Advanced Foundation Engineering
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Lecture – 01
Introduction and Soil Exploration - I

Hello everyone, so, this is the first lecture on advanced foundation engineering so, this course, I have developed for the UG as the PG students. So, before you take this course, so, for the UG students, you should already take the course on soil mechanics as well as the foundation engineering because this is the advanced foundation engineering course. So, you should have the knowledge of soil mechanics and some portion of the foundation engineering also.

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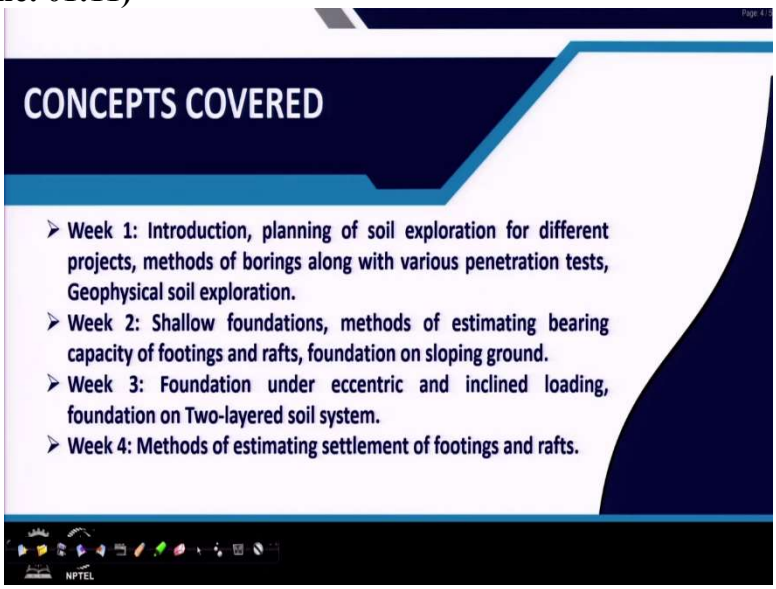

So, here are the things that I will cover in this course, that the introduction and the soil planning of soil exploration for different projects. So, and these soil explorations are boring and various penetration tests and geophysical soil explorations. Then I will discuss the shallow foundations and methods of estimation of bearing capacities for different shallow foundation, bearing capacity estimation theories and then we will discuss foundation on sloping ground.

Then foundation under eccentric and inclined loading and foundation on two-layered soil system then method of estimating the settlement of the shallow foundation or the footing and the rafts that I will discuss.

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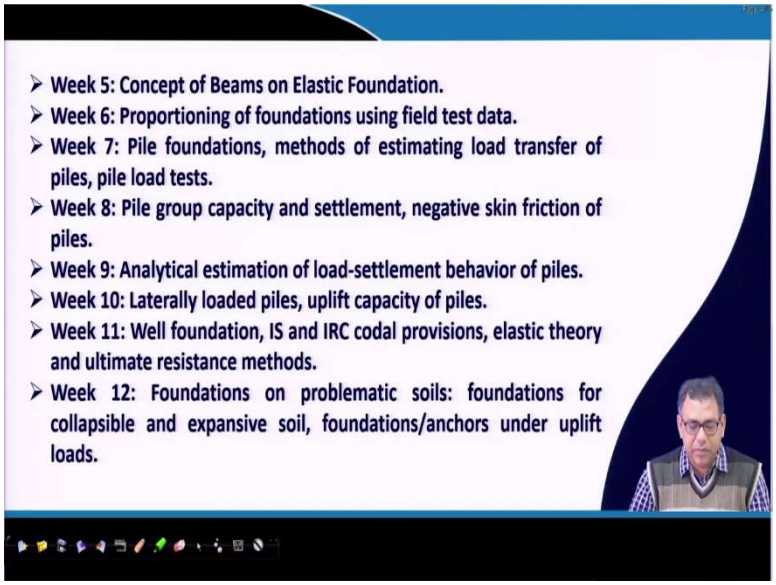

So, in the next part I will discuss the concept of beams on elastic foundation then by using field and the laboratory test data how we can determine the dimension and depth of foundation. Then I will discuss about the pile foundation, pile strength transfer or load transfer mechanism along the pile, then pile load test then piles group capacity and settlement, calculation negative skin friction then we will discuss about the analytical estimation of load-settlement behavior of piles.

Then lateral loaded piles, uplift capacity of the piles and I will discuss the well foundation and different codal provisions and then foundation on probabilistic soil mostly on collapsible and expansive soil and foundation or anchors under uplift loads. So, these are the contents of this course. So, these contents will not change, but this weak wise distribution may slightly change during my lectures. So, but the content will remain same. So, the first module the first part that I will discuss the soil exploration and before I discuss the soil exploration.

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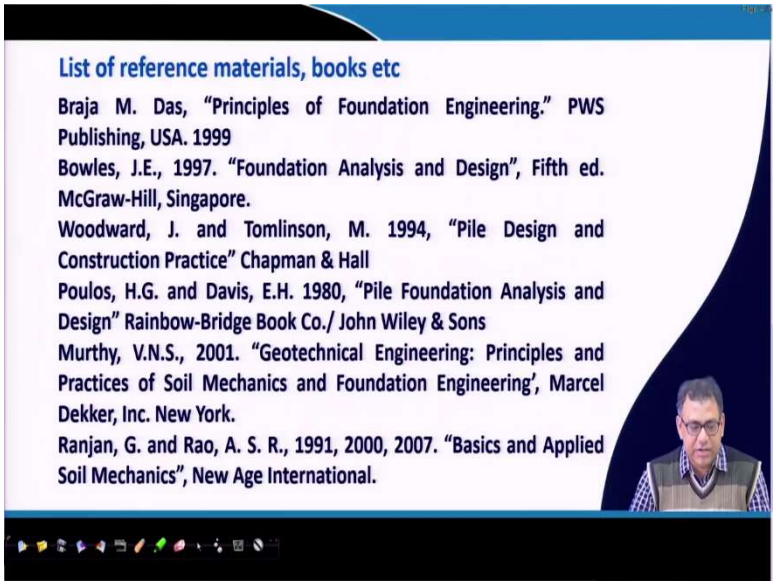

So, these are the list of reference materials or books that you can follow. So, these books are the principles of foundation engineering by BM Das, then foundation analysis and design by Bowels, then the pile design and the construction practice by Woodward and Tomlinson and pile foundation analysis and design by Poulos and Davis and geotechnical engineering principles and practice of soil mechanics and foundation engineering by V.N.S Murthy and basic and applied soil mechanics Ranjan and Rao.

