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Indian Institute of Technology Guwahati
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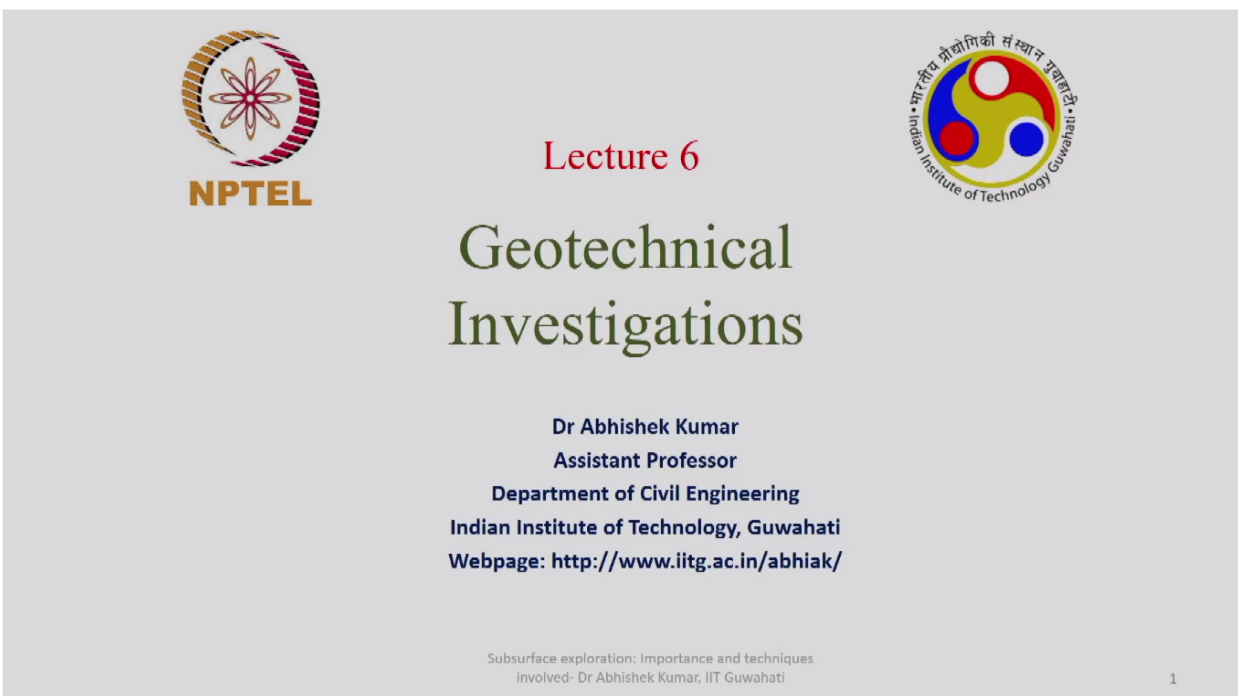
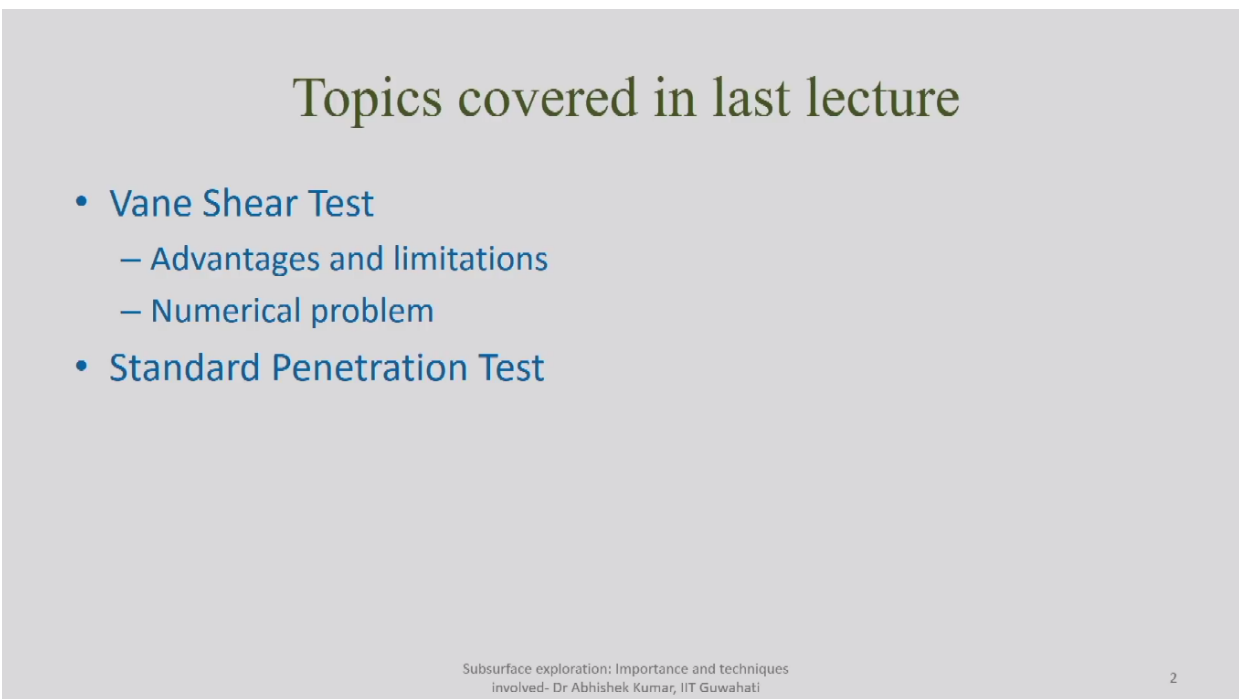


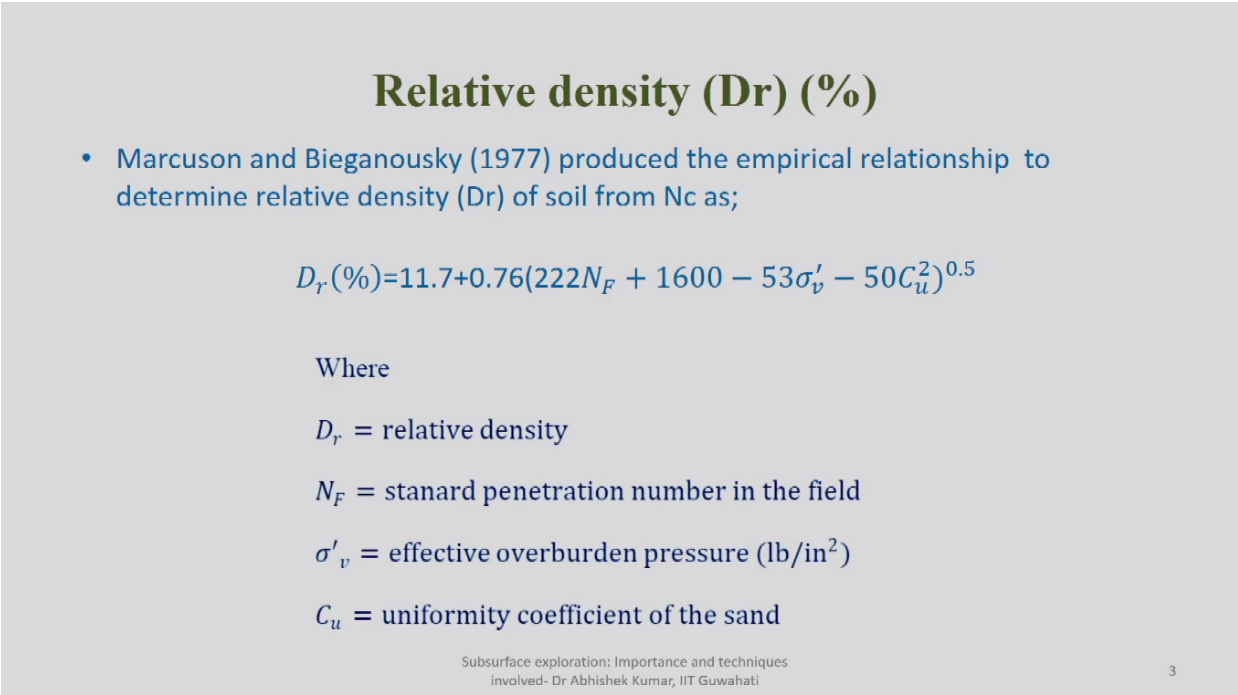
Welcome all to lecture 6. So again like last two classes we were discussing about different geotechnical investigation methods. Today also we will be discussing some more geotechnical investigation methods. So before we move to any other method, let's discuss about whatever we have discussed in next class.

