Geotechnical Engineering II / Foundation Engineering
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Lecture – 27
Geotechnical Investigation (Contd.)

Good morning. We are actually discussing on Geotechnical Investigation and we are almost at the end of it today I will just complete and summarize, plenty of things will be there, but we will not be able to discuss everything what are the importance and I will essential for undergraduate level I will try to discuss those.

And, last class last module I was discussing about the geophysical method. And, in fact, before that I have discussed SPT, CPT test and SPT and SPT is very very popular in India particularly. And CPT also becoming popular and they are field test while doing the borehole we can also collect sample, carry out test get the information of the soil whereas, in geophysical method actually is a quick method very quickly you can cover a large area.

And qualitative information about the soil profile and soil type we can get. And both are having some advantages and disadvantages and of course, I have discussed geophysical method under geophysical method there are refraction method, then cross hole down hole up hole there are so many methods we have discussed. And refraction method actually suitable where actually when the; with deeper, when you go deeper and deeper if the soil modulus increases that will become steeper and steeper.

As you go deeper and deeper, then this will be useful and when there is a particular stratification, then the soil will either move through the first layers or it will strike on the second layer.

And, partly it will be reflected and partly it will be refracted and considering that reflected wave by refracted wave that are based on first arrival time. We have seen that how to find out the velocity of the wave in the first layer, velocity of the wave in the second layer, thickness of the layer etcetera all calculation. And, it can be of more than 1 layer also the if you have more than 2 layers, that calculation will be little lengthy, which we have not I have not discussed, but any standard geophysical method book we can find out.

So, that we have discussed and then secondly, we have discussed about different methods like cross hole, down hole, half hole, there actually we have generated a vibration at a source. And, then we have a particular distance you have recorded the velocity and recorded the time when it is reaching, and based on the distance we have fixed and time taken we can find out the velocity.

So, that is the way once cross hole means both receiver and source both are at the same level; that means, the borehole itself and for to find out the velocity at different level you can fix at different level. Similarly, for down hole means actually a source will be off and the ground and measurement receiver will be in the borehole at different depths.

And, that is a down hole and similarly the reverse of that half hole means, source without borehole and receiver will be in the ground. And then, but just by doing the distance and the travel time we can find out the velocity. Those things we have discussed and the last method was that resistive resistivity method.

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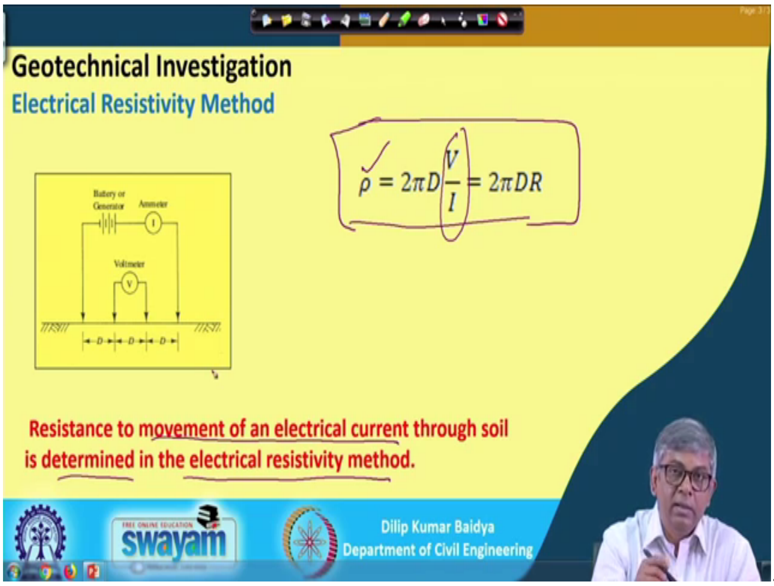

And, this resistivity method actually basically resistance of the soil actually by we measure and based on that we can qualitatively we can find out the type of soil. And, basically what we do in this resistance to movement of an electrical current through soil is determined in the electrical resistivity method. So, and this is a formula used actually that is your resistivity is equal to 2 pi D V by I and if I V by I is if I replace by R resistance.

