Foundation Engineering
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Lecture - 05
Standard Penetration Test

So, in lecture 5, I will discuss about the penetration test or Standard Penetration Test. In the previous lecture I have discussed about the direct method or the test speed or the trench speed or the semi direct method where we are collecting the soil sample by boring.

So, there are different methods by which we can collect the soil samples, and here this is the indirect method. So, that is the standard penetration test. So, this test is very important because we are using this test frequently to determine the soil properties. So, why it is called the indirect method, because in the first method is it direct method because we are collecting the soil sample directly from the soil.

But it is the indirect method here, we are not determining the soil properties in terms of that our strength properties or any other properties. Actually we are something measuring something else, and then we are correlating that that measure value with our required soil properties that is cohesion or friction.

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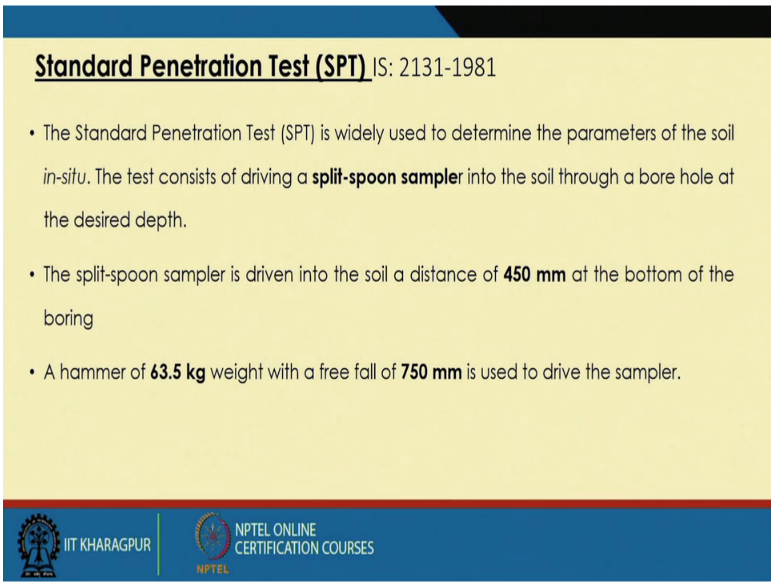

So, what is the standard penetration test. So, as I mentioned it is an indirect method. So, the standard penetration test is widely used to determine the parameters of the soil or in situ soil, the test consists of a split-spoon sampler into the soil through a borehole, at the desired depth.

So, and the and the split spoon sampler is driven into the soil, at the distance of 450 millimeter at the bottom of the boring. A hammer of 30 63.5 kg weight with a freefall height of 750 millimeter is used to drive the sampler. So, that is why these things are standard, you know height of fall is standard at 750 millimeter and the hammer is also standard 63.5 kg.

So, I am describing this method is as per the is 2131 1981. So, basically what we are doing here, we are driving a split spoon sampler into the soil up to 450 millimeter in 3 stages, 150 millimeter 150 millimeter and 150 millimeter and with a hammer blow up wait 63.5 kg and with the free fall of 750 millimeter.

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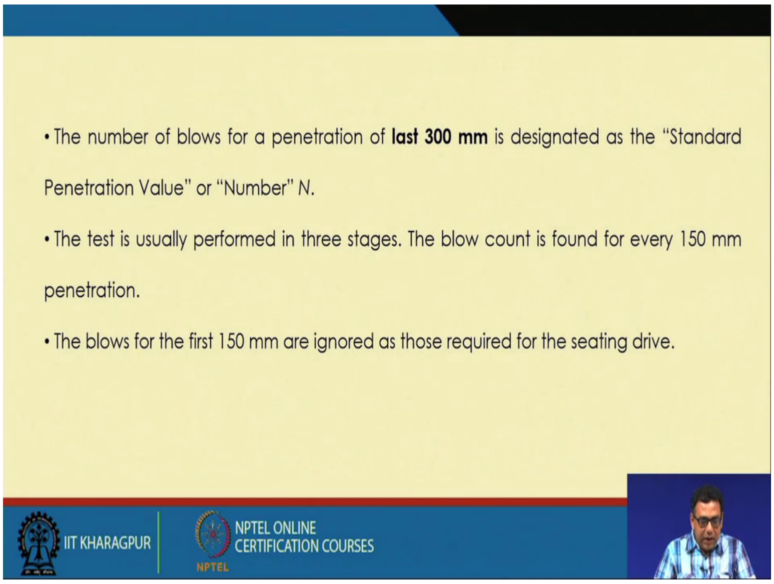

So, the number of blows for a penetration for last 300 millimeter is designated as the standard penetration value or the number N.