Yeah. So we were discussing yesterday we actually we had discussed about Vane Shear test. So we talked about how we do the test, what is the test procedure, what is the setup required and then we move to what are the advantages of Vane Shear test particularly when you are talking about very soft clays in fully saturated condition where you find it difficult to collect undistributed soil sample you can actually determine the Vane Shear properties there itself in its natural condition just by lowering the Vane and then measuring the torque in it's natural condition and of course depending upon your rate of rotation you can later on call it as remolded sample and that's how you can also determine the sensitivity of the material.

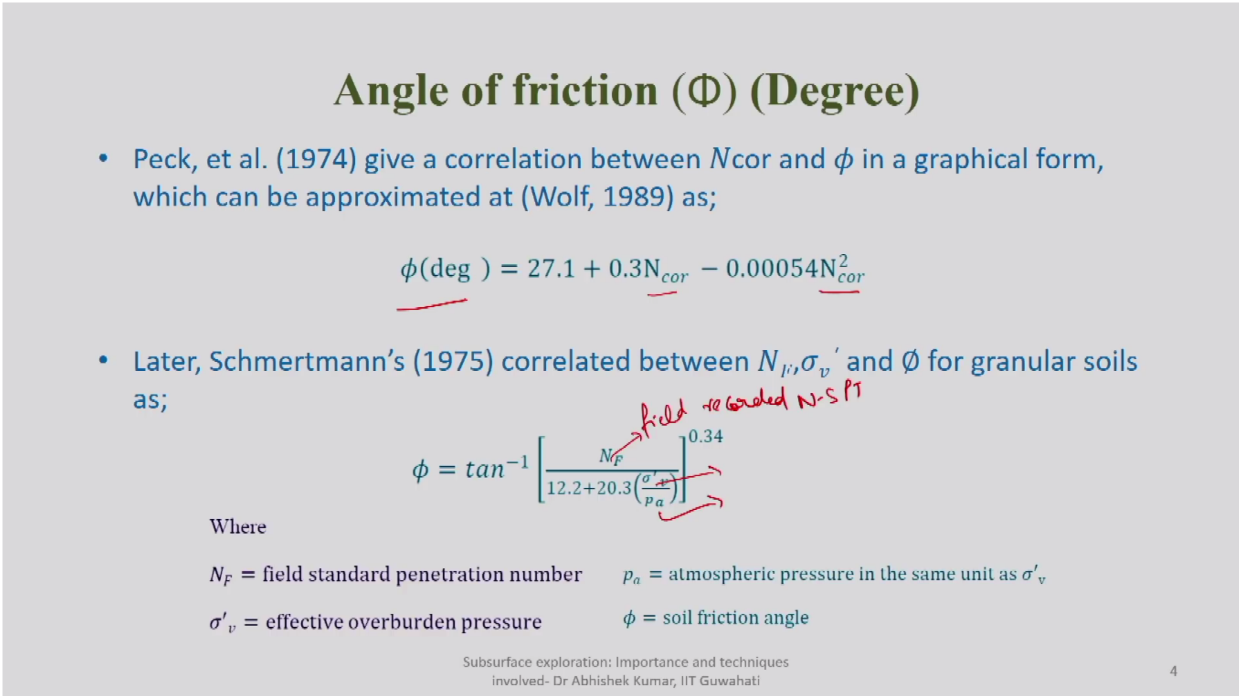
Then limitations also we discuss like in case of [00:01:40] material we cannot use it. Secondly, we cannot use it if the shear strength in horizontal as well as vertical direction are significantly different from each other. So we will discuss certain advantages as well disadvantage or limitations of Vane Shear test. Then we solve some numerical problem in order to understand like once you know the torque field measure torque once you know the dimension of the Vane to be used, and depending upon the depth from which you are determining you will be able to determine the shear strength property and Vane Shear properties. We solved some numerical.



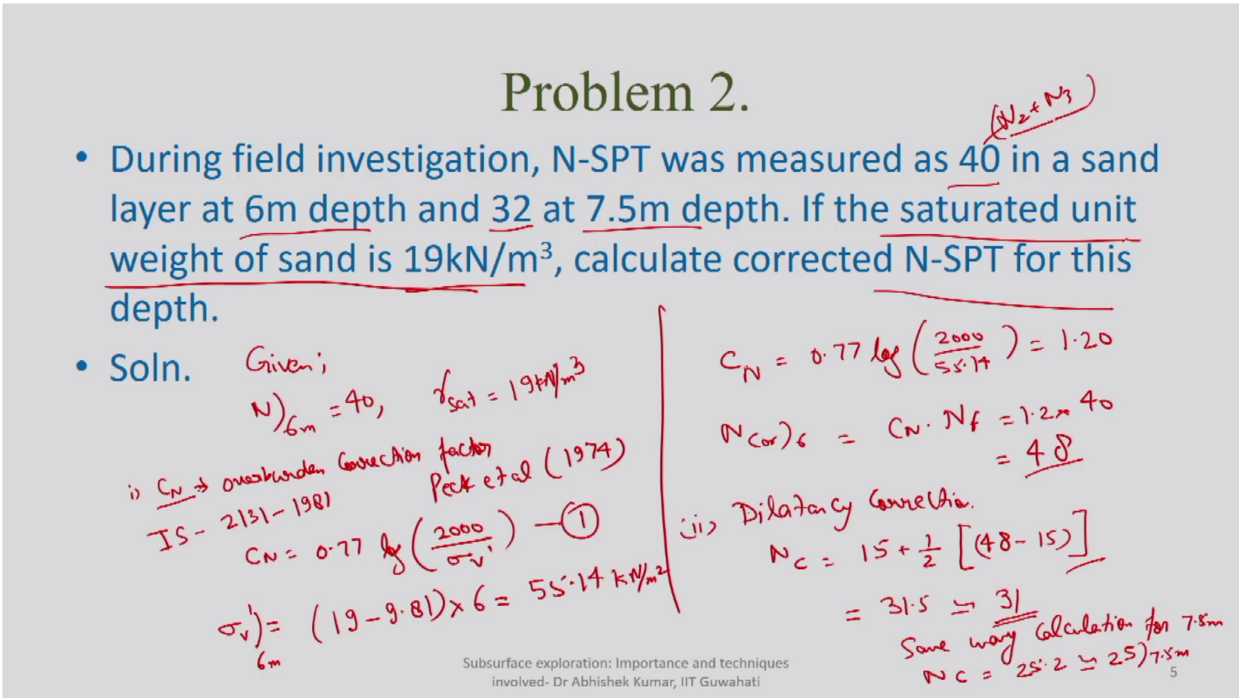
Then we also talk about another method which is called standard penetration test. More or less now it is being standardized method about the sample size upon number of blows interpretation and all that. So we had discussed about standard penetration test yesterday.



Today we will be discussing some more details about standard penetration test or probably what output we can get. So we were discussing like based on field investigation you get your NSPTN value. That is field recorded NSPTN value or NF and then depending upon the depth at which you are conducting the test once you get the value of sigma B prime that is effective over burden pressure NF value and CU values you can also determine the related density of the material at the site of interest.



Then same way if you know the corrected NSPT that is over burden correction as well as for [00:03:02] you can actually determine how much will be the angle of internal friction and same as per given by Schmertmann in 1975 you can also determine. You have to have the value of atmospheric pressure and you have to have the value of overburden pressure at the depth of the interest and then corrected NSPT for overburden correction you will be able to determine how much and this is like field recorded as NSPT value, recorded NSPT. So first panel requires corrected NSPT based for overburden correction as well as dilute integration. Second one, once you have field recorded NSPT you can actually directly use it for determination of angle of internal friction.