So, 2 pi DR is the resistivity and if the typical experimental procedure is something like that it will be some distance it will be fixed and it will be volt will be from here current will be passed through this. And from there actually by measuring the this fixing the distance and all we can find out the resistivity ultimately, because we will fix the voltage and we measure I and D and from there actually we can find out the resistivity. So, for a particular forces what is the current passing and based on that actually you can do it and the D can be varied.

So, by this way one can find out the resistivity of the trial and sorry.

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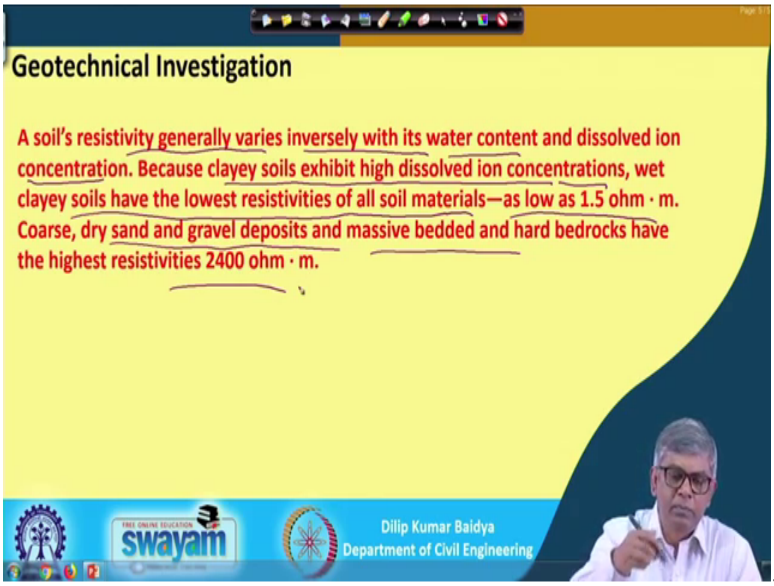

Some qualitative information about the resistivity as see if the soils resistivity varies inversely with it is water content; that means, if the soil has more water it will have less resistivity. Similarly, dissolved ion concentration, these two things; inversely proportional to the water content and these all, because of clayey soil exhibit high dissolved ion content concentration, wet clayey soil have the lowest resistivity of soil materials.

So; that means, in the clay soil charged particle actually in that ion concentration will be very high, because of that you will have lowest resistivity and the value can be as low as 1.5 ohm meter and coarse, dry sand gravel deposit and massive bedrock can have as high as 2400 ohm meters. So, these are some qualities; that means, where it will we expect less, where we expect high value.

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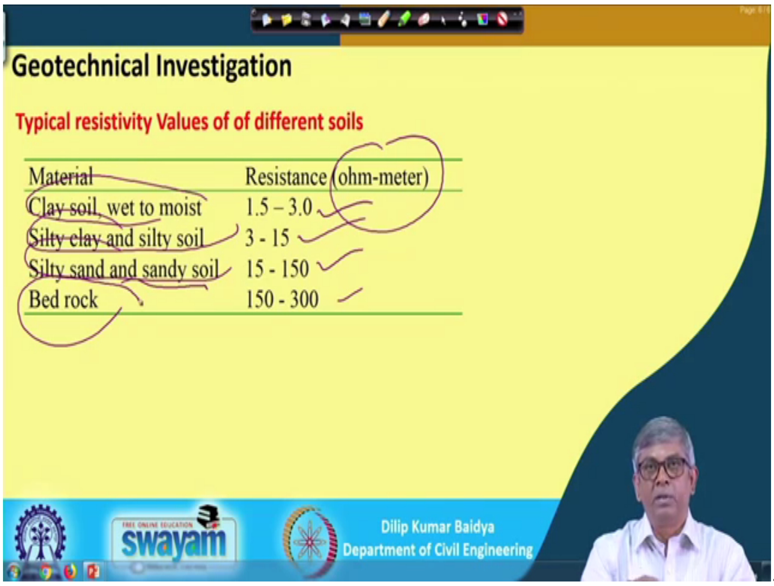

And, the typical values of different soils of resistivity is given in this you can see clay soil wet to moist 1.53 ohm meter resistivity.