So, basically we are measuring here the N value, we are not measuring the cohesions or the friction, we are measuring the N value, and then we will correlate this N with the question and the fiction or any other properties of the soil. So, that is why it is a indirect method. So, as I mentioned we are applying we first we are applying a hammer blow on a split spoon sampler and allow the sampler to penetrate up to 450 millimeter in 3 stage equally 150 millimeter. But we are not collecting we are not counting the or considering the first 150 millimeter penetration, because that is considered as a sitting load.

So, basically if I place this hammer in this split spoon sampler for a particular on a particular day into the soil, and if I apply blows and allow this sampler, to penetrate for 150 millimeter. So, it will require some number of blows; So, with a standard weight of hammer and with a standard freefall.

So, we will count those blows for first 150 millimeter, then second 150 millimeter and third 150 millimeter. But we will not consider the first 150 millimeter N value or counted blows, but we will add the second and third 150 millimeter penetration blows those are required and then we add those things; that means, if we say the number of blows required for first 150 millimeter penetration is N 1, and the number of blows required for second penetration for 150 millimeter is N 2 and third one is N 3. So, the N value will be N 2 plus N 3.

So, the this is as I mentioned this is perform in three stage, and the blow count is found every 150 millimeter penetration.

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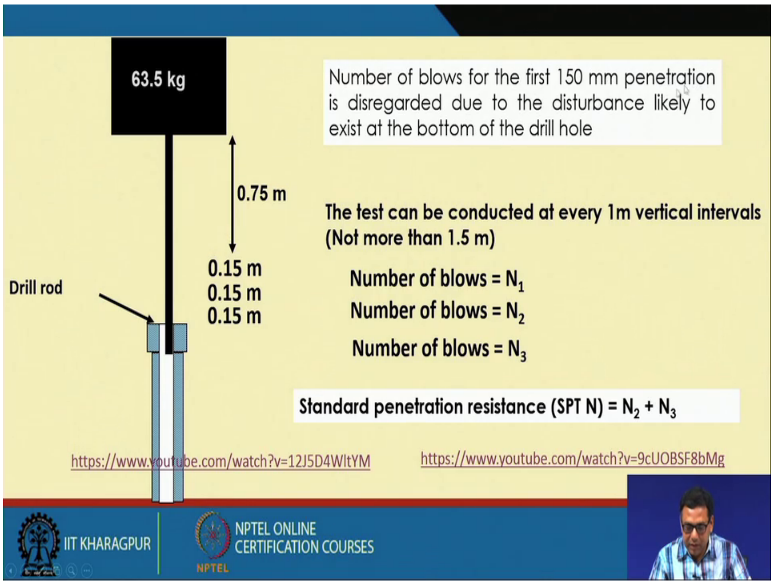

So, the blows for first 150 millimeter are ignored as these required for the sitting drive. So, this is the one animation that we have the freefall is 75, 750 millimeter or 75 centimeter, and this is the hammer 63.5 kg, and this is the if this is the sampler tube that we are applying blows. So, we are allowing this split spoon sampler to penetrate for 150 millimeter 150 millimeter 150 millimeter. So, that is the number of blows for first 150 millimeter is N 1, second 150 millimeter is N 2 and third one is N 3. So, the standard penetration resistance or SPT N is N 2 plus N 3.

And the number of blows the first 150 minute penetration as I mentioned that this is not considered for as it will act as a sitting load. So, the test can be conducted for every one meter vertical interval not more than 1.5 meter. So, I have couple of YouTube videos by which you can see that this is the drill rod. So, the in the bottom of this drill rod this sampler tube is attached. So, this is the sampler tube. So, it has it has the two hubs. So, this is the soil sample they are collecting. So, this is the drill rod.

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So, as I mentioned. So, you can you can increase the depth of these or the height of the drill rod by adding one after another. So, we can go up to the required depth.

So, this is the tripod kind of thing which is used for the penetration purpose. So, this is the drill rod. So, once so, this is this is the sampler tube, that is attached with the drill rod and then this is the sampler tube. So, these sampler tube will be attached with the drill rod. So, first you have to go first we have to go for the borings once the boring is done.

So, we attach the sampler tube with the drill rod, then we will apply the hammer go. Here this is the three marking are done, this is 150 millimeter this is three marking first, second and third. So, these three markings means each markings is 150 millimeter. So, because we have two count the blows required for each 150 millimeter penetration, then this is the hammer blow which is applied.