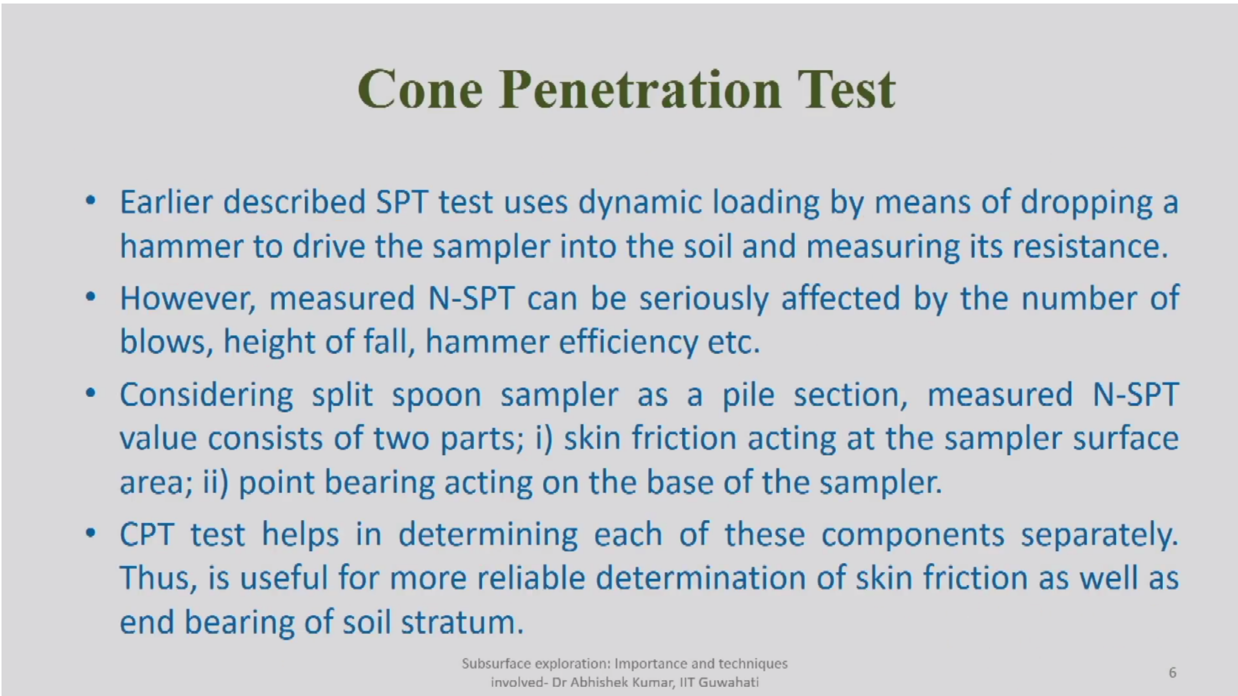
Okay. so today we will be solving some problem related to the yesterday discussion on standard penetration test. So the problem is like during field investigation NSPT was measured as 40 in a sand layer which is available at 6 meter depth and another at 7.5 meter it was measured as 32. if the saturated unit weight of the sand is 19 kilo Newton per meter cube so you know once you collected the sample you test it in the laboratory you will be able to understand what will be the saturated unit weight considering the ground water table is at the ground surface because no specific information is available in this numerical problem about the depth of water table. So we will assume the ground water table is at the surface. So you have to determine what should be the corrected NSPT. So you went to the site actually, you set up your SPT this monkey hammer and drilling arrangement, then dropping arrangement, then your sample you lower it at 6 meter depth once you reached you started measuring how many number of loads of 15, 15 and 15 centimeter penetration. And then last two penetration of 150 mm each how much is the number of blows, total number of blows like N2 plus N3 so this will lie here N2 and N3 values. So this is your N2 plus N3 values. N1 value we generally do not consider as I told you yesterday because it might be containing lot of disturbances from the surrounding activities as well as it may contain lot of agitations. So we will not go for N1 value. We will consider only N2 and N3 value.

Similarly, same test so after 6 meter you remove your sampler. You start again go for boring or drilling depending upon what kind of medium is available between 6 meter and 7.5 meter. You reach 7.5 meter then you again start, you replace your boring arrangement with your SPT sampler and then start again counting number of blows just like this for second and third 150 mm penetration. And it was found like 32 is the NSPT value.

It is told like considering this soil is saturated sand, having unit grade of 19 kilo Newton per meter cube which you can get from collected sample tested in the lab, you have to determine what is the corrected NSPT value. So corrected means you have to apply correction whatever we had discussed earlier. So let's solve this example but before going into detail let's see what things are given here. So we have – we know like things which are given here are number one is we should write here very clearly what is given here. So N value at 6 meter depth is given as 40 gamma saturated is given as 19 kilo Newton per meter cube. Okay. so based on this saturated unit weight what you can determine actually first of all you have to determine CN value that is overburden correction. Overburden correction factor. So for this we are actually using the correlation given by Peck et al, 1974. So specific correlation is suppose is asked to be used in the numerical problem it is generally mentioned.

Okay. this is also given. This is also recommended by IS 2131-1981 so IS 2131 also recommends you can use this correlation factor which is given as CN equals to 0.077 log 2000 over sigma V prime that is overburden pressure. So in order to use this first of all determine how much is the value of sigma V prime at 6 meter depth. So it will be corresponding to 19 is the saturated unit weight minus 9.81 is the unit weight of water. Then multiply by 6 that will give you how much will be the value of effective overburden pressure. So that comes out to be 55.14 kilo Newton per meter square.

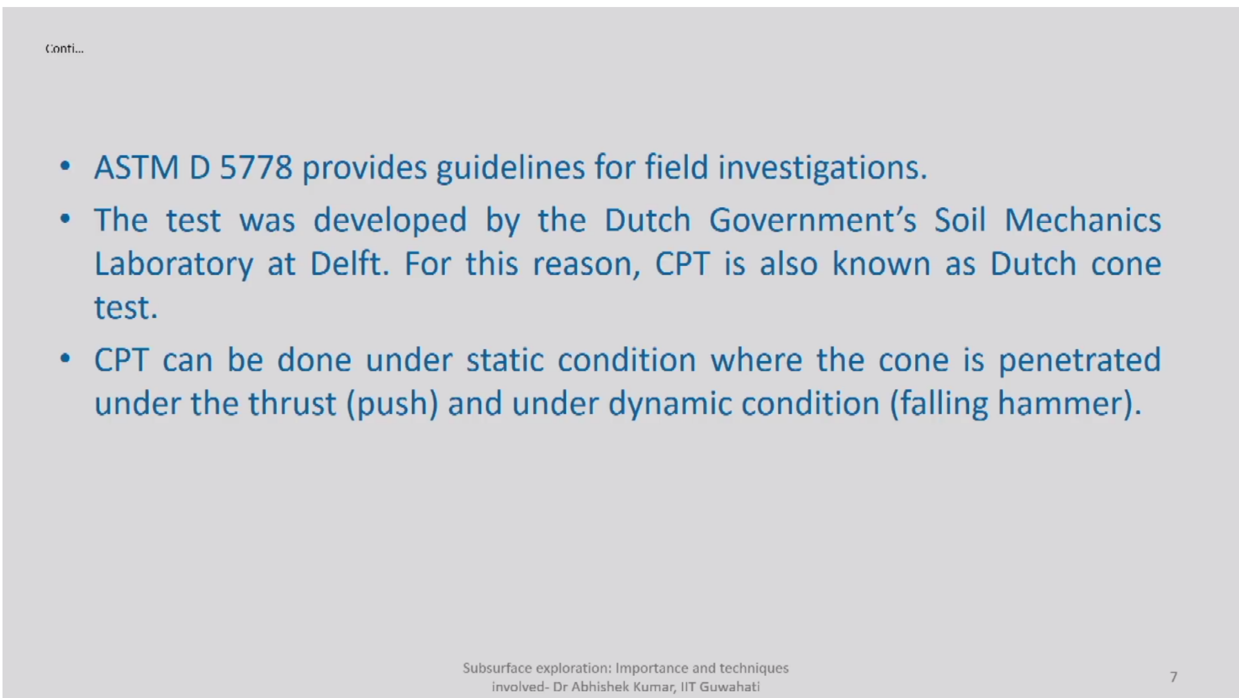
Okay. Once you know this value put this value in equation number one so you will get CN equals 0.77 log 2000 over 55.14 what you will get here is so you will get here CN value equals to 1.20. There are upper limits of CN values are also given. So then you will get N value corrected at 6 meter equals to CN times N field measured values. That will be 1.2 times 40 that will give you the value equals to 48. then apply second correction that is dilatancy correction. So dilatancy correction you have to apply that will be equal to NC that will be equal to 15 plus half because it is saturated and it is given as sand. So considering it is a fine sand condition then we will apply 48. So the corrected this dilatancy correction will be this minus 15 so that's how you can get how much will be the corrected NSPT for this correction. That will come around 31.5 because it's so the NSPT is actually the number of loads you have to round off to some whole number like 31 you generally round off at lower side because it is the indication of shear strength. So if you round off on higher side it will be considered as wrong because you will end up in over estimating the strength value. And same way, so same way you can do, same way calculation can be done for calculation for 7.5 meter depth also you can do it. So here you will get NC who are interested you can actually calculate the value of N corrected here. That will come around 25.2 so if you round it off it will come like 25 at 7.5 meter depth. So that is like though you have measured the value of NSPT as 48 at 6 meter depth but after overburden correction you found the value is 48 that is, it is actually somewhat more and then you apply dilatancy correction which is because of I mean if you remove the the effect of addition of resistance or additional force exerted by the pore water because of the rate of loading you ended up in over estimate. Actual NSPT of the soil at 6 meter depth is 31 depending upon that you can actually again classify or get an idea about what will be the related density of the soil, what will be the angle of internal friction, what is the consistency if it is other kind of soil. So same way you can do it for NC of 7.5 meter depth also. So this was about standard penetration test.



