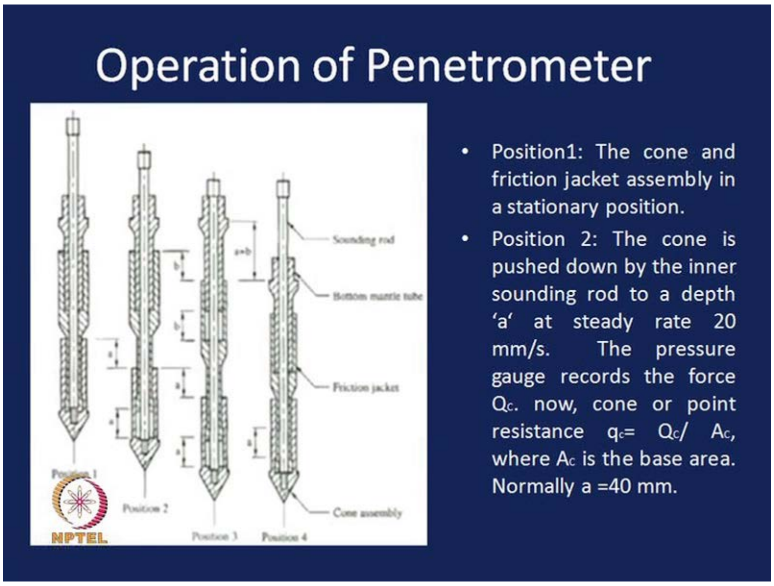

Where, this penetration tests this instrument. It has several components. So, this is the instrument. So, one component is cone assembly. This is, this portion is called cone assembly. Then this portion is called friction jacket, then this portion, this one is called the bottom mantle tube and this is the sounding rod.

So, these are the different components of this equipment. The cone have an apex angle 60 degree; that means this angle, apex angle is 60 degree plus minus 15 meter 15 minutes. So, this is 60 degree plus minus 15 minutes. And, the cross section area or the base cross section area is 10 centimeter square. So, that means this base cross section, area of this cone is 10 centimeter square.

Now, next is how we will use this instrument and how we will get the soil resistance from, by using this instrument. So, what are the steps? I will operate these things. So, these are the four stages by if, by which we can operate this penetrometer.

So, first position is, this is the first position where the cone and friction jacket assembly. This is the cone assembly and this is the friction jacket assembly. This is in the stationary position.

Now, this is the position two; where this cone assembly is only pushed by the inner sounding rod at a rate of 20 millimeter per second. Now, this pressure gauge records the force Q c. Now, here only cone assembly is pushed into the soil by using this inner sounding rod and the pressure gauge records the force Q c.

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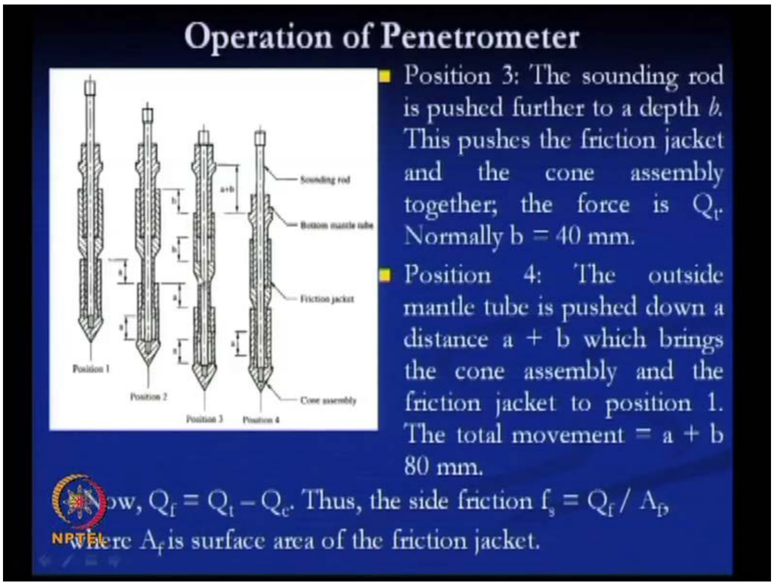

Now, this Q c is the resistance coming only due to this cone assembly or the cone. Now, if we know the base area of this cone, that is A c, then we can determine what is the cone or point resistance by divide by dividing this A c by… Why dividing A c with this Q c?

So, this small q c is the cone or the point resistance that is equal to capital c Q c or the force divided by the base area. Now, this cone assembly in the position two is pushed into the soil normally up to a depth of 40 millimeter.

Now, in the third stage; such position; the sounding rod is pushed further up to a depth of b. Now, here the sounding rod is further pushed into the soil up to a depth of b. That means, up to total a plus b. Now, here it push pushes the friction jacket and cone assembly together. So, here by using the sounding rod, in the first, second stage only cone assembly is pushed into the soil. Here in the third position; cone assembly, after in this condition from second stage, then in the third stage, this cone assembly and friction jacket both are pushed into the soil by using this in a sounding rod up to a depth of 40 millimeter. And, this is the total force that is measured. This is the force, which is coming due to this cone assembly and this friction assembly.