So, these are the references you can follow for this course. In addition to these books, I will also follow few journal papers. So, those references I will give directly during my lectures.

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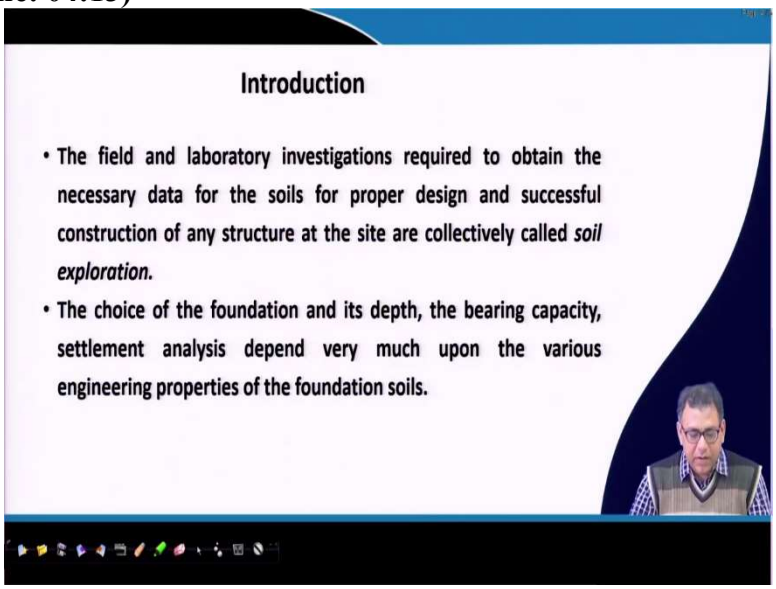

So, first part that I will start with a soil exploration because for the foundation design, we should know the properties of the soil. So, the soil properties can be determined either by field test or by laboratory test, so, for that purpose we have to do the soil exploration. So, the definition of the soil exploration, but the field and laboratory investigations required to obtain

the necessary data for the soil and the proper design and successful construction of any structure at a site is collectively called the soil exploration.

But in this part, I will discuss mainly the field investigations, the choice of foundation and its depth, then the bearing capacity and settlement analysis, all depends on the properties of the soil. So, that is why the soil exploration is very important.

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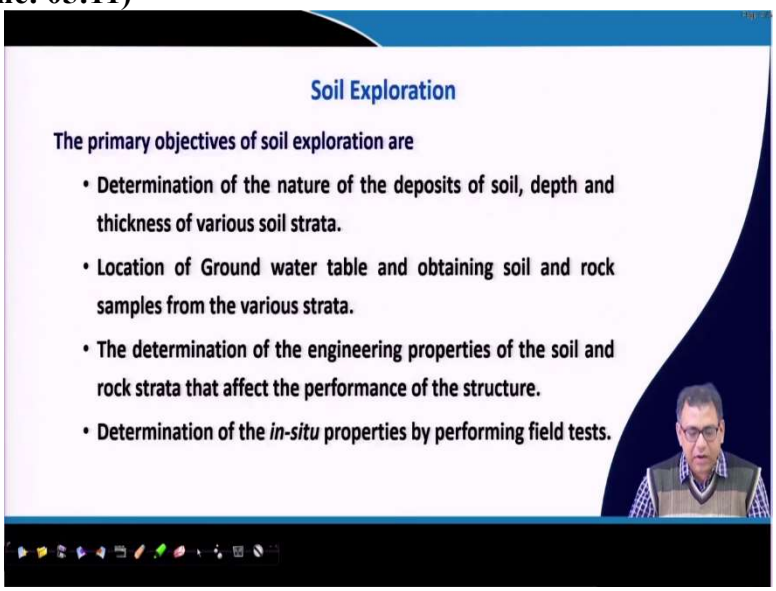

And the objective of the soil exploration is to determine the nature of deposits of soil, depth and thickness of various layers, the location of groundwater table, which is also very important, then the obtaining of rock or soil sample from the site. And then we will take those soil samples into the laboratory and we will determine the engineering properties of those soils and the rocks data for our construction purpose.

Then will also determine the institute soil properties by performing field tests. So, in this part, I will discuss these different field tests.

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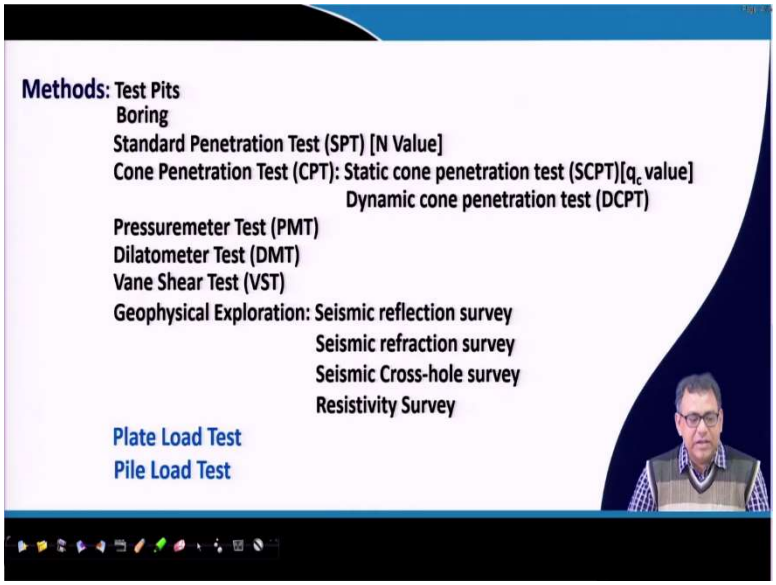

So, these are the different soil exploration techniques by which we can determine the soil properties. So, few of them are used directly to determine the soil properties and few of them are used to indirectly determine the soil properties for example, will determine or measure in the field something else then we will correlate those properties with our required design properties or the strength properties.

So that we can determine the bearing capacity or settlement of the foundation. So, these methods are test pits boring, then the penetration tests like standard penetration test SPT or cone penetration test CPT. Cone penetration test is of 2 types, one is static cone penetration test SCPT, dynamic cone penetration test DCPT then pressure meter test, dilatometer test, vane shear test and different geophysical explorations like seismic reflection survey, seismic refraction survey, systemic cross-hole survey and resistivity survey.

So, by these techniques we can get the soil properties and then we use those soil properties to calculate the load carrying capacity or bearing capacity or settlement of the shallow or deep foundation, what we can do with the plate load test also where directly we will get the bearing capacity and the settlement of the shallow foundation and we can do the pile load test where also I will get directly the pile load carrying capacity and the settlement.