Then we have another test called as cone penetration test. As we discuss about standard penetration test earlier. So when we go for standard penetration there are certain though we have corrected the soil sample by dynamic loading but often there are always the major [00:11:42] values are always affected by number of errors. It will be because of particularly like the hammer efficiency, then second one is manually you are counting the number of loads there. There might be chance you miss some number of some particular blow or you will count more number of blows than whatever is actually provided. Third thing, when you are raising your monkey hammer ideally it should be raised by 76 centimeter. But in case if you raise this by some more amount then the impact load on the sampler will be more and you will end up in under estimating the CN strength property because you are giving more impact load than the standard one. So for same soil if you are giving more impact load, the number of loads will be less. So you will end up in under estimating the CN strength and vice versa. If you do not raise upto particular level then you will end up in spending more number of blows for the same soil rather it should be for 76 centimeter height of loading.

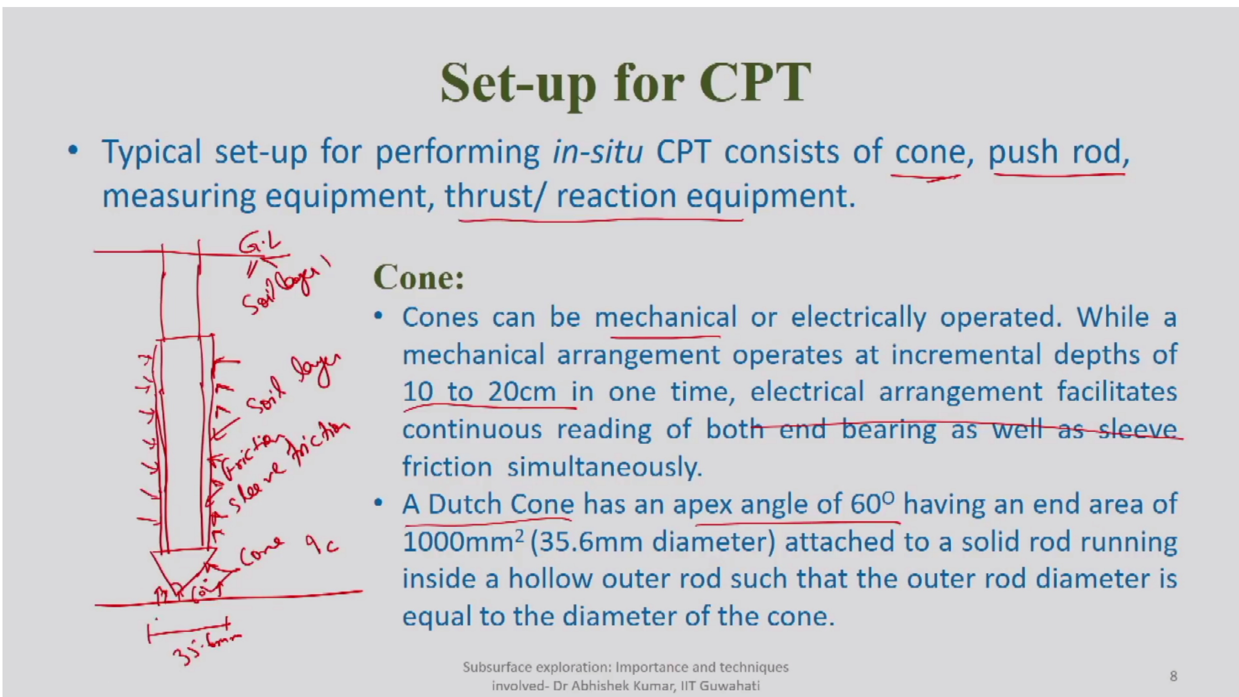
So overall to be summarizing here it's like the standard penetration test though it's standardized one but there are lot of error, I mean there are chances. Number of ways actually there are chances that the SPTN value you are measuring at the site can be affected or like two agencies are doing there might be chances because of these things like number of loads, hammer efficiency, height of fall or somebody has not marked the 15 centimeter interval by means of chalk properly then that will also affect your NSPT measure and values because and so on your CN strength of the material.

So finally what you mean to say like though you are conducting SPT test which is considered very dynamic test and you can get marginal disrupt sample or maybe times representative soil sample also but there are chances that the NSPT value whatever you are measuring it gets affect by number of parameters. So considering again considering split spoon sampler as I discussed earlier so you have SPT test. Once you reach the desired depth you push the sampler into the ground and then bring the sample onto the surface, you split it and then you have the sample with you.