So, it will be silty clay silty soil will be 3 to 15 ohm meter silty sand to sandy silt is 15 to 150 ohm meter, we have bedrock 150 to 300 ohm meter. So, these are actually unit of resistance and we can find out carry out the test at the site. And, then if you get these resistance and then we can classify the soil based on that at the range of values you get from the from the site, and based on that you can classify the soil either clay, or silty sand, or silty soil silty sand, or sandy soil, or bedrock something whatever maybe the values and based on that we can classify this.

So, these are actually some of the field test we carry out one is geophysical methods SPT CPT and there are some more tests that they are nowadays available the one is actually your pressure meter test, another is vane shear test and there are several other tests. So, I will discuss now about the vane shear test and vane shear test actually where it is applicable.

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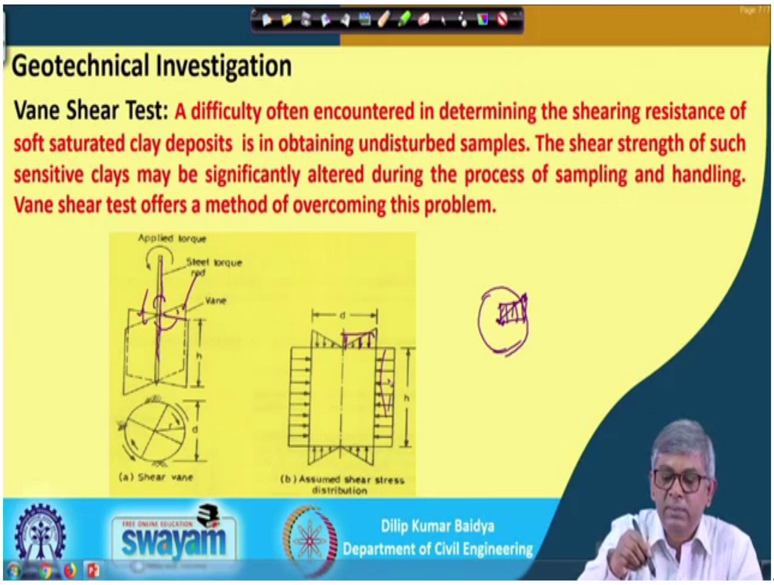

Basically, in the soft soil very difficult to get undisturbed sample.

And so, and why it is difficult and then while sampling ultimately if you sample it and you may find that it is it is structure is disturbed highly. And, as a result whatever we get that result from the lab test, it will vary significantly from the field condition. So, as a result these type of soil; that means, to the soft clayey soil, where sampling is difficult and during sampling processes too much disturbance happens. And, it happens particularly for sensitive clays sensitive clays means, that is a how much actually it vary when revolted and undisturbed condition.

So, that sensitive clay when it is there then in that case it is preferred to carry out vane shear test; that means, this vane shear test is a field test directly can carry out in the field. And, in this vane shear test. Basically it has 2 vanes; you can see one vanes here one vane is here, another vane is this they are at right angles to each other like this. And, then of course, it will be penetrate it will not be the penetrate at this middle of these were 2 rectangular sheet like, which is called here vane, they are making that point actually welded through a rod.

And, this is the rod actually and this rod when it is welded this is; that means, we can say at 4 part 4 blades molded at the rod at right angles to each other. So, this angle 90 degree, this angle 90 degree, this angle 90 degree, this angle 90 degree; so 4 vanes particularly in fact, 2 sheets meet at right angles to each other, but if you see with respect to rod then you can see the 4 vanes welded in the rod.

So, then this rod actually this vane it have particular dimension, it will have a height and diameter and where actually we need to carry out the test; first of all with this rod and we have to lower the vane inside the soil.