So, these 2 tests also will be discussed but not in soil exploration part, it will be discussed during the shallow foundation and the pile foundation part. So, one by one I will discuss all this technique in brief.

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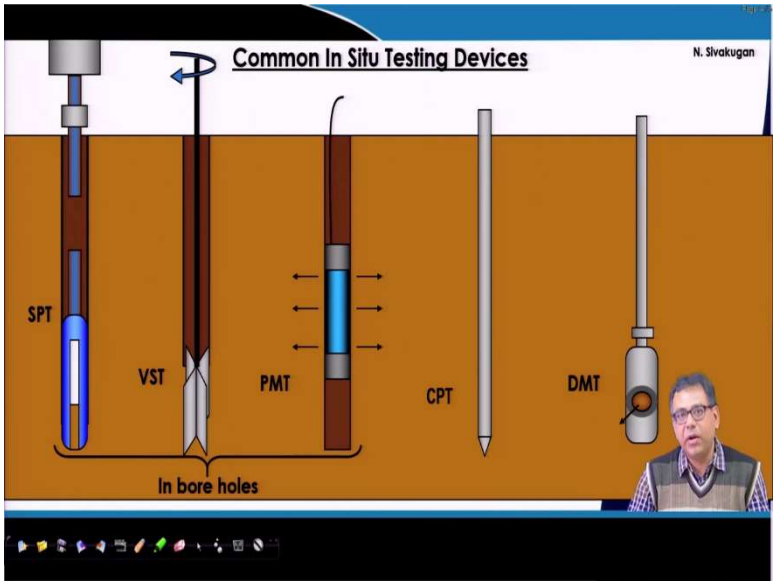

So, these are the different techniques that are used. The first one is the SPT, then the VST means vane shear test, then PMT means the pressure meter test, then CPT means the cone penetration test and DMT means the dilatometer test. So, out of these tests, for first three, that means SPT, VST and PMT, we need the borehole but when you have to construct a hole within the soil and then we will place the instrument within the hole at the required depth to get the soil properties.

Or here basically as I mentioned that few of the tests are indirect. So, these are basically the indirect tests, by which we will determine something else, then those things will correlate with our required soil properties. But for the SPT and DMT, we do not need the boreholes. We will push these instruments into the soil and then we will get the soil properties or will measure the properties which is required to determine the soil properties at different depths. We will get some reading as continuous and some at certain intervals.

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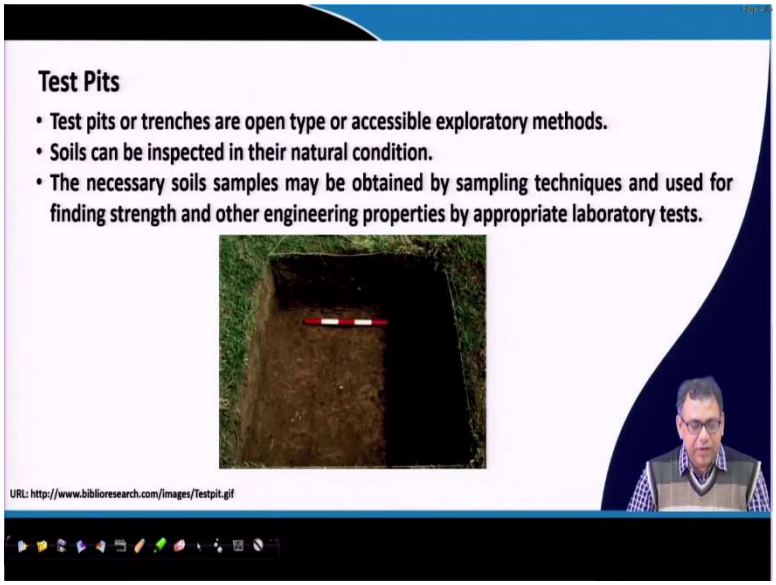

So, now, first one is the test pit which is our test pit you can see this picture which is the test pit. So, generally the depth of the test pit should be the depth of the foundation and then from these pits we can collect the soil sample. So, this is the direct method by which directly we can collect the soil sample and then we can take those soil sample into the lab and then we get the soil properties. But this test pit method is suitable for small structure and for very shallow depth.

So that means, the soil can be inspected in their natural conditions. And we can as I mentioned collect the soil sample from the base of the pit or the base of the foundation itself.

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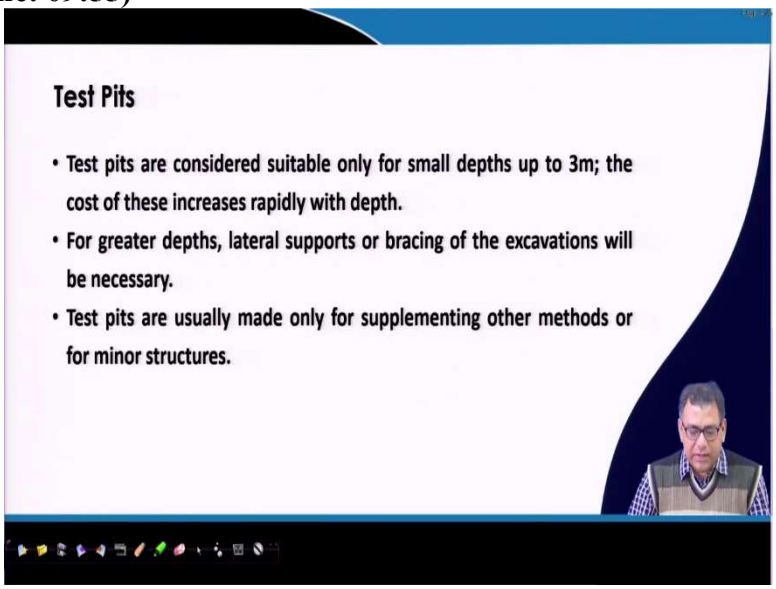

Now this method is suitable for up to a small depth of 3 meter, and as the depth increases the cost increases rapidly because of the greater depth you have to provide the lateral support for the soil, then these pits are generally used for supplementing the other methods or for minor structures.