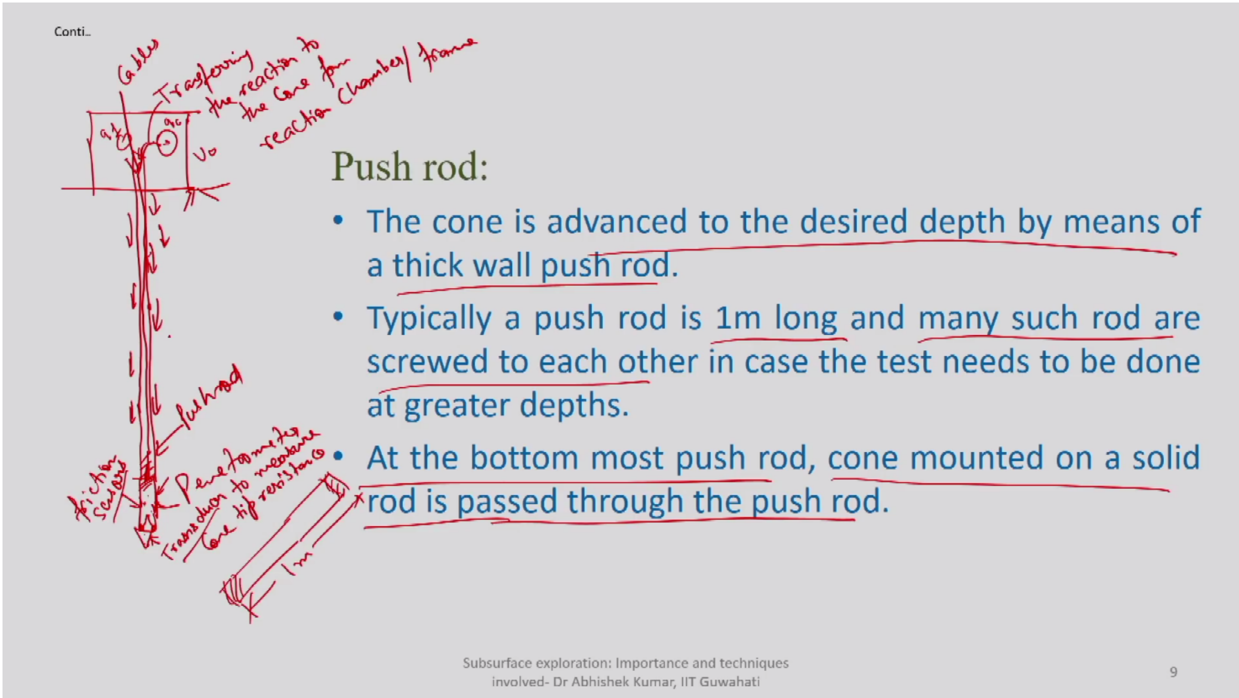


If you consider split spoon sampler as a pie section so measured NSPT value consists of two parts. One is skin friction acting along the surface of the sampler on the side of the sampler and second one is point bearing which is acting at the base of the sampler. But what is happening here you are measuring just one value. So you do not know what is the soil resistance in terms of skin friction, what is the soil resistance in terms of point bearing. You are getting a corrective measure here. So CPT test that is cone penetration test it helps in determining each of these parameters that is skin friction as well as end bearing separately. This will also provide a very useful information in determining the skin friction and end bearing because you are getting both the parameters separately, one is skin friction you are getting from observation. Other one is cone resistance or cone tip resistance you are getting from basically you are actually doing a test you are measuring two times measurements at the site. So one is at the base. Another one at the periphery of the test setup. So ASTM D 5778 provides guidelines which can be used for field investigation once you are going for cone penetration test to be conducted at your site of interest. The test was developed by Dutch Government's Soil Mechanics Laboratory at Delft that's why cone penetration test times many of the textbook they refer it as Dutch cone test because it was originally developed by Soil Mechanics Laboratory at Delft.

Okay. So this test can be done both under static condition where actually you push the penetrometer continuously into the soil and measuring its the resistance [00:15:49] by the soil in terms of end bearing as well as skin friction and secondly you can do under dynamic loading very much similar to your SPT where you will be applying some kind of impact load just like falling of hammer and then measure the two parameter. So one is continuous, other one is I mean regular interval you can actually measure the soil this thing.



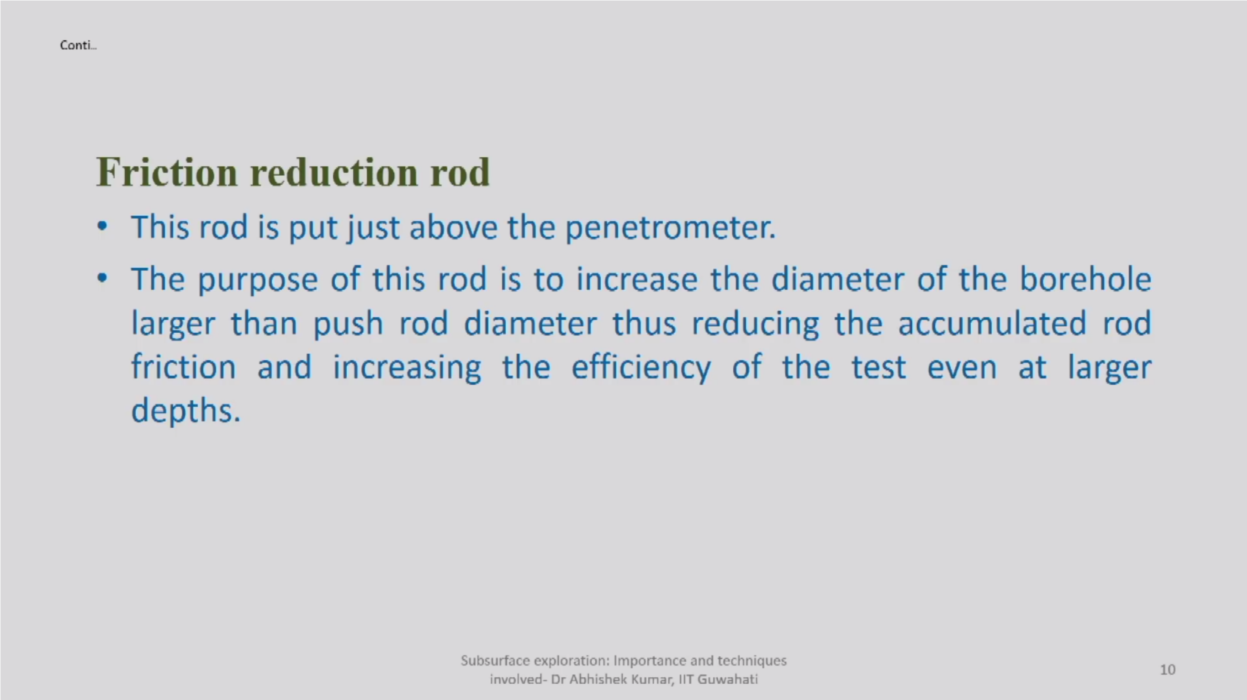
So when it comes to the test setup, so the test setup consists of so that typical test setup performing [00:16:19] consist of three parameter. One is the cone which is actually located by the lower end of the your test assembly which is actually pushing it into the soil. Then you have push rod [00:16:31] rod which are connected to your cone and transferring the reaction to the cone from the assembly which is maybe hydraulic or [00:16:41] platform which is actually transferring some kind of reaction to the cone so it is transferring getting by means of push rods. Then you are having measuring equipment which is actually measuring how much is the push or resistance you are getting from the soil layers at different depths and then thrust and reaction chamber with respect to which actually the cone is getting push force into the soil. So you are having cone so cone can be mechanical or electrically operated. So mechanically operated I told by means of fall of hammer then you can have electrically operated where you are actually continuously pushing it into the soil. When mechanically operated arrangement is made you can actually push it at an increment of 10 to 20 centimeter in one time. If electrically operated you can go for continuous recording. You keep on pushing the cone into the soil and every time it touches because as the cone is getting lowered it is actually displacing the soil. So the resistance offered by the soil at the tip and the resistance offered by the soil at the periphery of the cone both will be recorded. If it is mechanical the same pushing has to be done in stages that one stage can be 10 to 20 centimeter push at one then again another time then so on, it keeps on rotating, it keeps on adding more and more push unless it reaches the desired depth of interest and the other one is electrically operated so it will be continuously lowering into the soil of interest. So both can be done. Typically a Dutch cone hammer it consists of so there will be some kind of solid rod on which this cone will be attached. This is having 60 mm this angle and this will be corresponding to 35.6 mm. The solid rod after that there will be some kind of hallow rod will be there. Based on this you will be able to find out what is the friction. So you are pushing this assembly into the and then this will be connected to the solid rod or push rod. It will go to the ground surface, ground level where actually this assembly will be connected to the resistance chamber you can say or maybe hydraulic push kind of arrangement. So you see here you are having soil layers here. Soil layer. It can be one. It can be two and so on and then you are having another. This is called as cone. This is called as sleeve friction. So because of the soil which is available in this location you may get some kind of resistance here. Again penetration that will be called as cone tip resistance and then you will be getting another which is offered by the soil again in along the periphery of the this hallow rod and so on and so forth. So basically – so this is like Dutch cone setup which is called as Dutch cone which is having an apex angle of 60 degree having an end area. So if you take the cross section of this that will be corresponding to 1000 mm. So that will be 1000 mm square.