So, and at the same time for the this number of blows is counted for every and every 150 millimeter penetration, because on this rod drill rod the three markings are given. So, these three marks basically indicates for 150 millimeter each. So, and then once this is this total 450 millimeter is driven into the soil, then this drill rod or the sampler tube is again a remove or taken out from the borehole and then we collect the soil sample.

So, now it is the hammer blow is completed, now we are collecting this drill lord or the sampler tube will be taken out from the soil or from the borehole. So, for this test one borehole is required and the one particular depth or the required depth, hence the boron is constructed we place the sample tube and attach this sampler tube with a drill rod and over the deal rod.

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We apply the hammer blow, and then we count the number of blows required for each 150 millimeter penetration and this is the sampler tube. So, it is collected now.

So, later on I will discuss about the detail about this sample a tubes, and because now once this is collected; So, now, it is removed. So, there is a cutting edge or that is removed and then, the soil sample will be collected. So, this is the it has two hubs. So, by opening these two hubs you can collect a soil sample. So, this is the this it has a cutting edge. So, that edge is first removed and then this sample is collected because it is the two hub, this is the sample. So, these sample is collected from the required depth.

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So, the advantage is that in this test, we are collecting the soil sample as well as we are measuring the N value or the SPT value. So, this soil sample which we are collective, we can use it to determine the soil properties to the laboratory test as well as we can we have the N value, that N value we can use to determine the soil properties also.

So, we have another YouTube video by which also you can. So, this is another type of arrangement where this is the hammer and this is the free fall.

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So, hammer weight is 63.5 kg, free fall is 75 millimeter, here this is the drill rod and where these hammer blow is applied and in the bottom of this drill rod, this sample of tube is attached. So, this is the another way we can conduct these SPT test.

So, once it is done, now this drill rod with the sampler tube will be taken out from the soil, this is the drill rod and the sampler tube this is the sampler tube which is taken out from the soil and once it is taken out, then again the sample will be collected. So, this is the sampler tube and first the cutting edge is removed and this is the two hubs and this is the soil sample, which is collected from the ground at a required depth.

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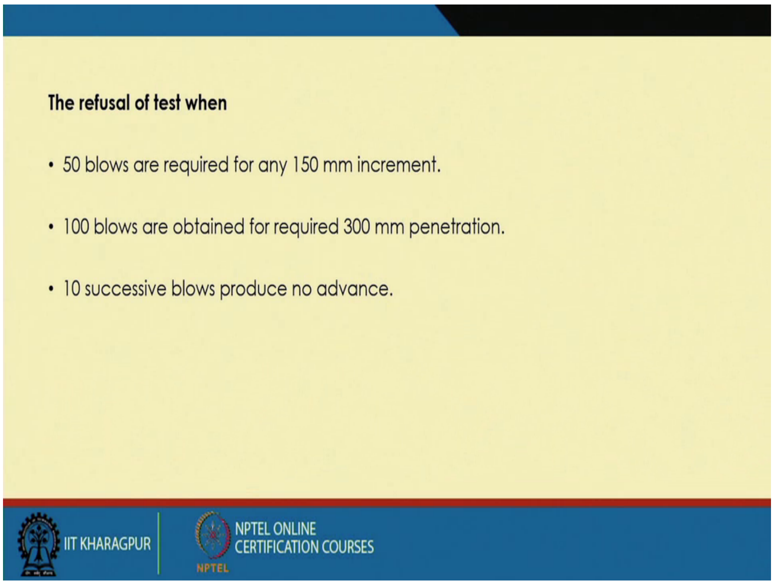

So, next one is that that when the refusal of test. So, now, if the fifty blows are required for any 150 millimeter increment or 100 blows are obtained for required 300 millimeter penetration or 10 successive blows produced no advance, if any of them occurs then we will stop this test because you cannot proceed further with this test.