So, that means here we are getting the cone resistance or the tip resistance and the frictional resistance. So, from the second position we are getting only the cone or tip resistance. But, that is the, that force is Q c. And if, and in third position, as this total system, that is cone resistance and there is friction assembly and the cone assembly both are pushed into the soil. So, we were getting the total force that is coming due to this cone or tip resistance and the frictional resistance that is q two.

Now, here we know this Q c, capital Q c, here we know the Q t. So, if we want to find the frictional resistance or the or the force that is coming due to only friction, then we can use this expression. We just subtract this Q c from Q t, we will get the q f; that is the force due to these frictional resistance. Now if we know thus this surface area of the friction jacket, then we can determine the side friction is f s. So, this is similar like a pile foundation, where we are getting this tip resistance as well as the friction resistance.

Whereas in the fourth position, so now this outside mantle tube is pushed up to a depth of a plus b; that is 80 millimeter to bring the cone assembly and the friction jacket and the… to the position one. So, now from the fourth position the fourth position we have to… By using this outside bottom mantle tube, we have to bring this total cone and friction correction assembly in its original position; that is in position one. And in this process, we can determine the cone resistance as well as the friction resistance that is coming from the soil.

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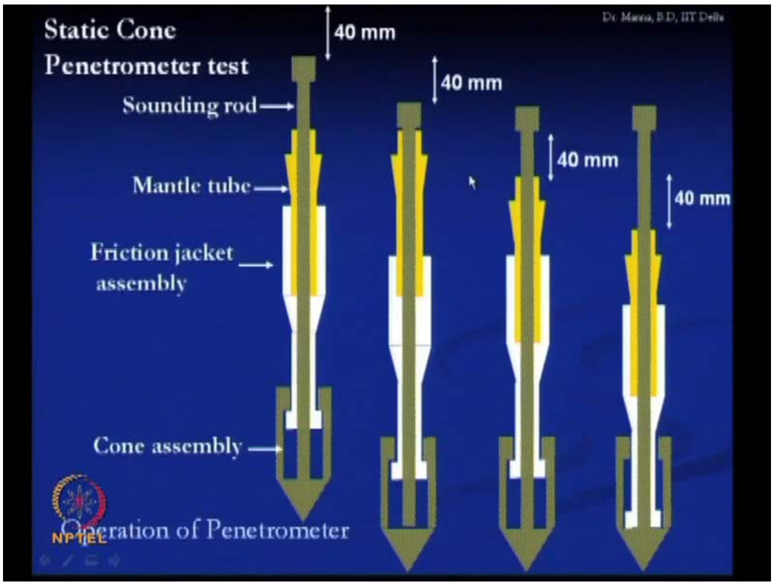

Now, so this is, if we further explain this process; so this is the total system which is in the stationary condition with the first stage. So, this is sounding rod, this yellow one is the mantle tube and this white one is the friction jacket and this portion is the cone assembly. So, in the second stage; this, with the help of sounding rod, only this cone assembly is pushed up to a depth of 40 millimeter. And, we can calculate or we can determine this force coming due to this cone resistance. And, if you know the base area, then we can determine the cone resistance from this stage.

Now, in the second stage… So, this is the similar stages. And in the second stage, by with the help of this sounding rod, now the total system, this cone assembly and the friction assembly, both are pushed further 40 millimeter depth. And here, we will get the total force and here we will get the force from the cone assembly. So, if we subtract this Q c from this Q t, we will get the forces coming due to this friction resistance. And, with the outer; if we know the outer here, we will get the friction resistance in this stage.

Now, in the third stage; here, it is the same stage. In the third stage with the help of this mantle tube, which is further pushed into soil for 40 millimeter; and this is the fourth stage, where this mantle tube is further pushed into the soil with the friction jacket and brings this assembly in the initial condition or the first condition. So, this is the total operation of this static cone penetration test or static cone penetrometer.

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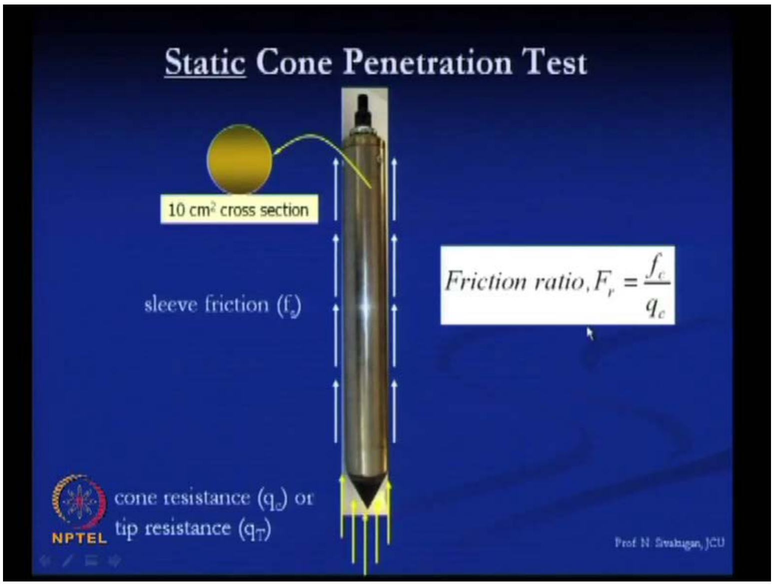