Okay. then you have push rod as I told you here. So this suppose this is the assembly which is you are actually pushing it into the ground. This assembly will be connected suppose this is your ground level. So in order to transfer the reaction or force or push from the ground surface you have to have some kind of arrangement which is actually attached to this assembly. So these are called as push rod which are actually transferring the reaction. You can write it transferring the reaction to the cone from reaction chamber or you can call it as reaction frame. So basically again this frame considering how much is the [00:21:21] weight of the frame you can actually provide any kind of push against the frame which is actually responsible for pushing this cone into the ground.

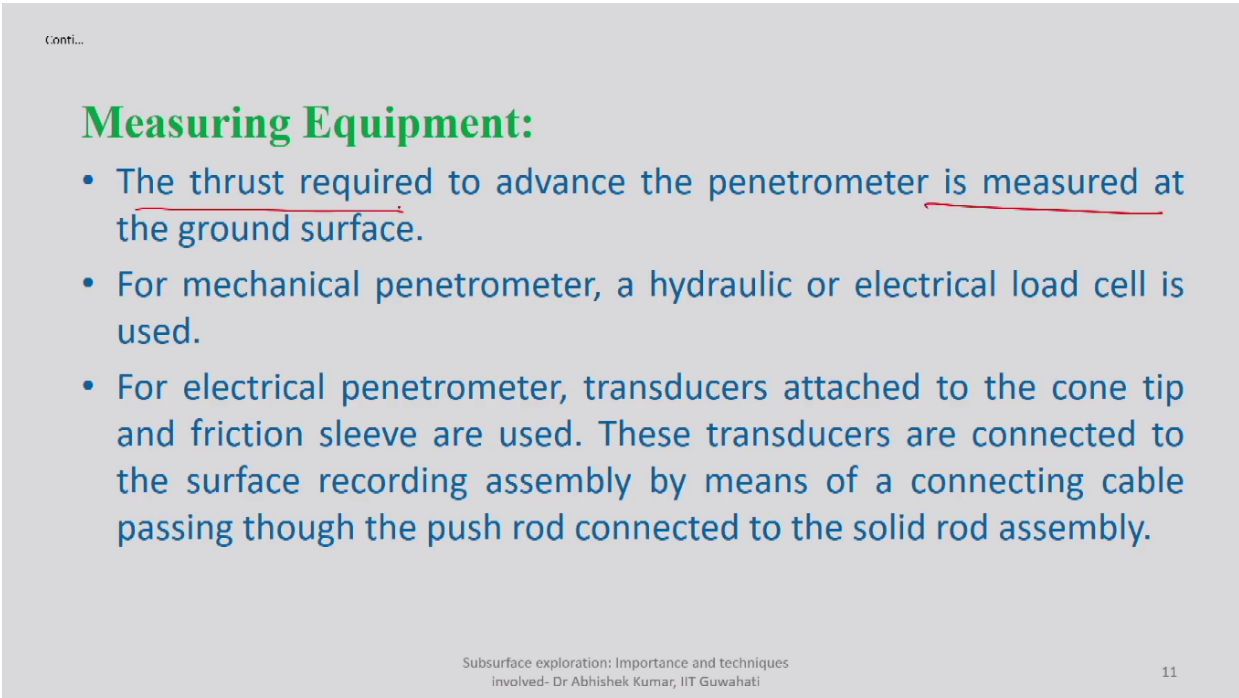
So this is called as push rod. There will be some kind of screws here and there will be some kind of screws here because of which both the cone assembly or penetrometer this entire assembly you can call it as penetrometer that will be connected to your push rod and that will help you pushing this rod or this penetrometer at deeper depth. So the cone is advanced. The same thing is written here. The cone is advanced to the desired depth by means of a thick wall so it is because you are depending upon the depth of which you are doing the test, the push rod should be strong enough so that it should not be get bend or it should not get distorted because of the reaction applied from the surface because the purpose is to transfer the huge amount of force on the surface to the depth of interest so the push rod should be strong enough. Typically a push rod is of one meter length and many such rods are screwed to each other so there will be screwed on both the ends so it depends upon each rod is suppose one meter length if you are doing the test for ten meter you will add up equivalent number of rods how many will be required minimum ten rods will be required once you are doing the test of ten meter depth and so on. So you keep on going for deeper depth you keep every time adding more and more rods but what happens at the center because you are actually measuring the resistance so there will be some kind of transducers here. Some transducers here also which are actually some kind of gauges or sensors which are actually measuring the – to measure cone resistance, cone top resistance. So once it measure it has to be transferred to the surface and same way here also there will be some kind of friction sensors. So each time you push it into the ground it will record something and then there will be some kind of cables will be there. It will be passing through this push rod because keeping these are hallows. So these are called as – these are cables which actually transfer the recordings or measurement done by the transducers or the sensors at these two locations. Sometime you are having pore pressure measurement sensors also here. So again that will also impact some additional field measurements because of the [00:24:08] these field measurements will be connected to some kind of assessment here or maybe gauges which will give you how much pressure will be required because this is lowering continuously so continuously there will be measurement of QC value that is cone tip resistance or there will be value of skin friction also. QS and QA value and same way you will be having some value of [00:24:31] that is pore pressure measurement.

So at the bottom most push rod the cone mounted on solid rod as I told you this is the cone which is mounted on solid rod and around this there will be hallow rod in between these two the assembly will be able to measure how much is the resistance along the surface. So the lower most rod that will be connected to the push and again there will be because push rod is hallow so the cable which is transferring the measurement from the sensor to the surface assembly will pass through. So it's like beforehand you should have some idea like what is the depth of investigation you have to do because equal number of push rods you have to make ready and before you start the test from those number of rods actually this kind of cables should pass. So every time one cable is lowered you have to attach another cable make sure that the push rod should contain the cable inside otherwise you will not be able to connect the push rod, you will not be able to connect the cable to the assembly. So because it's a continuous you cannot do such kind of alternation during the test.

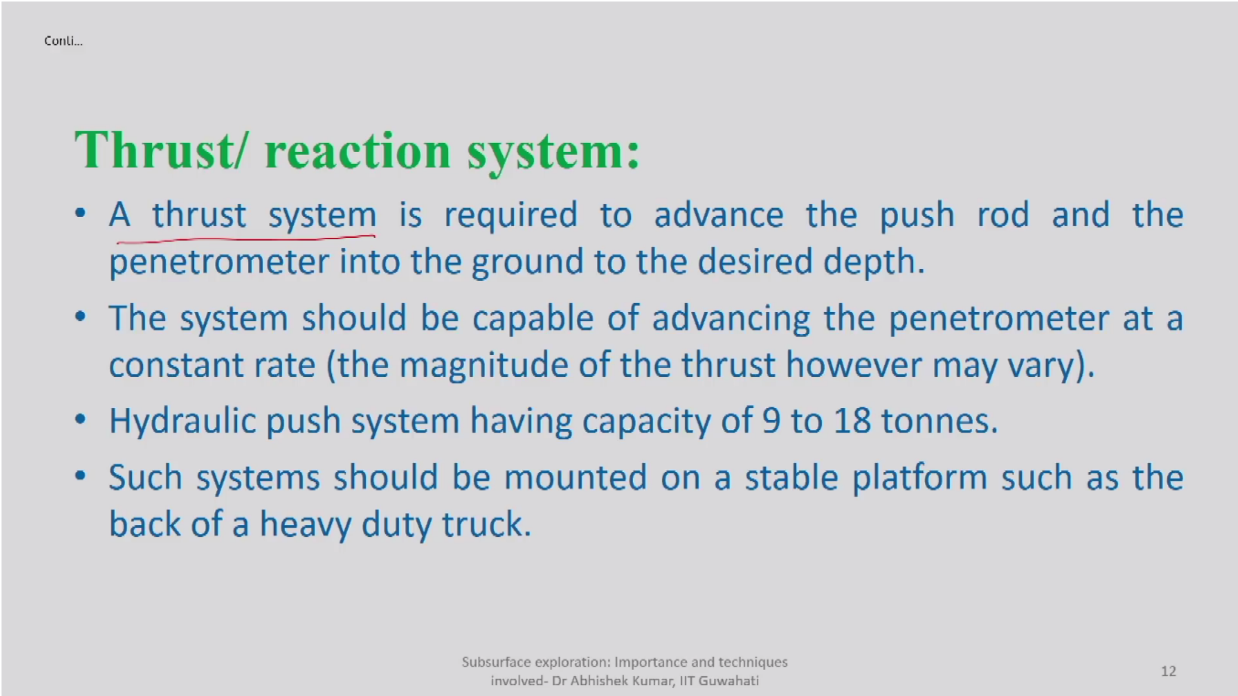


And the third one which is at times used it's not everywhere it is not practiced. So that is frictional reduction rod. This rod is put just above the penetrometer. So just above the solid rod this rod is put. The purpose of this rod is to increase the diameter of the borehole larger than the push rod so that it will reduce the amount of cumulative friction on the rod provided by the borehole material and thus increase the efficiency of the test even at larger depth. So if you do not put what happens there will be because friction whatever you are telling you may get more number of I mean large friction of friction even from the layers which are not surrounded by the penetrometer. There might be some you can get friction from superficial layer or surficial layers which you are actually not targeting once you reach a particular depth. So in order to ensure like the penetrometer is only measuring the resistance of rod by the soil surrounding this penetrometer you have to make sure that the soil which are above this penetrometer are sufficiently space apart from the [00:26:57] rod or push rod.