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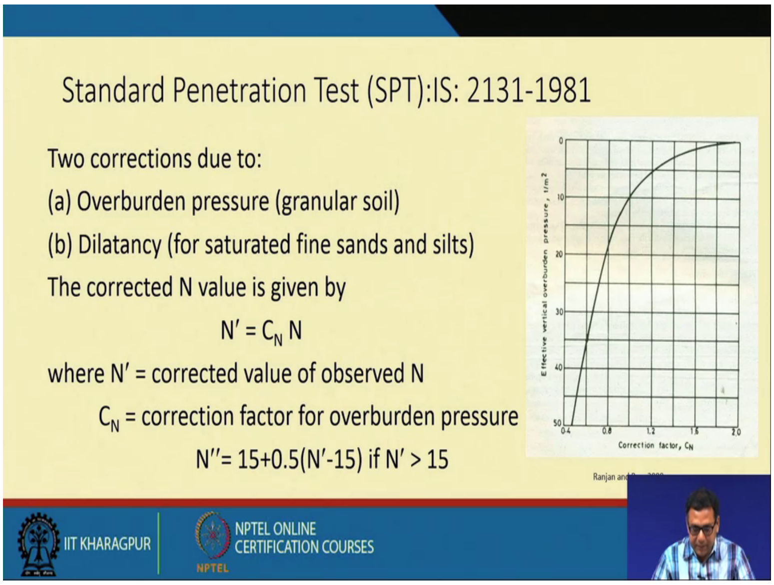

So, these are the condition to stop the test and then once we get the N value that is the measured N value. Now we have to apply some corrections over this measured N value. So, once we gave the measure N value. So, that was the one is measured N value, another is the corrected N value and most of the correlations are based on the corrected in value sometimes the correlations are given with measure N values also.

So, but the as per the is code there are two corrections, we have to apply. So, one correction is the overburden pressure due to the it is applicable for the granular soil only and the next correction is the dilatancy correction, which is applicable for saturated fine sands and silts. So, in one way if the soil is clay, then we do not need to apply any corrections. But remember that this SPT is mainly suitable for sandys granular soil, but we can use it for the clay soil also. So, but people are also sometimes use it for the clay soil, but any this I mean SPT is suitable for the sandy soil or the granular type of soil.

So, now the corrected N value, that we are getting. So, one correction is required for the overburden pressure, and because in the soil which is in upper portion the overburden pressure is less, but the soil where it is in very higher depth or the great depth, where the overburden pressure is very high.

So, that is why we have to apply a correction factor. And so, you can see after applying this correction factor. So, the measured N value and the shallow depth will increase. So, that the corrected N value at the shallow depth is greater than the measure N value and if it is the higher depth then the corrected N value is the less than the measured N value.

So, you can see that the corrected N value for the overburden pressure up overburden pressure correction N dash is C N which is correction factor N to the N, N is the measured N value. So, this is the C N value we will get from this curve. So, this curve is this the collection factor C N, and this is the effective or N pressure tone per meter square.

So, you can see this him this if the effective overburden pressure is 10 ton per meter square. So, your correction factor is 1. So, exactly one so; that means, if it is 10 ton meters 10 ton per meter square. So, the corrected N value and the measured N value both are same, but if your stress is less than 10 ton per meter square; that means, for the shallow depth.

So, this is the effective overburden pressure as I mentioned the how I will calculate the effective overburden pressure, because you know that when we are calculating the effective overburden pressure. So, that is why that overburden pressure means, the unit weight of the soil into the depth of the soil at which at the point, where you are calculating that pressure so; that means, the depth of the soil and the unit weight of the soil. So, later on I will solve one example where I will discuss that how I will calculate the effective overburden pressure so, depending upon the position, of the water table. So, effective overburden pressure will change.

So that means, the effective overburden pressure means the unit weight of the soil into the depth of the soil; So, now, if the stress effective overburden pressure decreases. So, it means the if I say that the unit weight of the soil is constant, then definitely the depth decreases, that is why the effective overburden pressure decreases. So, at the shallow depth, you can see the correction factor is greater than 1. So, the correction factor is greater than 1, because here your effective overburden stress value is very low.

But at the higher depth, your the correction factor is less than 1. So, this is the zone where the correction factor is less than 1, which is applicable for the higher depth. So, and here this is for the lower depth. So, that is why we apply the corrected correction factor C N and once we correct this N value with the help of with the due to the overburden pressure, now if our N dash. So, this N dash is the corrected N value after applying the overburden pressure correction, if greater than 15, then we will go for the second correction. So, if the N dash is not greater than 15 then we will not go for the second correction.

So, what is the second correction. So, the second corrected after second correction, the corrected values N double dash is 15 plus 0.5 within bracket N dash minus 15. So, dash is not the measured value, it is the corrected values after applying overburden pressure. So, then we can see that finally, we will get the N double dash.

So, now, if you look at this expression; So, suppose if I or N dash value is 25. So, if it is 25. So, what will happen? 25 minus 15 is equal to 10 by half. So, it is 5; So, 15 plus 5 20. So, after applying the dilatancy correction our N value will further decrease. So, if the N dash is 25. So, after applying the dilatancy correction it will become 20. So, we are reducing the N value further.