Now, here we can say; so this is the cone, here we will get this cone resistance which is coming from here. And, this portion we are getting the frictional resistance f s and this is q c. And, this is the cross section area or the base is ten centimeter square. Now from here, we can calculate this friction ratio F r which is f c by q c or sorry f s by q c. So, this is the friction resistance divided by the cone resistance.

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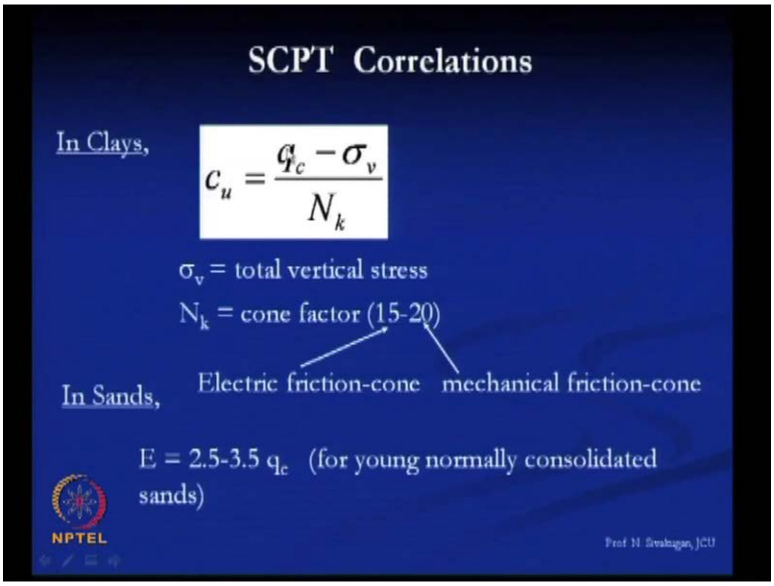

Now hereby if we know the cone resistance, then by using this expression we can determine the undrained correlation of the clay soil by using this expression. Now, here this sigma v is the total vertical stress. And, N k is the cone factor; depending upon the type of cone we are using. So, if it is the electric friction cone, then these cones are basically two types. One is electric friction cone; another is mechanical friction cone. If we use the electric friction cone, then this N k value is 15. Now if we use mechanical friction cone, then this N k value is 20. So, if we know the total vertical stress and depending upon the type of cone we are using, we can we can use the N k value. So, and if we know the q c from the field measurement, then we will get the undrained correlation of the clayey soil.

Similarly in the sand soil, we can find the E value; elastic modulus of the soil for normally consolidated sand. That by using this expression 2.5 to 3.5 q c; where q c is the cone resistance.

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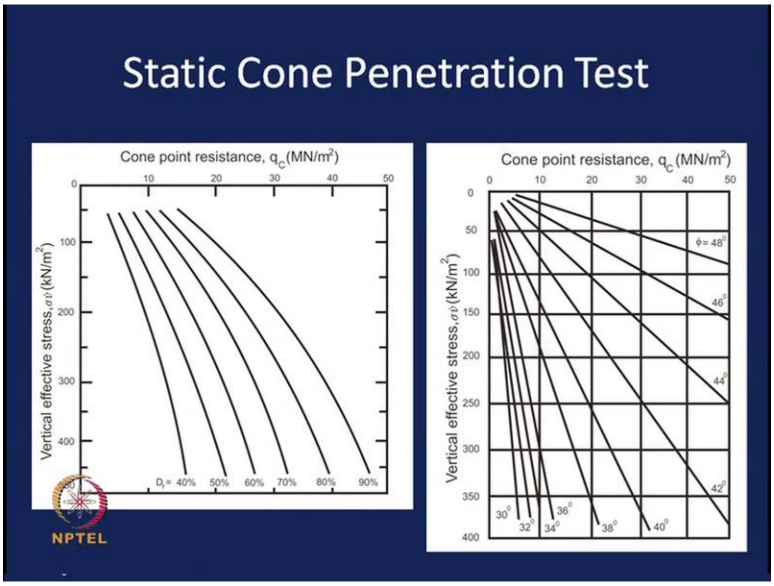

Now again, this is similar to this SPT value also here. If by, from this SCPT test also, there are various charts are available. Well, if we know this cone resistance or cone point resistance q c, then by using these charts we can determine what is the relative density of the soil, and which is the friction angle of the soil. So, this is so normally consolidated what is type of sand. So, for the granular soil we can determine the friction angle by using these charts.