So for that you have to actually provide some kind of friction rod. Friction reduction rod because you are not – once you provide this kind of rod you will not be getting additional friction from soil layers which are actually located above the penetrometer in a particular role.



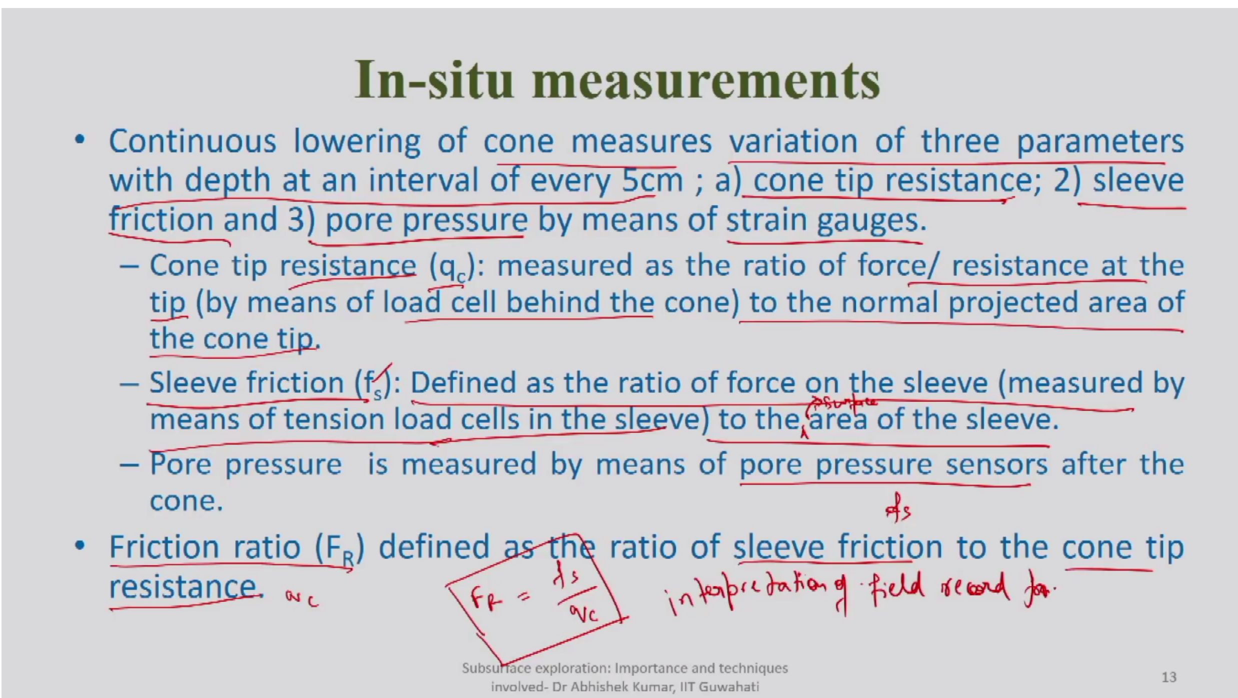
Okay. So then field measurement this measuring equipment the thrust required to advance the penetrometer is measured at the ground surface. That's what I mentioned earlier also because you are pushing it into the ground so every time you push it will be measuring some kind of cone tip resistance. It will be measuring the skin friction also. Once it records because it's constantly pushing the same thing you will be recording at the surface. This is called as the thrust required to advance the penetrometer will be measured at the ground surface. For mechanical penetrometer hydraulic or electric load cell is used that can directly – you can quantify how much is the load you have applied. For electrical penetrometer transducers attached to the cone tip and frictions sleeves are used. These transducers are connected to the surface recording assembly by means of connecting cables. So whatever cables I was discussing those are called as connecting cables passing through the push rod because push rods are hallow. So through those push rods it can actually connect your measuring assembly to the penetrometer which is kept at the surface.



Then thrust reaction or because finally you are pushing it so you have to have some mechanism based on which you can apply some kind of reaction. You can build up that reaction or force which is responsible for pushing this cone to different depths. So a thrust system is required what we will do. So we will have some kind of generally like truck pounded reaction chambers will be there. So your entire assembly for whether it's push rod, whether it is penetrometer, whether it's friction reduction rod connecting cables, gauges for measuring different kind of resistance everything will be kept in a chamber and that chamber will be mounted on a mobile truck. The truck should be heavier so that whatever reactions we are getting because you have to push the cone into the deeper depth so unless the reaction chamber or the truck is heavy enough what will happen as you start pushing a deeper depth it will actually the resistance offered by the soil if it more than the reaction chamber capacity it will lift the truck itself. So a thrust system is required to advance the push rod and penetrometer into the ground to the desired depth. So you have to again just like I told like depending on the depth you are targeting for you have to arrange so many push rods and from each of those push rods you have to pass the connecting cable. Same way if you are targeting for deeper depth your reaction chamber or the thrust chamber which is actually providing the force which is driving the cone to that particular depth you have to take into account what is the capacity or what should be the capacity of the reaction chamber.

The reaction chamber should be capable of advancing the penetrometer at constant rate. The magnitude of the thrust however, may vary. Hydraulic push systems having a capacity of 9 to 18 tons. Now you consider 9 to 18 tons itself is required when you are targeting to measure the SPTN value for to measure CPT value maybe in the range of 15-20 meter like that. So now you understand what you should understand like as you go deeper and deeper there will be lot of confinement and in order to measure the resistance by this particular method there should be some kind of failure happen in the soil. Otherwise, it will not give you the resistance offered by the soil. So in order to make that kind of failure to occur you have to apply sufficient amount of thrust or reaction.

So this is like 19 to 20 is fair enough to give you idea like what is the magnitude of the reaction we are looking. Such system should be mounted on stable platform because otherwise if the platform is not stable you go deeper, you start applying reaction, by chance if it gets tilted then either it may break the push rod or whatever values you are getting it will not be correct. So it's mandatory like even though you have mounted on the truck, that truck once you setup at the – once you position at the site of interest there will be some kind of lifting arrangement which will actually lift the entire truck or reaction chamber and provide more stability against later movement. You can check also. Example is given like heavy duty truck. You can use it so once you go to the site, once you enter it at your specific location where you have to do that test you can actually provide those steady platforms or legs lift the truck entire truck so it will not go any kind of little movement then you start applying reaction against the load of the truck itself. And whatever resistance offered it will be measured by the gauges available at the.