Now, the question is as we know the if overburden pressure correction is required as the overburden pressure is shallow depth is less and the greater depth is very high. So, we have to apply correction you have to adjust the N value, and for the shallow depth you will increase the collected N value because it was under very less overburden pressure , but at the greater depth, you will decrease the corrected N value as compared to the measure N value because it is tested under very high overburden pressure.

So, but why we will apply the dilatancy correction. So, that is a very important question. So, we are applying these collections, but why we are applying these corrections. So, overburden is fine because of the difference in overburden pressure, as the overburden pressure is different at different depth we are applying the overburden pressure correction, but why the dilatancy correction.

Now, the delicacy correction why it is required to know that, we should know what is the dilatancy. So, dilatancy in one word it is mean that when we apply the load or the shearing.

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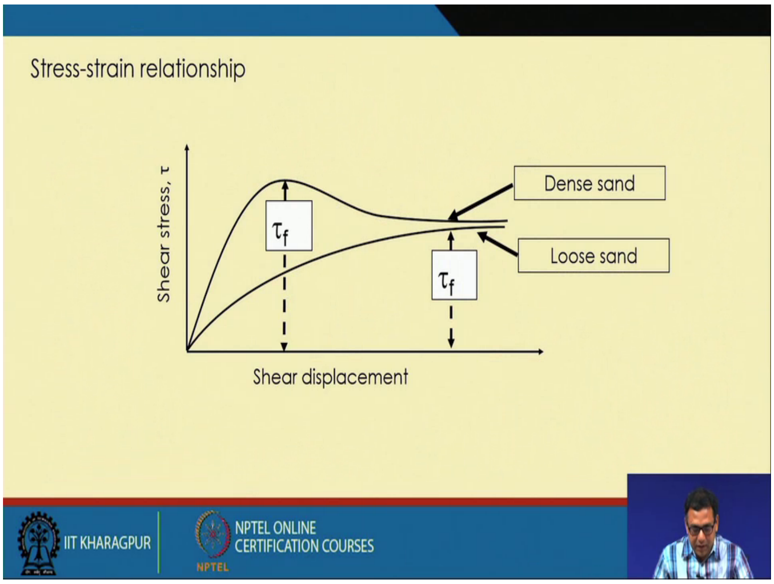

So, as I mentioned that if you look at this stress strain curve and the volume change curve.

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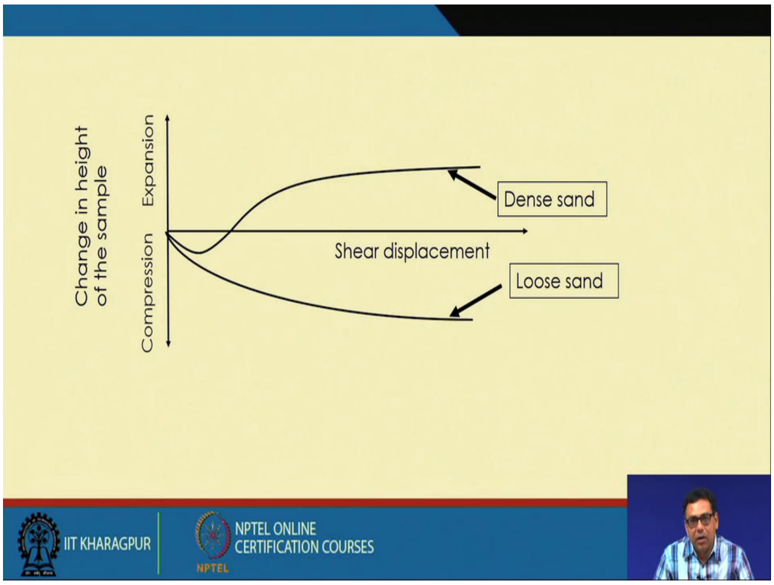

So, what will happen that in the dense sand, your volume first decreases then increases and loose sand your volume continuously decreases; So, in case of dense and your volume increases. So, dilatancy means that increase is in volume due to the shearing or the.

So, now, here because of the shearing where our volume will increase now what does it mean? So, now, as I mentioned that we have that our soil which is filling the soil particles and the within the particles the if it is a saturated soil.