And, then slowly you have to rotate the rotate the rod; that means, by rotating what we are doing? We are applying a torque. And; that means, when you apply torque through this rod, then that vane will try to rotate within the soil. When you will try to rotate within the soil, then what will happen, there will be resistance at the bottom of the vane when vane is rotating like this, I rotating like this, rotating like this. Then you have actually will have resistance at the bottom similarly at the top also it will have resistance.

Because when it is rotating like this, that will be resistance and also when the vane is rotating like these then it on the surface there will be resistance. So, 3 different places it will have resistance and we can draw the resistance at the surface. And, the vertical surface actually cylindrical we can everywhere is average actually uniform pressure we can assume. And when it is at the base actually at the at the base actually what happens, you know the circular shaft when you apply torque, the shear stress distribution actually something like this, maximum at the center and 0 at the actually; maximum at the periphery and minimum 0 at the center. So, this is a distribution here also most likely it can be like that.

But, we can assume different types of pressure distribution and most of the time we consider uniform pressure distribution. So, this type of distribution we consider this type of the uniform distribution for simplicity. So; that means, we can assume everywhere this to this uniform pressure distribution there. So; that means, what from the bottom uniform the shear resistance from center to periphery. The top also uniform shear resistance from the center to periphery and that is nothing, but average and then surface there will be again this shear resistance will be there. So, now all shear resistance whatever is getting from bottom top and for the surface cylindrical surface that if is taken moment with respect to the center that actually must be equal to the torque applied.

So, that is the concept used here and if you do that you can see typically let me show you the in the next slide.

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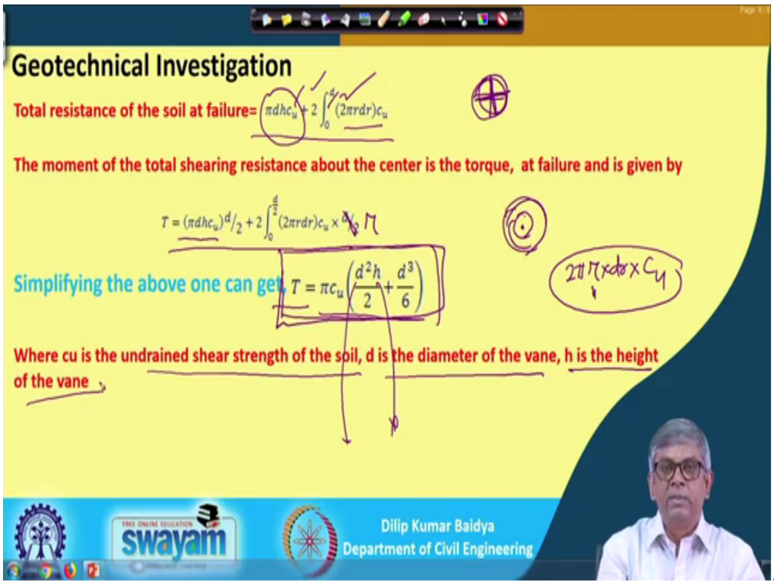

That you can see that so, here actually 3 parts, this is actually pi d. So, if this is the diameter of the vane suppose 1 and 2 other it is this is 1 and 2 other end. So, that and this is and 2 other end so; that means, this is the diameter of the vane. So, pi times d is the perimeter and then if you h multiply them vertical cylindrical surface and cu is the if the shear strength if I assume then; that means, from the vertical cylindrical surface we are getting this much resistance resisting shear test.

And, if I consider the at the bottom suppose one circular area and if I consider a at a distance r a small thickness dr, then it will have 2 pi r is the perimeter and thickness is dr and cr is c c u ; that means, that small thin annular ring if I assume for that shear resistant 2 pi r dr cu 2 pi r dr cu ok. So, and that can be integrated from 0 here I have taken a radial distance r so I can take 0 2 d by 2. So, it is not d it is d by 2. So, 0 to d by 2 you can integrate and since it is there at the top and bottom. So, I can multiply by 2.