So, here if we know the vertical effective stresses, then cone point resistance q c, then for using this particular chart, suppose this vertical stress is 200 and cone resistance is say 30 mega newton per meter square; so this will be, this value will be between 80 to 90 percentage. So, relative density would be 80 to 90 percentage or around 85 percentage.

Similarly, if the cone resistance value is 30 and this is 200, so you will get the corresponding phi value is within between 44 degree and 41 degree. So, it is around 43 degree. So by this, using this chart, if we know this cone resistance, then we can determine the phi value and the relative density of the granular type of soil.

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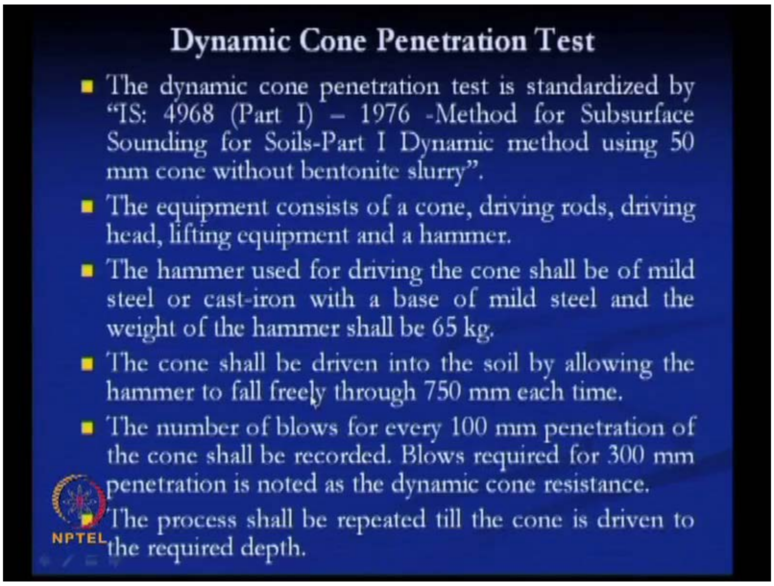

The next one is dynamic cone penetration test. This IS code is standardized by this IS code 4968 part I 1976. Now, this equipment consists of a cone, driving rods, driving head, lifting equipments and a hammer because here it is a hammer driven like SPT. So, hammer used for driving the cone shall be of mild steel or cast iron with a base of mild steel and the weight of the hammer is 65 k g. Now, cone is driven by a hammer of free fall is 750 millimeter each time.

Now, this number of blows for every 100 millimeter penetration of the cone is recorded. Now, blows required for 300 millimeter penetration is noted as the dynamic cone resistance. Here also this 100 millimeter penetration, each 100 millimeter penetration, this blows, required blow is recorded. And blows required for 300 millimeter penetration is noted as the dynamic cone resistance. Now, this process shall be repeated till the cone is driven up to the required depth.

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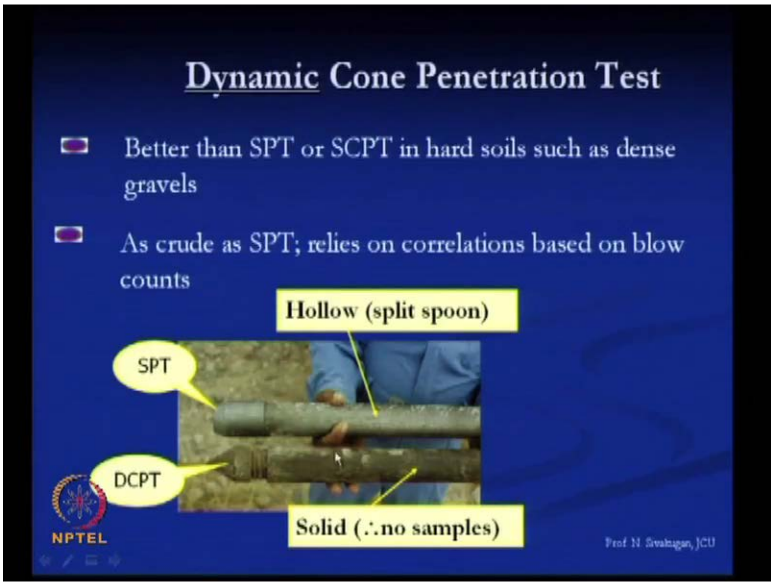

So, again this dynamic cone penetration test is better than the, this is better than SPT or static cone penetration test if the soil is very hard such as the dense gravel. When as crude as SPT because we have to rely on the, were to rely on this correlations based on the blow count. So, again this is the split-spoon sampler which we used in case of SPT and this is the cone which is the cone assembly, which is this, which is used for the dynamic cone penetration test. So, here we can say this is the split-spoon sampler; this is hollow. We can collect the soil sample by through this tube, but here it is solid. So, no sample is collected.