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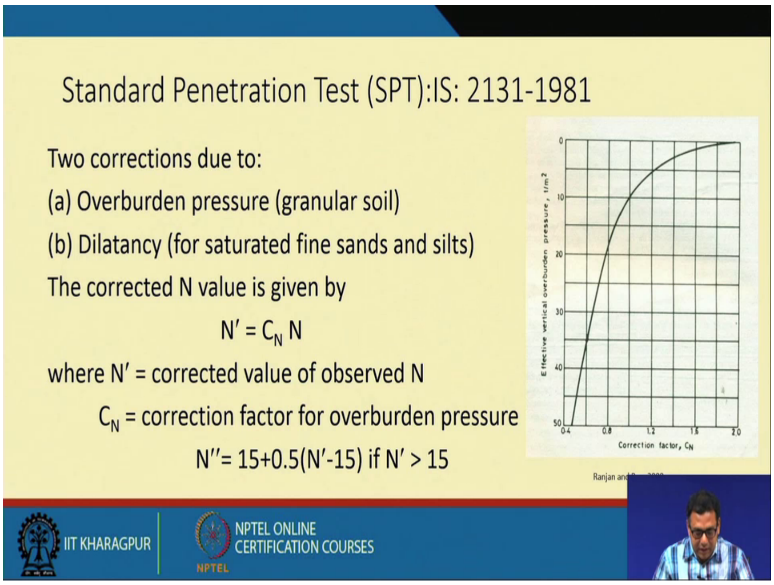

So, as I you can see that it is mentioned that dial the correction will be required for saturated fine sand and silts saturated. So, if the soil is saturated then all the pores will be filled with water. So, and if we now if the we applied shearing, if the volume of the soil decreases then what will happen? The volume of the soil decreases so; that means, your pore water pressure will increase.

Now, opposite trend will happen if volume increases because here because of the dialatancy volume increases, because as I shown you the volume change versus shearing or the strain or the displacement curve, where for the dense sand your volume increases due to the shearing. So, if the volume increases. So, pore water pressure will decrease.

So, decrease means the both the cases one is first case if the volume increases decreases, then there will be a positive pore operation and if the volume increases, there will be a negative pore water pressure. So, the first is the dilatancy because the volume increases and because of the volume increases your negative pore water pressure will induce.

So, now, if the negative pore operation will induce then what will happen? Because we know our strength expression is that our shear strength expression is tau is equal to C plus sigma N dash into tan phi in terms of effective stress. So, as I mentioned it is fine sand and silt, where cohesion we are assume it cohesion is 0. So, shear strength expression will be sigma N dash into tan phi. So, sigma N is dash is total stress minus pore water pressure into tan phi.

So, now as I mentioned that our pore water pressure is the negative pore water pressure. So, what will happen? Now, total stress minus pore water pressure. So, it becomes plus so; that means the total stress plus u into tan phi. So, now, that is ultimately the strength expression will be total stress minus pore plus pore pressure into tan phi. So, basically your strength of the soil will increase.

So, because of this phenomena. So, you will get as the strength of the soil increase. So, you will get the higher N value. But when these things will when we actually construct the foundation or. So, these things will not happen in the field. So, that is really here during the N value because we are applying hammer blows and why it is happened. So, that is why 15, because if the N value is greater than 15 N value N dash is greater than 15.

So, as N value increases so, that it indicates the soil become more dense. So, if it is greater than 15. So, it is become towards the dense sand. So, that is why the dilatancy will occur and pore water pressure negative pore water pressure will induce and your strength will increase. So, and you will get higher N value.

But we will we will do it for the actual foundation calculation design, we cannot consider this effect we are that because your strength increases and so, we will not consider that strength increment or test strength increase during our design so, but because of this phenomena you will get a higher N value. So, as we will not consider this thing during our design. So, we have to apply correction. So, that is the dilatancy correction. So, because of this dilatancy correction, we are basically reducing the N value and that is why you are corrected N value.

Because of the dialatancy is less than the N value, which you have which is the N value you got after the correction overburden pressure. So, that is why these dilatancy corrections are applied in the two cases in these cases. So, it will be a saturated soil it will be slightly it will be in the more than 15. So, that in the den side so, that the dilatancy can occur, and it will occur for your sand fine sand and the silt. So, the next one that these things I have already discuss.