So, it will become total resistance become this. Now, I as I have told that I finally, you are applying torque. So, I have to get torque here also. So, to get torque what I will do pi dh cu in to d by 2 that gives you the torque. And, here 2 pi r dr cu is your d by 2 I should write r actually because at a distance r I have taken. So, these r multiplied by these.

So, these become actually your total torque. Now, if I integrate these and simply, then you will get torque equal to pi c u d square h by 2 plus d cube by 6 this is the final formula equating relating applied torque, and shear strength of the soil undrained shear strength of the soil and dimension of the vane. What is the dimension of the vane d is the diameter h is the height. So, this is the way I can get and cu is the undrained shear strength of the soil d is the diameter of the vane h is the height of the vane.

So, this is actually I have got best on what actually though at the bottom at the above the vane at top and bottom when you are connected through the rod. And, you are rotating the rod while rotating the rod then entire vane will be rotating. So; that means, the entire vane within the soil is deep enough, then the above the vane and below the vane in both places there will be resistance. So, we have considered both surfaces actually at the bottom and top and based on that we have got relationship between the external torque and the shearing resistance of the soil occurring in terms of dimension of the vane.

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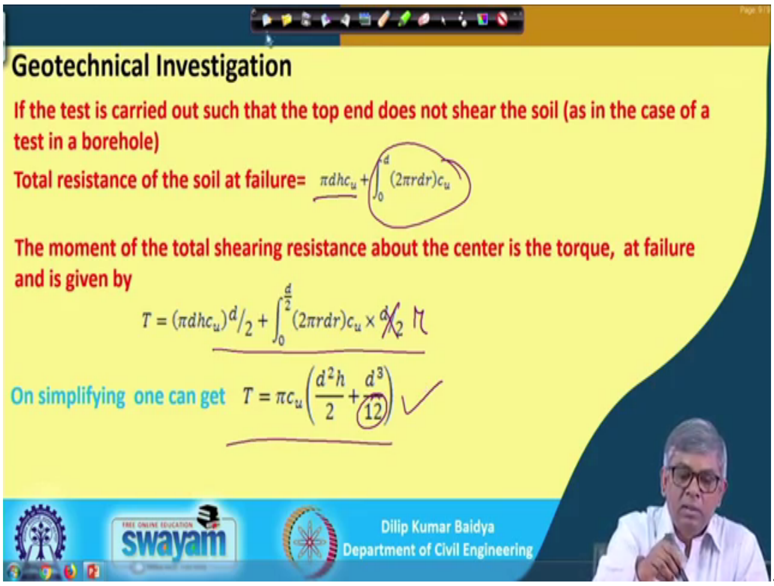

Now, this is actually many times many times you vane actually it may not be penetrated deep enough and as a result resistance from the top may not be. So, what is the procedure for carrying out vane shear test? We generally make a borehole and suppose I want to carry out test at 5 meter depth? So, I will make bore hole up to 5 meter and then through the bore hole I will lower the vane. And, then at from the bottom of the vane we may we may penetrate little distance, if that distance is not enough then actually what happens, then while rotating that resistance at the surface above the vane may not be enough so, can be ignored.

And, if you do so, if you do so, then you can see that in that case when one side resistance is that the pi d it is u is the vertical surface resistance and 2 pi r dr c u is the resistance from the bottom. So, I have not multiplied by 2, because I have ignored the top. Now, if I integrate now if I considered the moment, then it will be pi da cu d by 2 plus this is not again d by 2 it will be r. So, 2 pi r dr cu in to r then it become torque and I have not multiplied by 2 because only 1 I have considered. And, if I simplify this one integrate and simply, then I will get torque equal to pi cu d square h by 2 plus d cube by 12.

So, this is only from the previous equation it was 6; now it will become 12 because, if this was multiplied by 2. So, now, so, this is to; that means, based on the field condition; either you can use that one previous equation or you can use this equation that this equation is for what? This is actually ignoring the resistance from the top and other one is considered resistance from both top and bottom.