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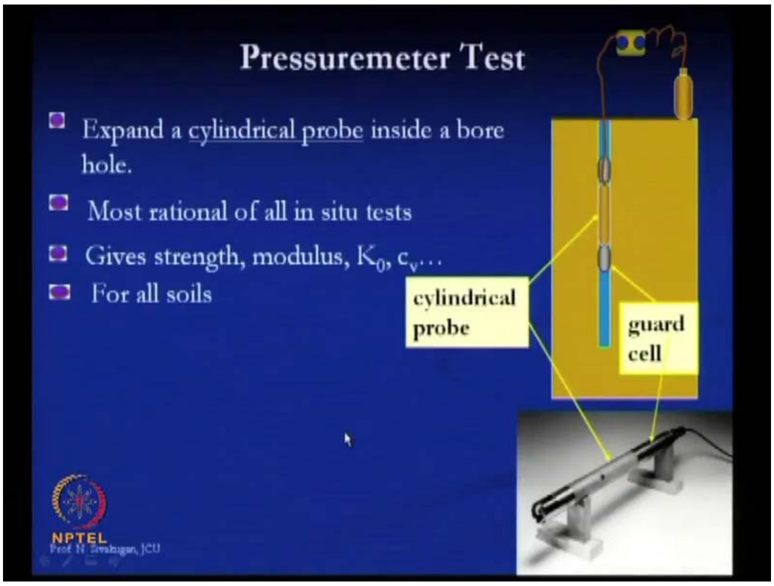

So this, after these two types of penetration test, now I will explain another field test by measuring the property of the soil; that is pressuremeter test. Now, this pressuremeter test, these are the different components of this pressure meter. This is the pressure meter. So, this is the cylindrical probe. So, which expand inside the bore hole. So, inside a borehole you have to insert this instrument. And then these two things; these are the guard cell and the middle one is the cylindrical probe or the measuring cell. So, this measuring cell is expandable.

So... so this expands inside the borehole. And, by using this expansion we can determine the properties of the soil. Now, this is most rational in all in-situ tests. This gives strength modulus, K 0, c v, 0 c v values. And, we can use this for all type of soils.

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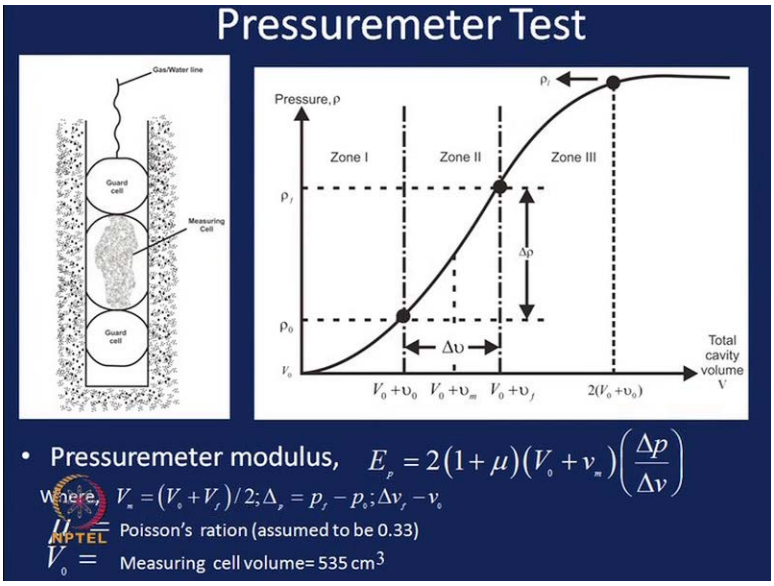

Now, sub soil; how will we expand? So, here this is the borehole and here this is the measuring cell and this is the guard cell. So, this is the expandable measuring cell and this… when this measuring cell is expanded, this guard cell is also expanding to reduce the end effect of the measuring cell.

So, now after this measurement; so initially we will measure the measuring cell volume; this is 535 centimeter cube. So, this is the initial volume or the measuring cell volume; capital V 0. Then we insert this measuring cell with guard cell into the borehole and then we allow this measuring cell to expand.

Now, this process goes until the soil fells or this volume expansion reaches the limit of this measuring cell expense. So, now it is assumed that if the expansion; so this and then we have to draw a curve by this applying pressure. So, corresponding pressure when we… this volume is expand, this volume during the volume expansion, we are also measuring this pressure. So this, we have to draw the pressure versus volume graph. So, this is total cavity volume and this is the pressure p. So, this is the initial volume of the measuring cell.

Then, there is c three stages; this is zone one, zone two and zone three. Now, this zone one is called as reloading zone. So, this zone one is called as reloading zone because due to drilling, this soil volume in this hole that will… In this, that is not in this in-situ condition. This volume will change. So, when in this zone, after when it reaches p zero condition; that means, this from capital V zero to V zero plus small v zero portion, here it is reached in this initial condition and this pressure p zero is the initiative soil pressure. So, this is reloading zone.