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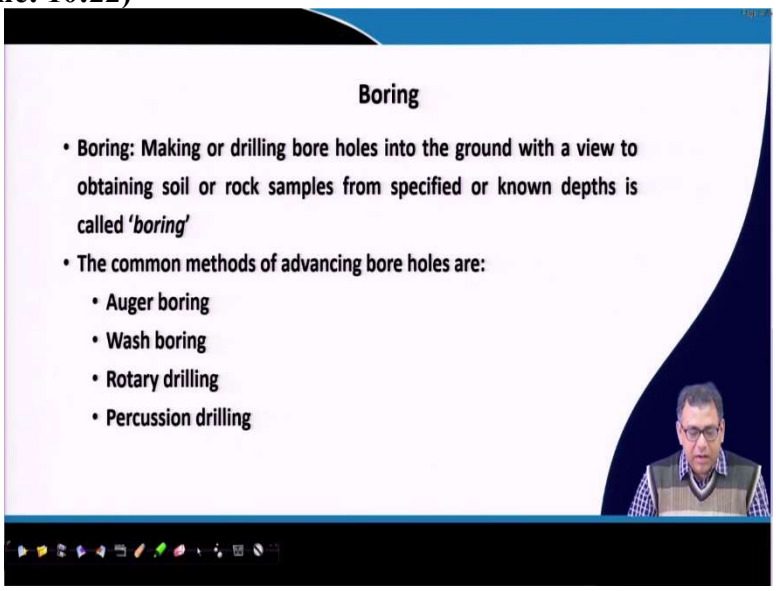

For next one is the boring. So, this is the making or the drilling of borehole into the ground with a view of obtaining soil or rock sample from specific or known depths that means, a boring is basically done to collect the soil sample from a particular depth which can be a specific or known depth. So, there are different common boring methods available such as, auger boring, wash boring, rotary drilling and percussion drilling.

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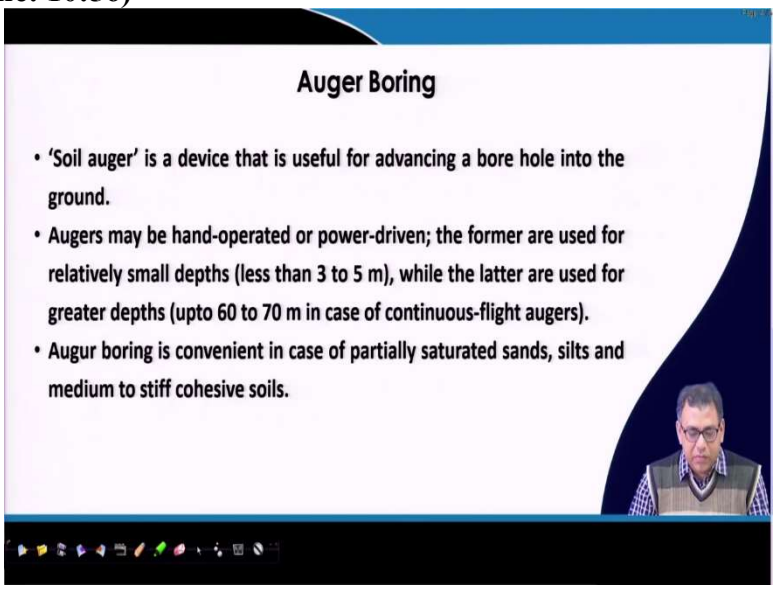

So, the auger boring, this is useful so, advancing the borehole into the soil auger may be the hand-operated auger or power-driven auger or with a hand operated auger is used relatively for small depth up to 3 to 5 meter and then the power-driven auger we can use for the greater depth we can use it for up to 60 to 70 meter in case of continuous-flight augers. So, auger boring is convenient in case of partially saturated sands, silts and medium to stiff cohesive soils.

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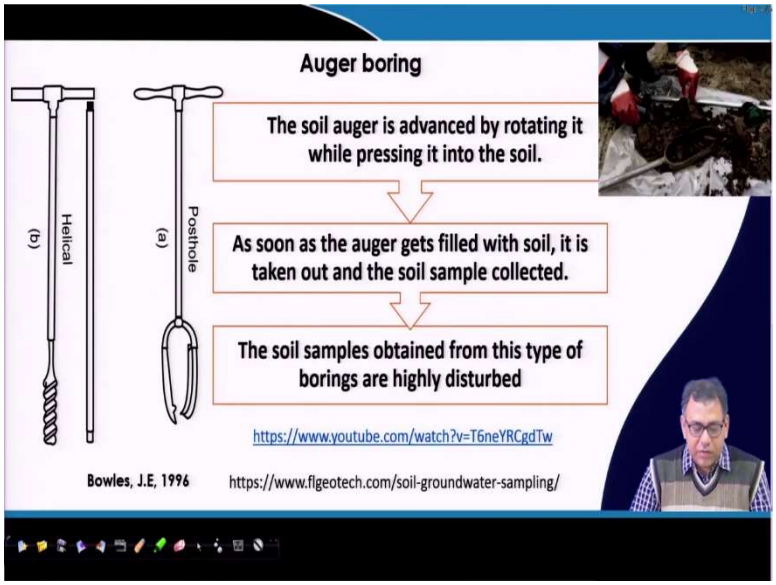

So, these are different augers, you can see these are the different augers, these are helical auger and these are the rods. So, these rods are attached with the augers to increase the length and so that we can place this auger at any required depth by attaching these rods. So, you can see these photographs where these samples are collected in the auger. So, the soil auger is advanced by rotating it within the soil and you also push it.

That means you have to push it and at the same time you have to rotate it so that it will insert into the soil as well as at the same time the soil will enter into the auger. So, when the auger is filled with soil, then you have to remove it from the soil and then we collect those soil sample. So, and definitely the way we are collecting the soil sample the soil those we are collecting are very disturbed sample and some YouTube video link is also given. So, you can see this link and you can see these videos also anyhow you can see these videos also these links are given.