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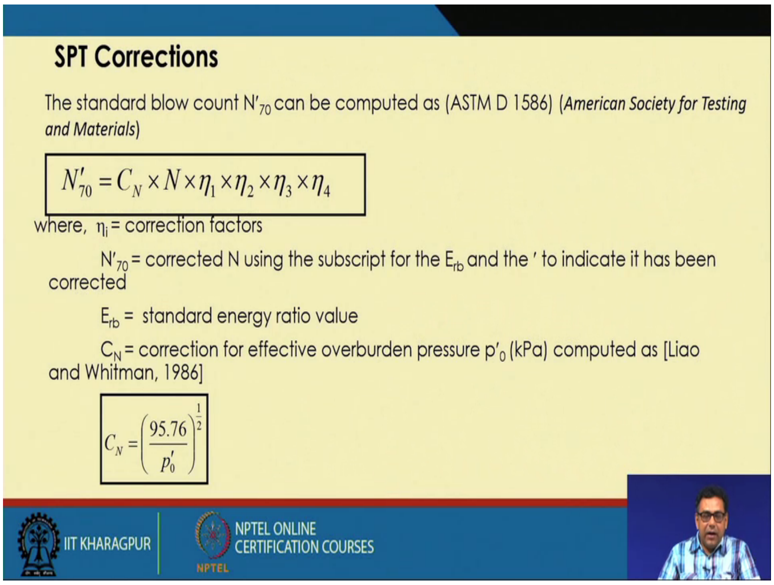

So, the these previous corrections is as per the as per the IS India standard code you have to apply the two corrections, one is overburden pressure correction another is the dialatancy correction. But as per the ASTM American society for testing an material. So, they are suggesting more corrections. So, they are basically we have to apply five corrections instead of two corrections. So, what are those five corrections? So, you can see this is the N dash, dash means again it is a corrected value and 70. What is 70. So, I will discuss that thing.

So, let me explain that why C N again C N is the correction for the effective overburden pressure, and that C N here we can calculate by this expression that is 90.76 by p 0 by. So, as I mentioned this effective overburden pressure can be shown in different way it can be p 0 bar it can be p 0 dash it can be sigma dash it can be sigma bar or sometimes it can be p bar or p dash also.

So, here. So, in this course in different places it can be shown in different way maybe although, I will try to show them in one particular format, but. So, these all are same so; that means, effective overburden pressure is p 0 dash. So, it is in as these expressions you are using. So, it is in kPa kilo Newton per meter square. So, we have to calculate the p 0 bar in kilo Newton per meter square and we put this value here and then we will calculate the C N, that C N we will use as a correction factor. This is the measure N value and these are the four other correction factors.

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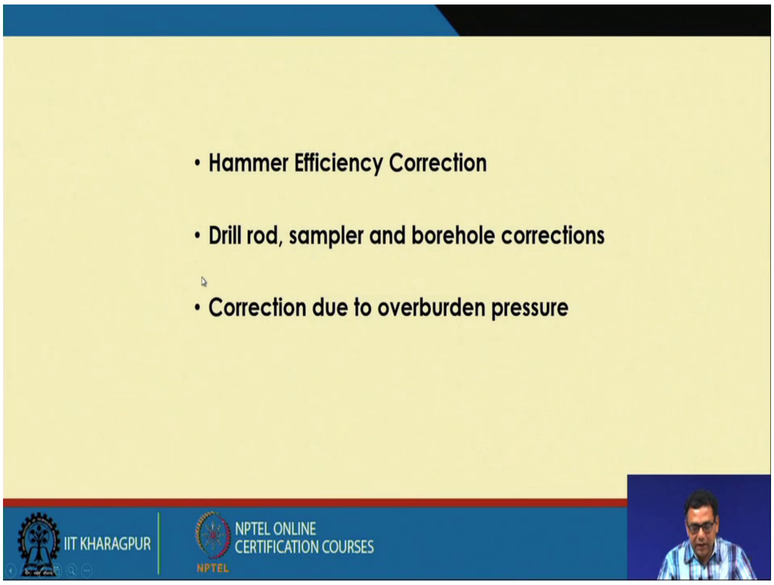

So, these four other correction factors are hammer efficiency correction, drill rod sampler and borehole correction, and correction due to overburden pressure that we have already explained. So, in addition to other four corrections are hammer efficiency correction, drill rod, sampler and borehole corrections.