Then this portion, it is pseudo elastic zone. So, here we can see this volume expansion and the pressure. This curve is linear. So, this is pseudo elastic zone. And this third zone, it is called plastic zone. So, here we can see from this first zone to second zone, this del p is the pressure increment and del v is the volume increment.

So, here v f is the final volume and p f is the clip stress or the heel stress and p l is the fluid pressure. So, p f is the clip pressure or the heel pressure and p l is the limiting pressure. Now, here it is assumed that the soil is filled, when the total expansion of this measuring cell is two times the in-situ expansion. Therefore, if it is two times the capital V 0 plus v 0, under this condition we can say that soil fails. So, that pressure, corresponding to this pressure is called the limiting pressure.

Now by using these values, we can determine the pressure meter modulus E p by using this expression. Now, where this v m, we can find this is the mean value of V zero plus v m. And, del p is the pressure dependence between the heel pressure and the in-situ pressure. And, del v is the volume difference between the v f and V 0. Now, mu is the Poisson ratio. Now, it is assumed to be 0.33. So, this is Poisson ratio; it is assumed to be 0.33.

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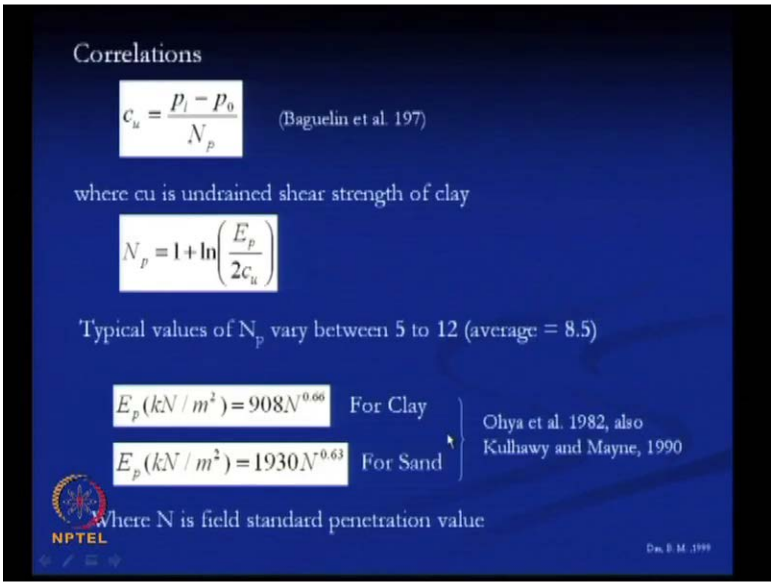

So now, once we calculate this E p, now by using these correlations we can determine the soil properties also. So, for the clay soil undrained correlation where we can determine by using this expression; that is P l minus P zero by N p, where P l is the limit pressure and P 0 is the in-situ pressure. And N p, we can calculate by using this expression. So, here also this is the undrained correlation.

Now N p value is taken between 5 to 12, and the average value is 8.5. So, now in this, using this expression we can determine the undrained correlation of the clay. Now by using the different correlations, this is the N value. This N is the field standard penetration value. So, this is the correlation between the field N value and the E p value. So, if for clay, this is 908 into N 0.66 and for the sand this E p value is 1930 into N 0.66 for the sand. So, these are the two types of expressions were generally used.

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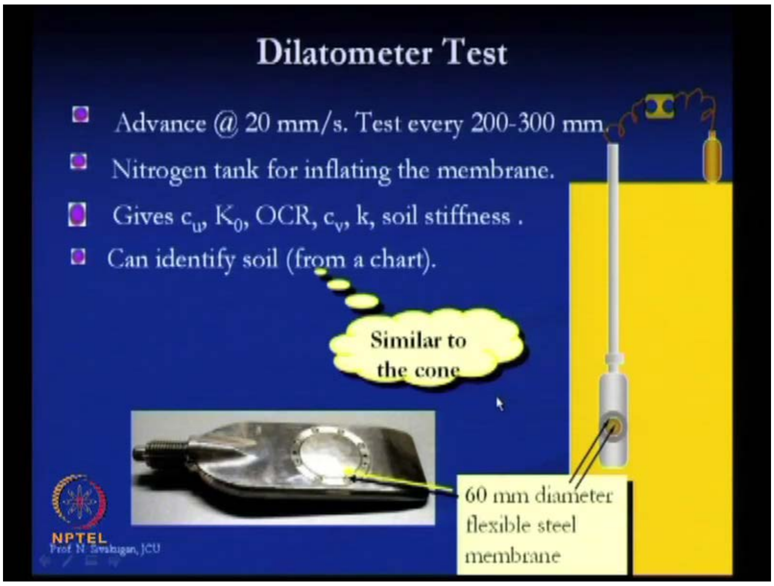

So, next test is the dilatometer test; which is a similar type of test, where this advance at a rate of 20 millimeter per second and test every 200 to 300 millimeter. So, a nitrogen tank is used to inflating the membrane. So, this is the membrane; 60 millimeter diameter flexible steel membrane. So, we can use the nitrogen tank for inflating this membrane. And, we can measure corresponding resistance. And by using the chart like the cone penetration test, we can identify different types of soil. And, here it will give the undrained correlation K 0, over consolidation ratio c v, k and soil stiffness.