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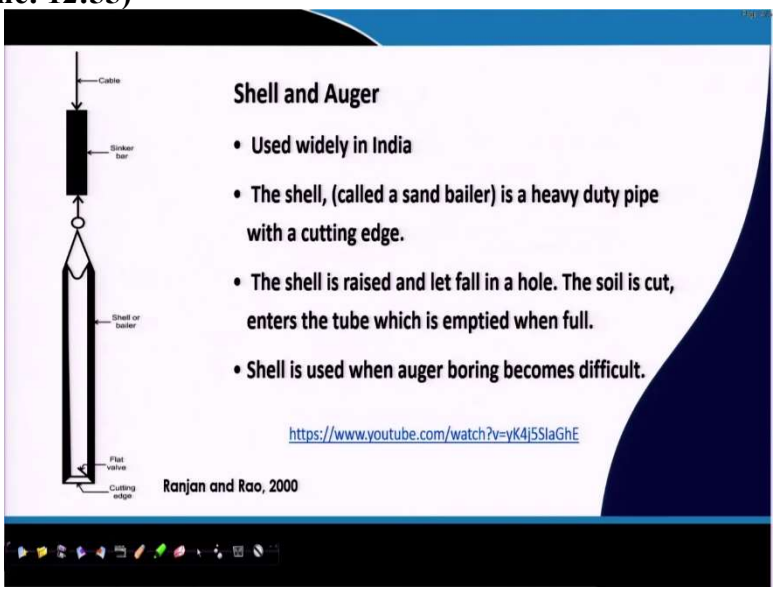

And then we can go for the shell and auger boring. So, these are used widely in India. So, shell

which is a heavy-duty pipe, you can see the shell is a very heavy-duty pipe. So, these are the cutting edge and here is a one-way valve is attached. So, these shells are raised and let fall into the hole. So that means in a borehole these shells are allowed to fall from a certain height and then soil is cut because as the cutting edge is there and this soil enters into the shells and there is a one-way valve.

So, it will allow the soil to enter into the shell but it will not allow the soil to come out from the shell when it is removed from the soil. And when a shell is filled with soil then we can remove it and then we collect the soil samples and this shell is used when the auger boring is very difficult. So, otherwise we can go for the auger where the auger boring is difficult and you will go for the shell.

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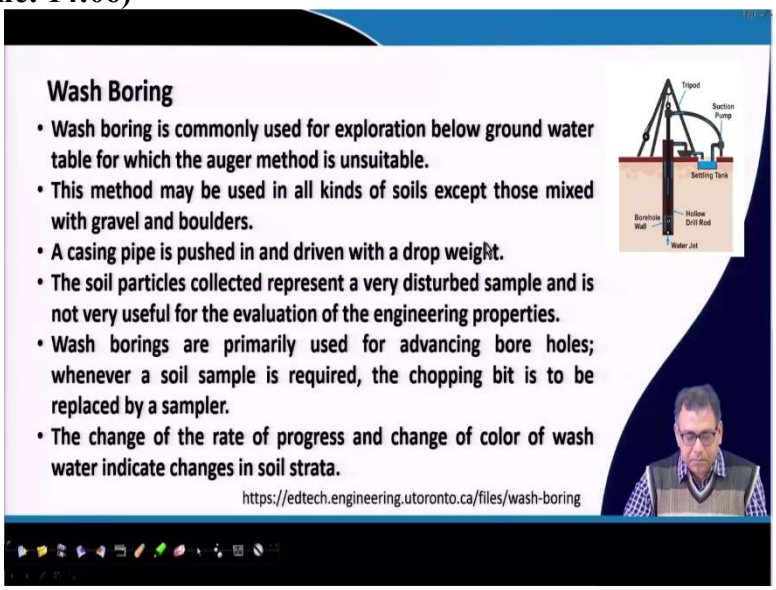

Then our next one is the wash boring. Wash boring is commonly used for the collecting the soil sample below the water table where the auger boring is not suitable. So that means where we want to collect the soil sample below the water activity, we have to go for the wash boring. So, this method is very used for all kinds of soil except those mixed with gravel and boulders.

So, if the soil is mixed with gravel and boulders then this method is not suitable. So that means there is a casing pipe which is pushed and driven into the soil by a drop hammer. This is a casing pipe which is pushed into the soil by a drop hammer and soil particles collected represent a very disturbed sample and is not very useful for the strength properties, or the permeability properties, a calculation part determination purpose.

So, later on we will discuss that where you will use the disturbed sample where we can use the

undisturbed sample. So, suppose for the strength properties or for example, cohesion and the friction or the permeability or the consolidation properties, we need the undisturbed sample that means, soil in its natural condition, but the way we are collecting the soil sample by wash boring is a totally disturbed sample.

So, we cannot use these disturbed samples for these tests for this purpose, but we can still use this sample for other purposes also those I will discuss in the later one. So, that wash boring is primarily used for advancing the boreholes. So, but whenever this sample is required, then these chopping bits, so, these chopping bits are replaced and then a sampler is attached in this chopping bit. So, the change in the rate of progress and change in color of wash water indicate the changes in soil strata.

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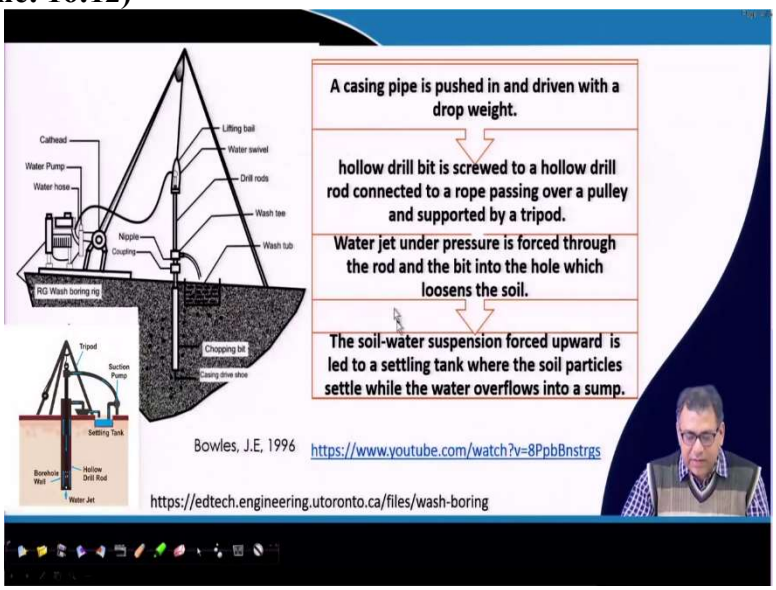

So, now, I will discuss it in the steps by which we can perform this boring technique that the casing pipe is pushed into the soil and driven into the soil by drop off weight then hollow drill bit is screwed to a hollow drill rod. So, this is the bit which is attached to a hollow drill rod inside the casing first the casing is inserted into the soil, then this pit is screwed in this rod and height of these rods can be increased by attaching another rod or number of rods.

So, and then this rod is connected to a rope passing over a pulley and supported by a tripod. So, this is the tripod and when a jet is applied through the rod and the pit into the hole to loosen the soil sample then the soil and water suspension is forced in upward direction. So, that mean by only applying the water jet the soil become loose. So, these soil with the water this slurry is forced to that means here we apply the jet in this direction.