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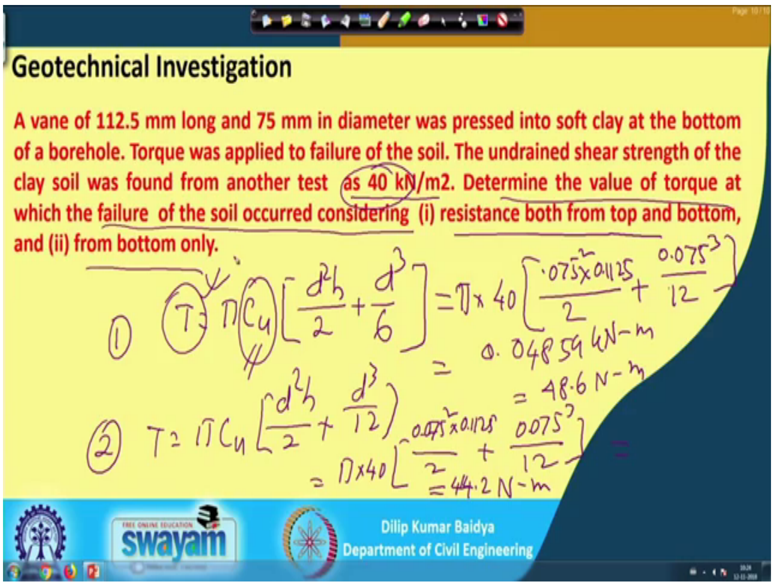

So, with this there will be a simple problem, you can see there is a a vane of 112.5 millimeter long and 75 millimeter diameter, was present pressed into soft clay at the bottom of a borehole. Torque was applied to failure of the soil.

So, we do not know the torque the undrained shear strength of the clay was found from the another test as 40 kilo Newton per meter square. Determine the value of torque at which the failure of the soil occurred considering resistance both from top and bottom and from bottom only. So, 2 cases; that means, first case; that means, if you consider a failure at both places resistance from both. So, that will be T equal to pi C u d square h by 2 plus d q by 12 d q by 6 actually this is 6; this is 6.

And, if I now put all those values pi multiplied by 40 multiplied by.0 7 square multiplied by 0.1125 all millimeter is converted into meter by 2 plus d q 0.075 q 12 by divided by 12. If I do this then you will get a value equal to simply you calculate in a using a simple calculator, then you get the value equal to oh sorry first one is actually 6 first one is actually 6 ok, they have done that.

And, it is actually coming 0.04859 kilo Newton meter or 48.6 Newton meter whereas, for second actually T equal to pi C u d square h by 2 plus d q by 12. And, if I put pi multiplied by 40 multiplied by 0.075 square multiplied by 0.11125, there were 2 plus 0.075 q divided by 12.

If, I do this one you get a value equal to this value will be equal to your 44.2 40 44.2 Newton meter. Initially it will come in (Refer Time: 21:39) Newton meter and then finally, convert 44.2 Newton meter you can see that when both side resistance was considered the resistance was 48 and one side is 44 definitely that is required, that is obvious, because torque when it will be one side is there torque will be less, but both side torque will be there then that value will be more.

So, that is the thing this is a simple calculation some time instead of giving this value torque instead of asking torque many a times, which will be given that that the test failed at a torque equal to these much, then what is the value of a shear strength of the undrained shear strength of the soil. So, torque will be given some time this will be asked.

So, here actually it is given here that value of the shear strength is determined from other tests this value, then what will be the torque that is actually before going to the test sometimes we may have to estimate what will be the torque required.

So, this type of calculation you have to, but again you go to the field will get the actual torque anyway.