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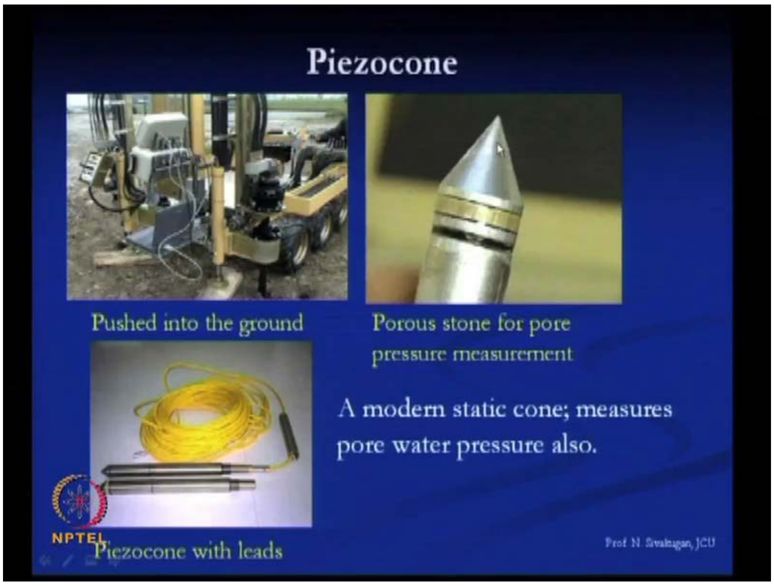

So, piezocone is the another type of… This is the modern static cone penetrometer, which… So, in the normal SCPT test we can measure the cone resistance and the friction resistance; where this, with this the piezocone, this is the modern static cone where we can measure the pore water pressure also. This is the different component. So, this is the porous stone for pore water pressure measurements. So, this is the cone where we can measure the cone resistance, friction resistance as well as the pore water pressure.

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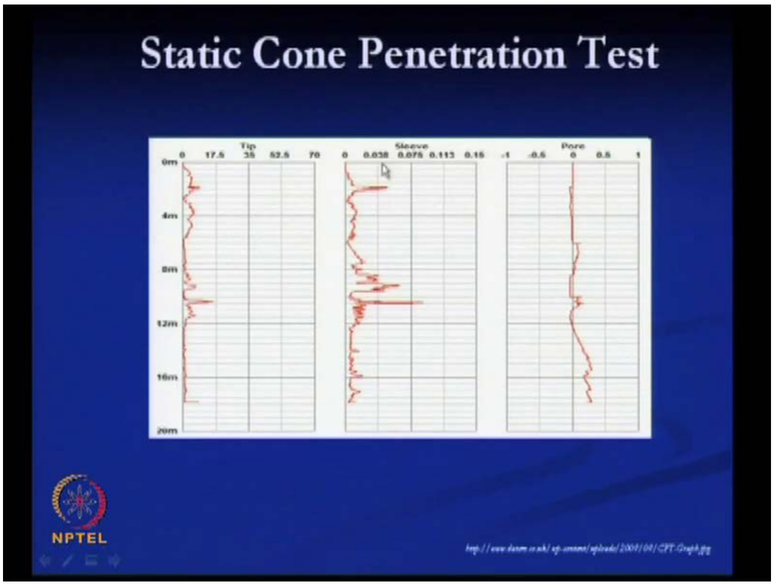

So, once we get this static cone penetration test, so these are the different readings. This is the tip resistance, this is the friction resistance or the slave resistance and this is the pore water pressure. So, these are the different graphs.

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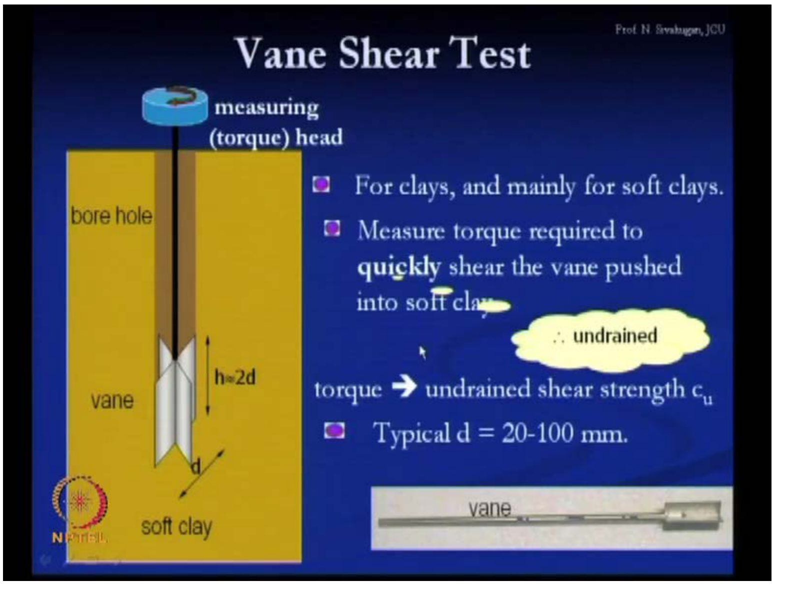