We can see in the downward direction we apply the jet and it is forced to move these water jet water and the soil particles this slurry in the upward direction so then it will go in the upward direction through this casing pipe and it is collected to a place. So that means this place this is called a settling tank when the suspension force upward and this is collected in the settling tank where soil particles settle and water overflow into the sump.

That will allow us this slurry to settle the soil particles and the water will overflow and then we collect the soil sample definitely as I mentioned the way it is collected is a highly disturbed soil sample and again these are the YouTube link are given. So, you can use this link and you will get that video.

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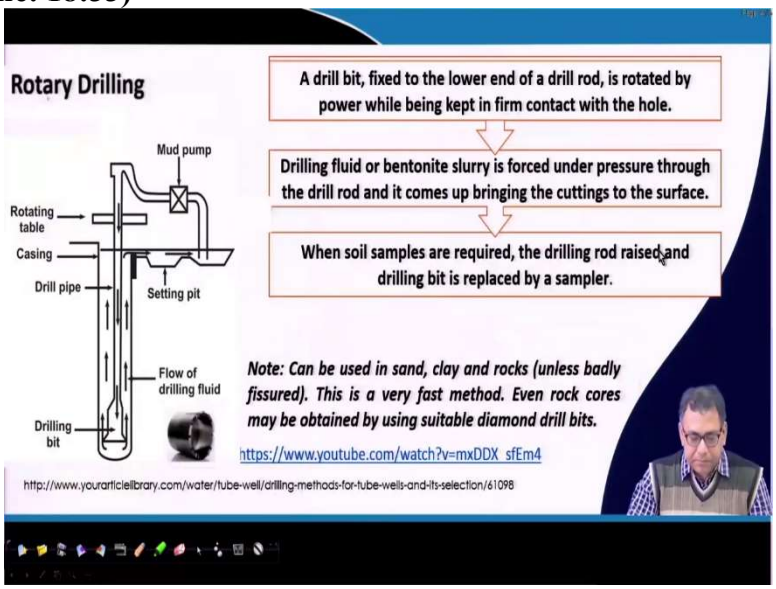

Then the rotary drilling. So, this is the drill bit. So, this is the bit which is fixed lower into the drill rod. So, this is the drill rod, where this bit is fixed at the lower end and it is rotated by power while being kept in firm contact with the hole that will firm contact with the soil this bit which is attached with this drill rod is rotated and so that means these rotated and the bentonite slurry is forced under pressure to these drill rod and it brings the cutting to the surface.

That means when we rotate this bit along with the drill rod at the same time, a bentonite slurry is applied to this drill rod. Now this bentonite slurry what it will do? It will mix with the cutting pieces and then again it is forced to come in upward direction that will again this is this arrow direction we can see this is a bentonite slurry is applied and here does cutting bit which is rotating with the soil or rock then the pieces which are generated.

Then these mixed with the bentonite slurry and it is then forced to move in the upward direction

and then again it is collected in a settling pit. So, when soils again this way we can make the boring or bore holes and then when we want to collect the soil sample, then this bit is removed and sampler is attached and we can collect the soil sample. So, we can collect the soil sample as well as you can advance the borehole also. So, these can be used in sand, clay and rocks.

So, this is very fast method even rock cores may be obtained by using suitable diamond drill bits. So, using suitable bits also we can collect not only the soil, but also, we can collect the rocks also but it is a very fast method.

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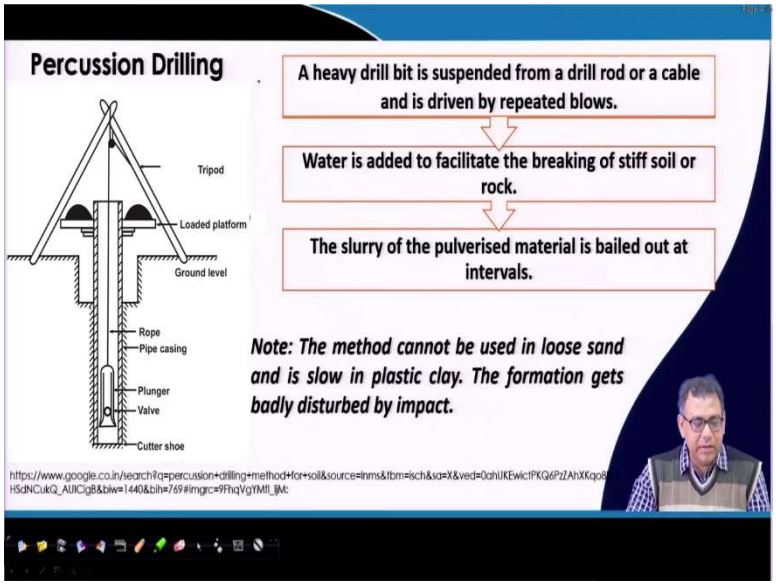

Then the percussion drilling here is a heavy drill bit is attached with a drill rod and the cable and is driven by a repeated blow. So, previous one this bit is rotated by power, but here it is inserted into the soil by driving with blows. So, then again, the water is added to facilitate the breaking of stiff soil or rock and then the slurry of this material is bail out in intervals that means here when this water is added and this slurry is bailed out in interval.

And then the boring is advanced, but the method cannot be used for loose sand and it is slow in plastic clay and formation gets badly disturbed by impact because here we are applying the impact by applying the blows. So, that means we are applying repeated blows or the impact. So, that means the formation may get badly disturbed by this impact.

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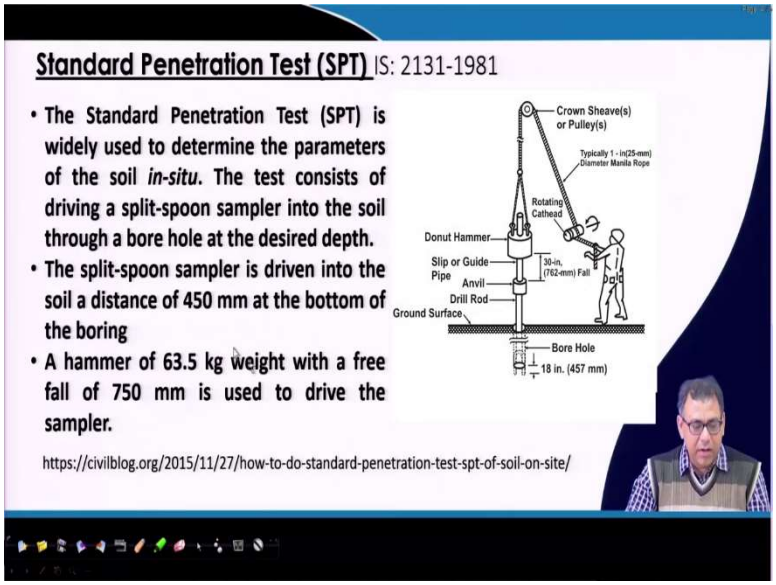

So, now, we will go for the next part, which is the penetration test. So, first one that I will discuss the standard penetration test. So, this is a very popular test. So, here we use a split-spoon sampler, that sampler is attached to rod and this rod I can extend by using number of rods and we can put the sampler at any depth as we required and then we apply the hammer blow on this rod.