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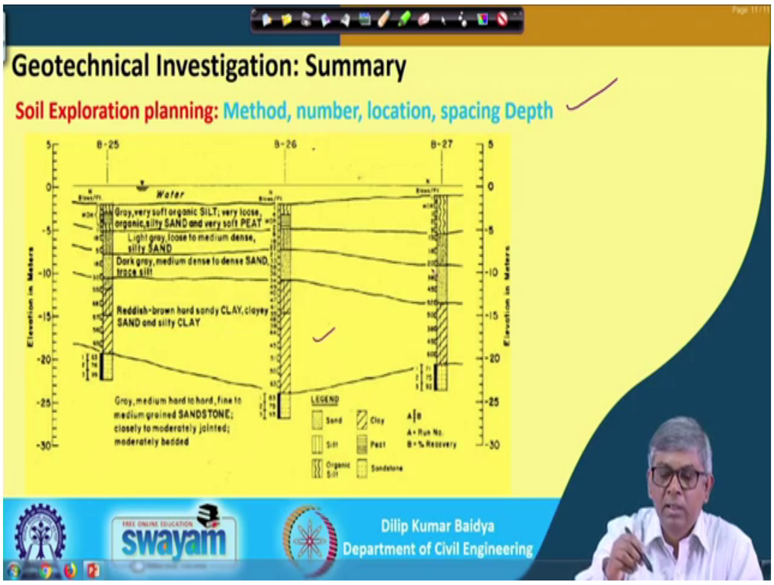

So, I will go to the next slide. And, you can now I will just with this I will complete the geotechnical investigation and just I will summarize actually. And, first of all as I have mentioned that when you plan for geotechnical investigation and you have to first plan actually you have to visit the site.

And then what method to be used for geotechnical investigation that to be fixed. And, then after knowing that then you have to find out borehole location number depth and spacing all those things to be fixed based on the importance of the project, or actually type of soil based on the type of soil. And type of project you have to first select what methods will be used, then first of all how many number of boreholes is required that to be fixed, and then where will be the bore holes actually bore hole location to be fixed, and then what should be the page spacing, and what should be the depth so, all those things I have discussed elaborately at the beginning, just I have summarize that in geotechnical investigation means what you have to do the boring first.

And, for that boring you have to fix the equipment and after fixing equipment you have to do how many bore holes where their location, what will be their spacing, what will be their depth based on the type of project. So, all those things to be done and after doing all those things finally, you have to get a you have to get a bore lock something like this. You can see borehole one about 25 26 27.

And we have got different types of soil within the borehole here actually we have got different types of soil, here you have got different and they are actually side by side some distance.

Then, if you get these type of variation then the by and large, you can visualize the profile of the soil in that area. So, that is the thing shown here, if possible that is the thing also one has to do in the soil testing report; that means, bore holes actually bore logs with details or stratification, this is the first part.

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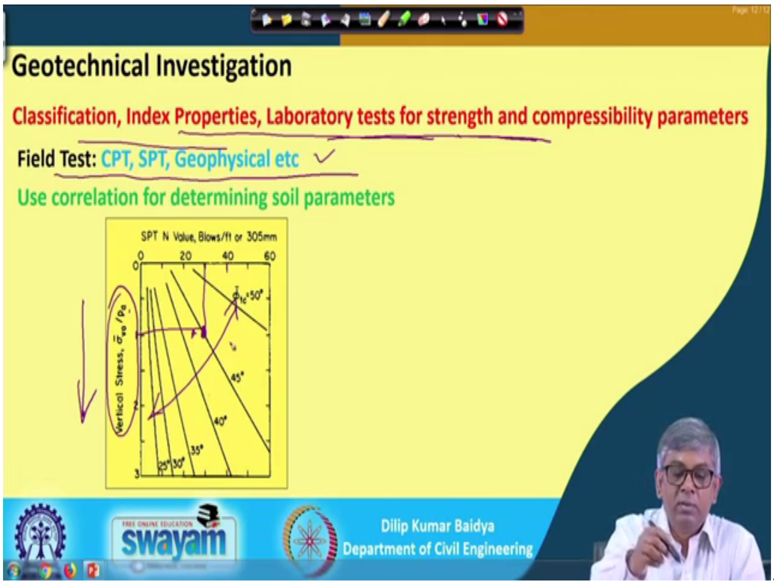

And then next is then after doing that, you need to do the classification of the soil; that means, after knowing that you have to collect sample.