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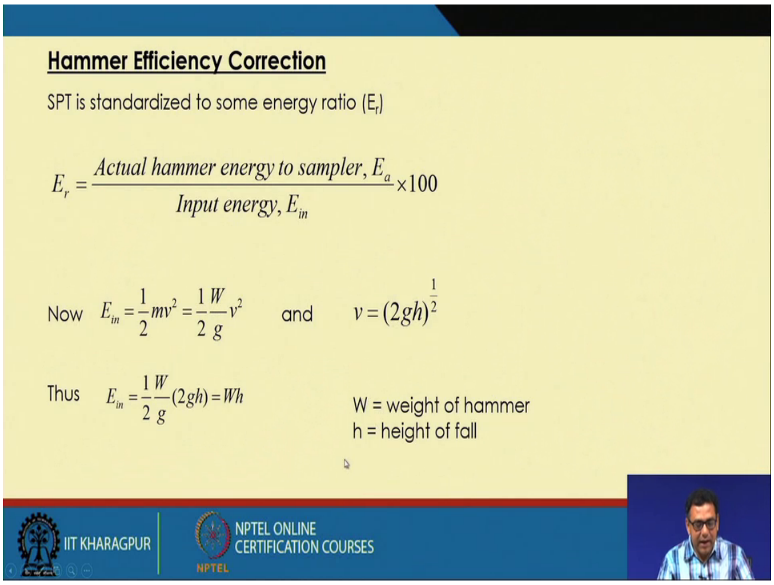

Now, what is hammer efficiency correction. So, here and why it is required. Because here we are talking about that we are applying a standard hammer, and for to conduct the SPT. Now, suppose if I use different hammer there energy values are not same for all the hammers because of because some we are not we are applying these blows in different ways for different hammer. So, we our energy is may not be same for all the cases.

Now, suppose for a particular site we are conducting say 200 SPT and we are using different hammers for different site for a particular location your hammer using one hammer in for a particular location were using another hammer or our energy is applied energy means the applied energy is different for different cases.

So, now, we have to represent them in a particular common way. So, that is why we have to apply a hammer efficiency corrections, because in all the hammers the efficiency are not efficiency is not same. So, that is why you have to apply this hammer efficiency correction and represent them in a common format.

So, now quickly I can discuss you this E r is a some energy ratio. So, which is the actual hammer energy that you are applied and this is the theoretical energy or input energy. Now, this is the theoretical energy finally, it will be weight of the hammer into the free fall height of fall. So, this is the input energy, but your applied energy may not be equal to the input energy because your efficiency is not same for different hammer. So, this that is why you are get a ratio.

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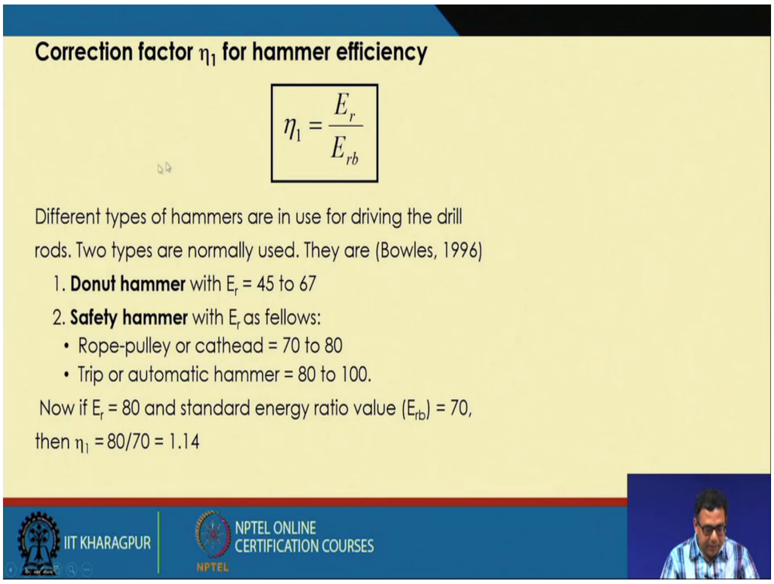

And then for this is the correction for hammer efficiency, this is the E r in E rb. So, E rb will E r will get from here and E r b is the energy that is standard energy. So, this we can represent the all the N value in terms of this E rb; that means, we have to convert all the hammer N value for different hammers, that we are using in the field and we convert all the energies to E rb. So, I will show a example then you will find how we can do all these things.

So, any as I mentioned this E r value this is different for different hammer. So, this is for donut hammer, it is 45 to 67 safety hammer. If it is rope pulley or cathead then it is 70 to 80, if it is trip or automatic hammer it is 70 to 100. So, now, we will get some hammer efficiency correction. So, now, you can see if our E r is 80 and standard energy is 70. So, the correction will be 1.14 80 by 70 to 1.14.

So, now I am finishing this class here. So, in the next class I will discuss about the other corrections factors, which is required as which is recommended as per the ASTM, and then I will solve two problems one as per the is code and one as for the ASTM code to show you how we can use these corrections.

Thank you.