The sampler or this split-spoon sampler is driven into the soil by a distance of 450 millimeter in 3 intervals that means 150 millimeter each. So, and we measure the number of blows required for each 150 millimeter penetration of the sampler into the ground. So, here we apply a hammer of 63.5 kg weight with a free fall of 750 millimeter. So, this hammer weight is 63.5 kg with a free fall of 750 millimeter.

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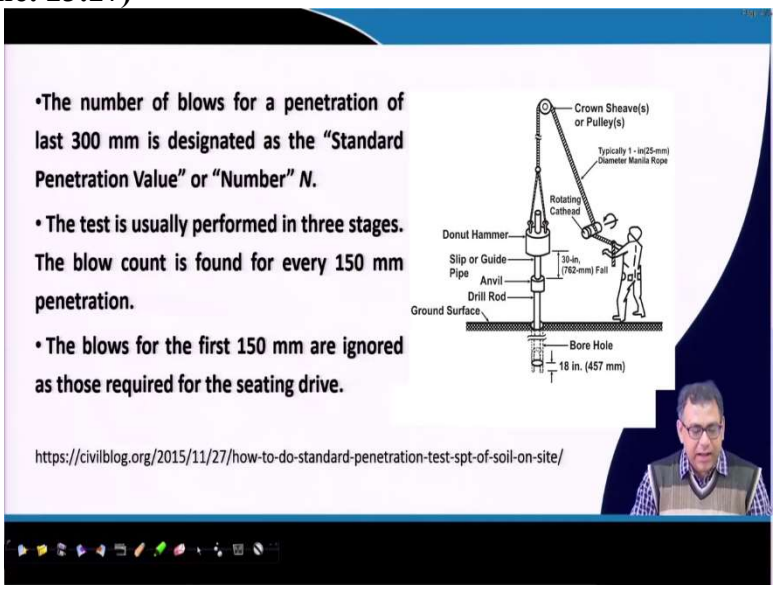

And then as I mentioned that we are measuring the number of blows required for each 150 millimeter penetration. So, the summation of last 300 millimeter penetration N value is the SPT

value that means, we will neglect the initial 150 millimeter penetration required blows for the sitting load purpose because that will be treated as a sitting load. So, that there should be a proper contact between the soil and the sampler tube. And then the number of blows required for last 300 millimeter penetration or 30 centimeter penetration is the N value.

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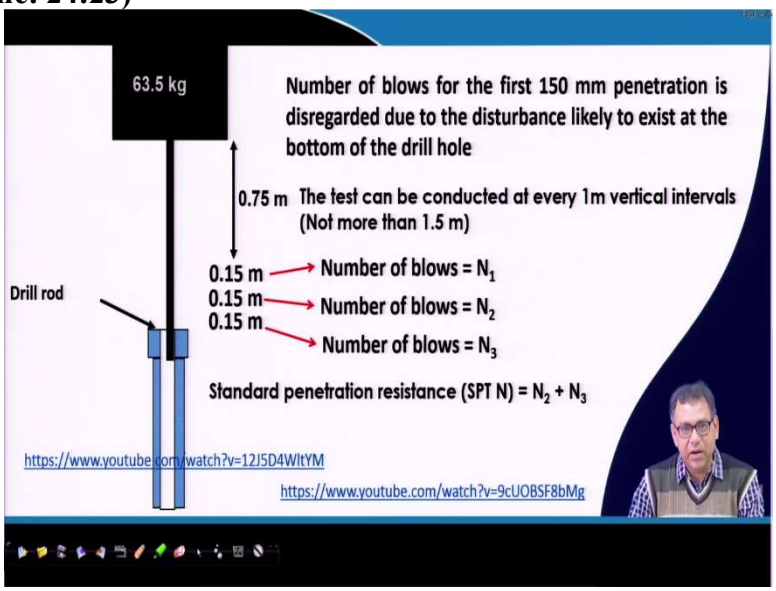

So, the blows of 63.5 kg hammer which is applied for 150-millimeter penetration and each time we measure the number of blows that is N_1, N_2 and N_3. As I mentioned N_1 will not be considered. So, the SPT value will be summation of N_2 and N_3. So, this SPT is $N_2 + N_3$. So, summation up N_2 and N_3. So, it will be SPT value. So, these tests can be conducted at 1 meter interval, but not more than 1.5 meter interval.

So, that means here advantage is that we will get the N value so, that N value later on we will use to determine the soil properties as I mentioned those few tests are directly, we can get the soil sample. So, from boring and test pit we can collect the soil sample directly, but here in penetration test SPT we are getting the N value, but advantage is that here also we can collect the soil sample which is not true for another type of penetration test, that is cone penetration where, we will not get the soil sample directly from the field. So, but in the SPT will get N value as well as the soil sample.

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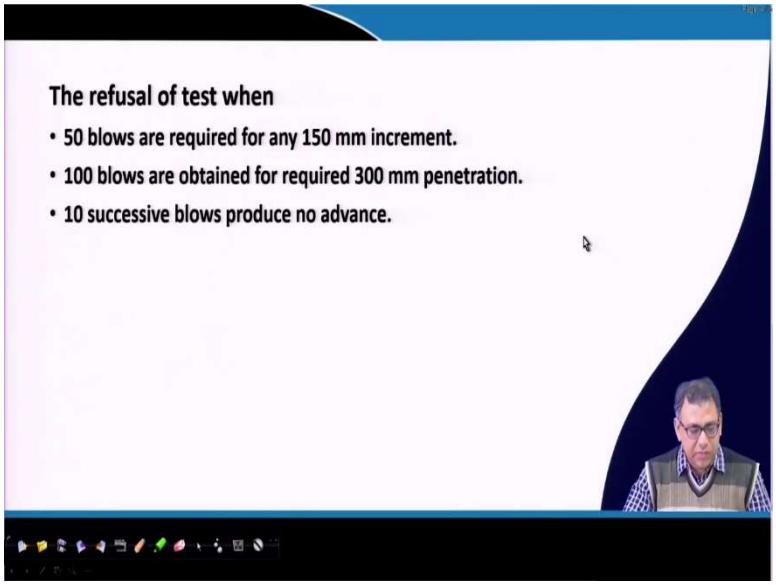

So, that when you will realize that we have to finish our tests. So, one is that then we will fix that up to which level we will do that test. So, that is one option another option that every time you have to go for 450 millimeter penetration, but sometimes because of the very hard strata, we cannot go for 450 millimeter penetration then when will stop that test in such case.