And, from that sample actually maybe undisturbed sample you do classification and index properties. And, then afterwards if you have some your undisturbed sample, then you carry out laboratory test different types of sorry different types of laboratory test was there, different types of laboratory tests we have discussed that that like (Refer Time: 25:26) direct test, axial test, then concentration test, all those things to be considered and based on that you have to determine that different soil properties.

And, those soil properties has to be again reported the main value to be reported in a particular place and maybe details test results can be put into an excel. And, this is the one type of carrying out the test and then simultaneously, if there is a possibility, if there is possible, if it is possible then you have to carry out a number of field test and those are SPT CPT vane shear test (Refer Time: 26:08) test and some other test. So, to be carried out and then there may be some correlation with the soil properties with the SPT CPT, that you have to check and from there you find out the values of soil properties and at the same time you have to get you get the laboratory test.

And, you have to see that how they are actually with they are too much varying, then you have to do some more tests and you have to repeat, or you have to take some judgement. For finally, finally, to the (Refer Time: 26:38) the value of the of the soil properties. And, this is after doing this are the test field test and field test can be correlated with different soil properties. I have shown in the tabular form there are some charts form also available this is one of them actually that is PT values with effective stress and phi.

This is actually I have taken from old publication, because of that this is the new publication slightly different version is available this is directly effective stress. Here actually in non-dimensional falls is given vertical stress over P 0 and here it is given blow, similar to that only this side directly effective stress and this time blow, and these are the curve for different values of phi.

And, so, if I have suppose a blow count of 40 and effective stress of some value then, I will project on to that and then get the value of phi if the value comes somewhere here then I can interpolate between these. So, like that we can use that chart also to find out the value of the phi value.

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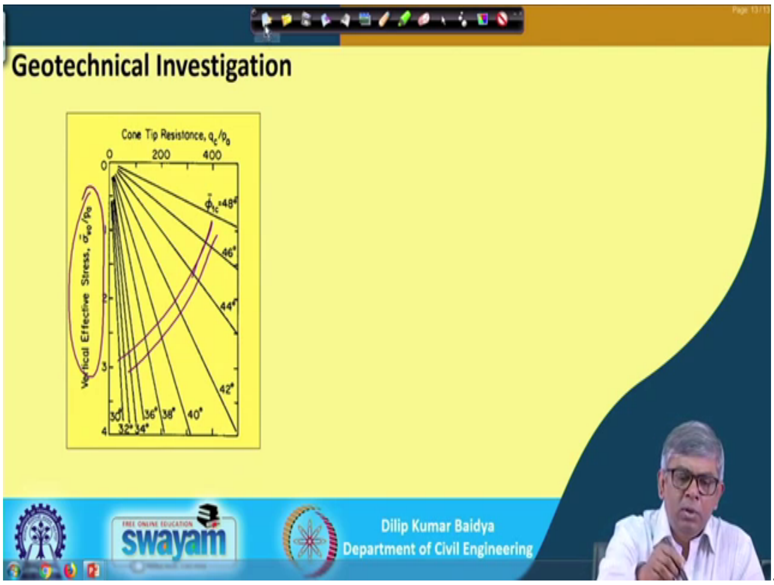

So, this is one chart similar to this using CPT also similar charge is available again this is also you old one so, that newer one. So, it will be directly effective stress and this is deep resistance and these are actually phi value. So, you can use the this type of chart after field test, the field test actually what you are getting cone resistance or SPT value and then use the chart to get the value of phi.

So, whatever tabular form I have given those table can be used also to find out or estimate the value of the c r stand parameter or some other parameter there are plenty correlations are available. So, with this I will just close geotechnical investigation there may be many things to discuss, but this is I have to stop somewhere. So, what are important I have just considered. Now I will go to the next topic maybe that earth pressure and stability of retaining water (Refer Time: 28:47).

Thank you.