Now, another test… which is also important in in case of clay or very mainly for soft clay to determine the in-situ properties of the soil; that is the vane shear test. Here in the borehole, where this vane is inserted and we can apply a torque as a desired depth. And, this measured torque required to quickly shear the vane pushed into the soft soil. It is quickly so that, we can simulate the undrained condition into the soil.

So, by applying this torque and the corresponding resistance; by using the corresponding resistance, so if we can measure the torque, the torque that we are applying. So, by using these things we can determine the undrained shear strength of the soil. Now, typical d value is using for 200 to 100 millimeter. So, this is thus n set inserting the soil. Then we apply the torque and from that torque we can measure the undrained shear strength of the soil, which is suitable for mainly very soft clay.

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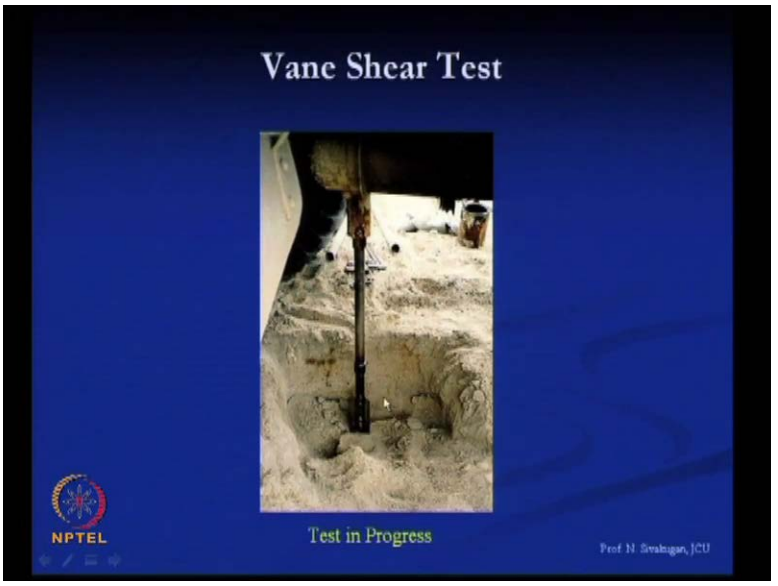

So, this is the vane shear test which is in progress; apply the torque in the soil.

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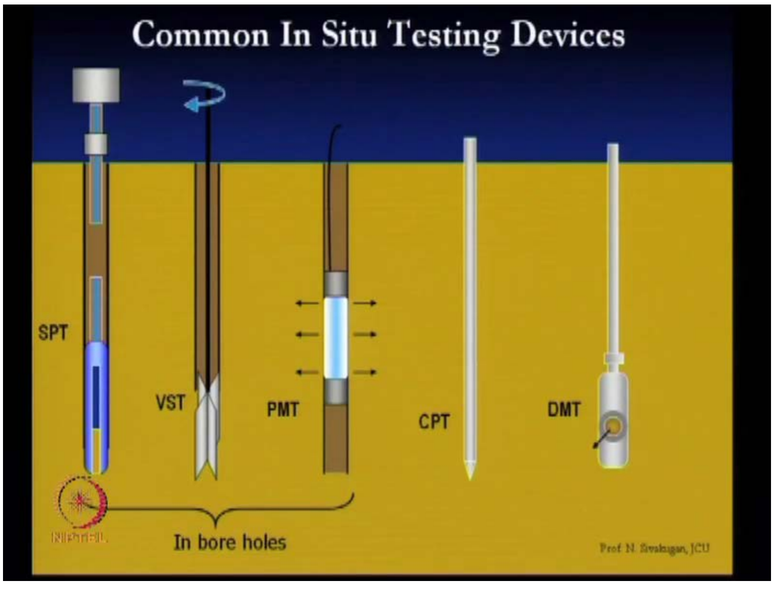

So, these are different types of soil. So, these are the soil, this is the SPT test where borehole is required. So, first we drilling the borehole, then we apply the SPT test. Then this vane shear test, we apply the torque in the borehole as desired depth. Then in the pressuremeter test also this borehole is required. And this is the CPT test, where we pushed this into the soil and this is the, this test also, DMT also will push in the soil in the soil and then we expand this membrane. So, these are the different types of soil.

So, in the next class I will discuss about the soil exploration by geophysical exploration. So, in next class I will discuss this geophysical exploration and that will be the last topic for this soil exploration part, and how we will use the geophysical exploration to determine the soil thickness and the properties; that I will explain in the next class.

Thank you.