So, for that purpose we have to satisfy few conditions. So, those conditions are that if 50 blows are required for any 150 millimeter increment, then we will stop there or 100 blows are required for any 300 millimeter penetration then also will stop there or if 10 successive blows, if produce no advance, then also we will stop and when if any of these criteria or condition is occurred in the field, then we will stop the test. So, what one is 50 blows for 150 millimeter penetration and 100 blows for 300 millimeter penetration or no penetration for 10 successive blows.

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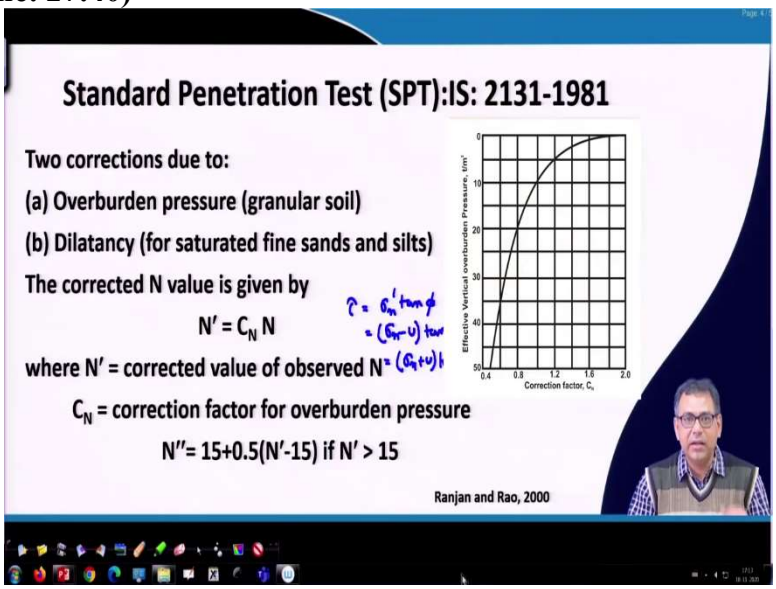

And then once you get these *N* value, then will bring collected soil sample into the lab and we will do the test, but this *N* value is very important for us because we will use this *N* value to

determine the soil properties by using different correlations. So, now, once we get this N value, then we have to apply different corrections. So, what are those corrections? So, as per IS code we have to apply 2 corrections.

One is the overburden pressure correction that we have to apply for granular soil and another is the dilatancy correction that we have to apply for saturated fine sand and silts. So, because overburden pressure correction is required, because you can see that at very shallow depth your overburden pressure or the pressure that the existing soil is given is very less, but at the greater depth this overburden pressure is very high.

So, because of that in a shallow depth, you will get a very less amount of N value and in the greater depth, because of this high overburden will give you a very higher amount of N value. So, you have to apply a correction, so, that we can remove this overburden effect. So, you can see the IS code recommends to use a chart. So, this chart you can see. So, this is the correction factor C_N and here effective vertical overburden pressure. So, effective means it is effective not a total.

So, effective vertical overburden pressure in ton per meter square. So, you can see that if effective overburden pressure is 10 ton per meter square on this graph, then no correction is required because your correction factor is 1 and if the effective overburden pressure is less than 10 ton per meter square then you can see the C_N value is greater than 1. And if the effective overburden pressure is more than 10 ton per meter square then C_N value is less than 1.

So, which means that if your effective over burden pressure is more than 10 ton per meter square, then you will get the higher N value that you have to reduce by applying these over burden corrections. So that is why the C_N value is less than 1. And if your effective over burden pressure is less than 10 ton per meter square, then this is in a shallow depth. So, you are you are measuring with less so, you have to apply the correction to increase that N value. So, that is why C_N value is more than one.

So, if effective over burden pressure is 10 ton per meter square if it is less than that, then your corrected N value is more than the measure N value. If effective overburden pressure is more than 10 ton per meter square then the corrected N value is less than the measured N value. And then we will go for the dilatancy correction. So, that dilatancy correction is applied for saturated

find sand and silt. So, first we will apply the correction due to overburden then I will get the N'.

Now if this N' is greater than 15 and if this is the condition that when saturated fine sand and silt then I will go for the dilatancy correction and if N' is less than 15 then you will not go for the dilatancy correction. If it is greater than 15 then only, I will go for that dilatancy correction and this is the dilatancy correction. Finally, I will get the N'' but these dilatancy correction we are applying the dilatancy correction also we will reduce the N value.

Now, why I will apply the dilatancy correction because these dilatancy correction why it is 15 that is also another question because these dilatancy correction is generally applied for the dense soil. Generally, if the soil is dense, then it will give you a higher N value. So, if N value is more than 15, then we treat soil as a medium dense soil. So, in such case what will happen that if we apply any impact on a dense soil? Then they the soil will dilute because of these dilatancy the soil will expand.

So, that means your volume will not decrease it will increase and this will happen for dense sand and it will not happen for the loose sand it will happen for the dense sand of the volume will increase. So, because of the volume will increase if the soil is saturated, if the soil is dry then also these dilatancy correction is not required, if the soil is saturated, because of this expansion of the volume, the negative pore pressure will develop.
So, negative pore pressure will develop. So, because of the negative pore water pressure, what will happen your strength will increase for example, we know the strength expression is $\sigma_n' \times \tan\phi'$because it is granular soil. So, C is 0 and this $\sigma_n' = \sigma_n - u$ that means total normal stress minus water pressure. Now, if the negative water pressure, then this will be $(\sigma_n + u) \times \tan\phi'$, ϕ is the friction angle.

So, what will happen your strength will increase? Because of this impact, but that means you will get the higher N value. So, the because of this effect, you will get the higher N value. So, to reduce that effect, and we have to reduce the N value. So, that is why you will have to apply the dilatancy correction. So, that means to nullify this effect, we have to reduce the N value and that is why we will apply this dilatancy correction. So, this is the as per IS code and then as per ASTM American standard also they have recommended few more corrections. So that I will discuss in the next class. Thank you.