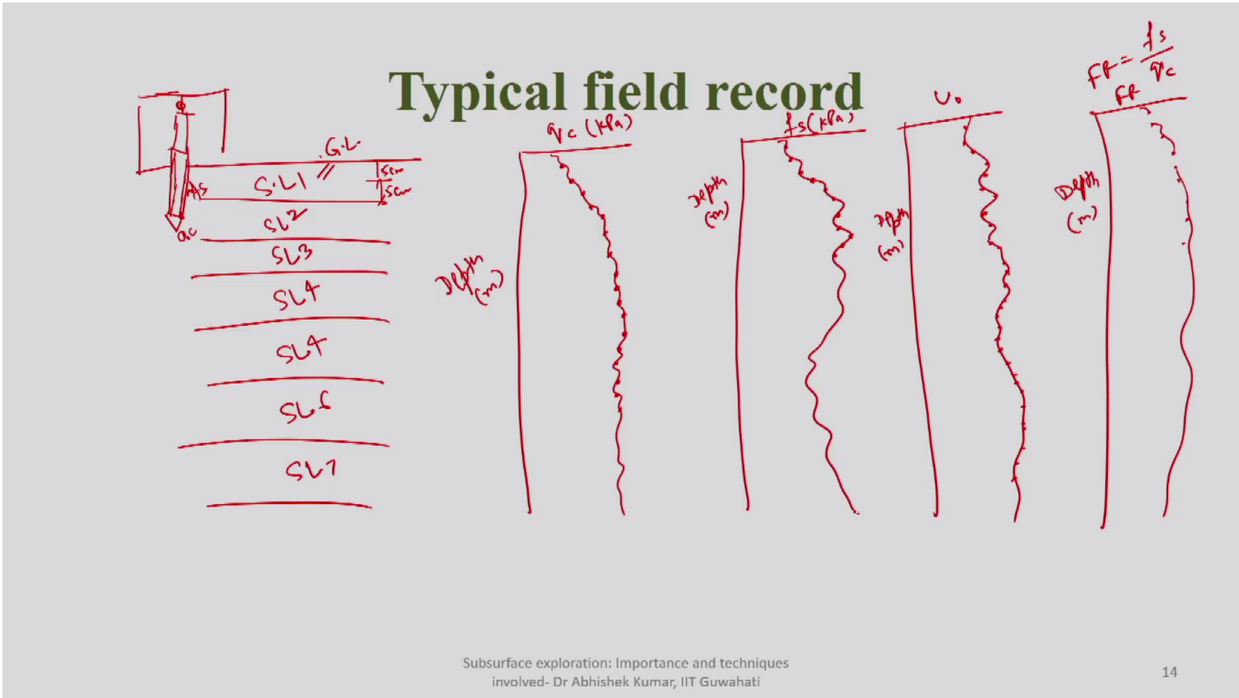


So it's like okay you went to the site, you centered your equipment, you started lowering then what field recordings you have to do. So first one is contentious recordings so let's discuss about field measurements. Continuous lowering of cone measures variation of three parameters. As I told here it keeps on recording at every interval of five centimeter. So you will have some recording then after five centimeter another set of data will be there. Another five centimeter another set of data and so on till the depth you go for – till the depth of your interest. So once it reaches any depth it measures cone tip resistance, the resistance offered by – offered against the push by the soil available at the tip of the cone by means of transducers in terms of cone tip resistance. Second one is sleeve friction or the resistance offered by the soil which is available all around the penetrometer and third one in case it is saturated condition you may get pore water pressure also by means of [00:33:33] gauges. So cone tip resistance that is generally indicated by Qc measured as the ratio of the force or resistance at the tip by means of load cell behind the cone to the normalized projected area because finally this particular load whatever you are applying from the top and which is causing the failure at the base of the cone it is like the load will be there and then the projected area. So the load divided by area that will give you the tip resistance. So that is kind of stress.

Then you have additional stress that is called as sleeve friction also called as Fs defined as the ratio of force on the sleeve or on the vertical edges of the penetrometer measured by means of tension load cell in the sleeve itself between the hallow rod and between the solid rod to the area of the sleeve, to the surface area of the sleeve. So you have one resistance at the base. It's like the force at the base causing the failure divided by the area of that projected area. Then another one is the failure happening around the sides. So you have to have how much is the force taken by the surrounding soil divided by the peripheral area or this is called as the – you can call it as the surface area of the sleeve.

That will give you this thing and the third one is pore pressure measurement that we generally do by means of pore pressure sensors directly. So you need not have any area to be used here. Okay.

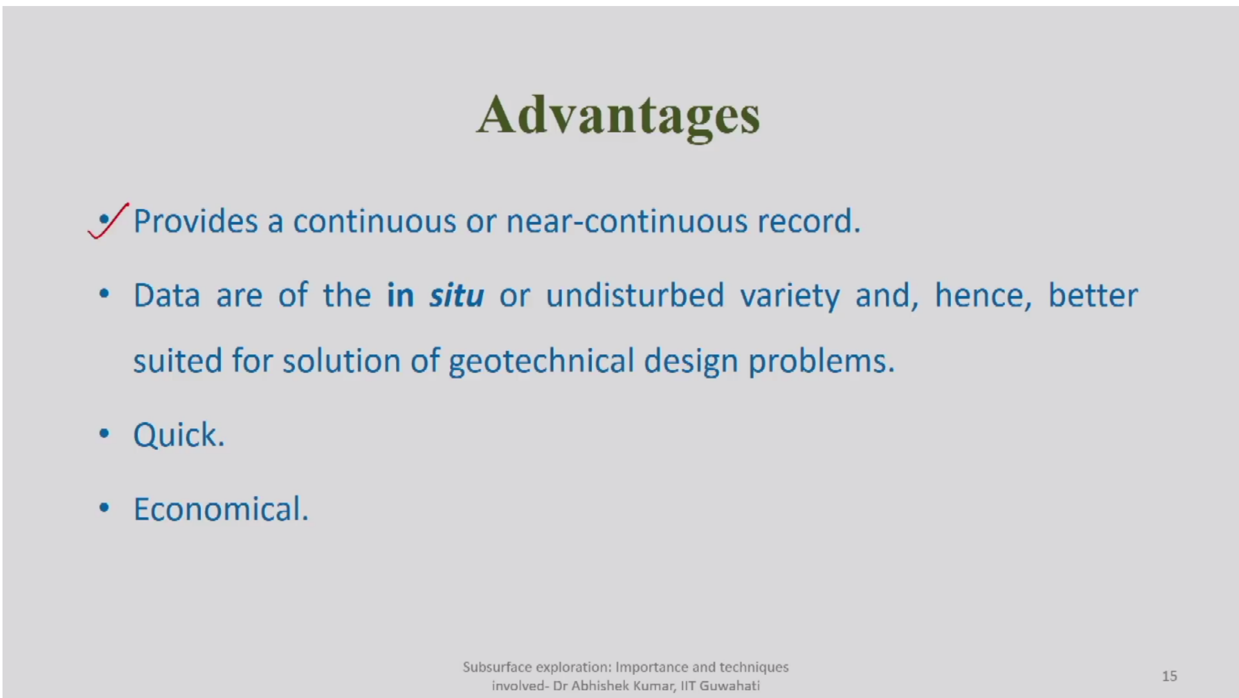
So then you can determine one parameter which is called as frictional ratio. Friction ratio is defined as the ratio of sleeve friction that is Fs and then cone tip resistance and that is Qc. So you can call it FR equals to Fs over Qc. So you went to the site measure this parameter based on your gauge readings and then determine this parameter. This parameter will be required because now you see your target was determine to identify the soil to find its [00:35:53] strength and other properties so that you will have better understanding about what kind of soil is available whether the soil is sufficient enough for the kind of load I am targeting for. So for easy now it's like now your field measurements are done you are going for interpretation of your field records from SPT from your CPT test.



Okay. So typical field loads you can see like as you go at the site of interest you will be having different soil layers. I can say soil layer one. Soil layer two. Soil layer three. Soil layer four. Soil layer five. Soil layer six. Soil layer seven and I am considering here also within this this is like five centimeter. And so on other thickness and this is your ground level. You start pushing your penetrometer here. There will be this hallow rod and solid rod which is and then this is connected to your reaction chamber which is actually pushing it with reference to this you are actually pushing this into the ground every time it reaches it will measure your Qc value it will measure your Fs values.

So if you see here with respect to the depth because it is giving you continuous recordings you will have with respect to the depth maybe measured in meters you will have some value of Qc depending upon the unit, depending upon the soil type of resistance offered by the soil. So you will have some value like this, kind of this.

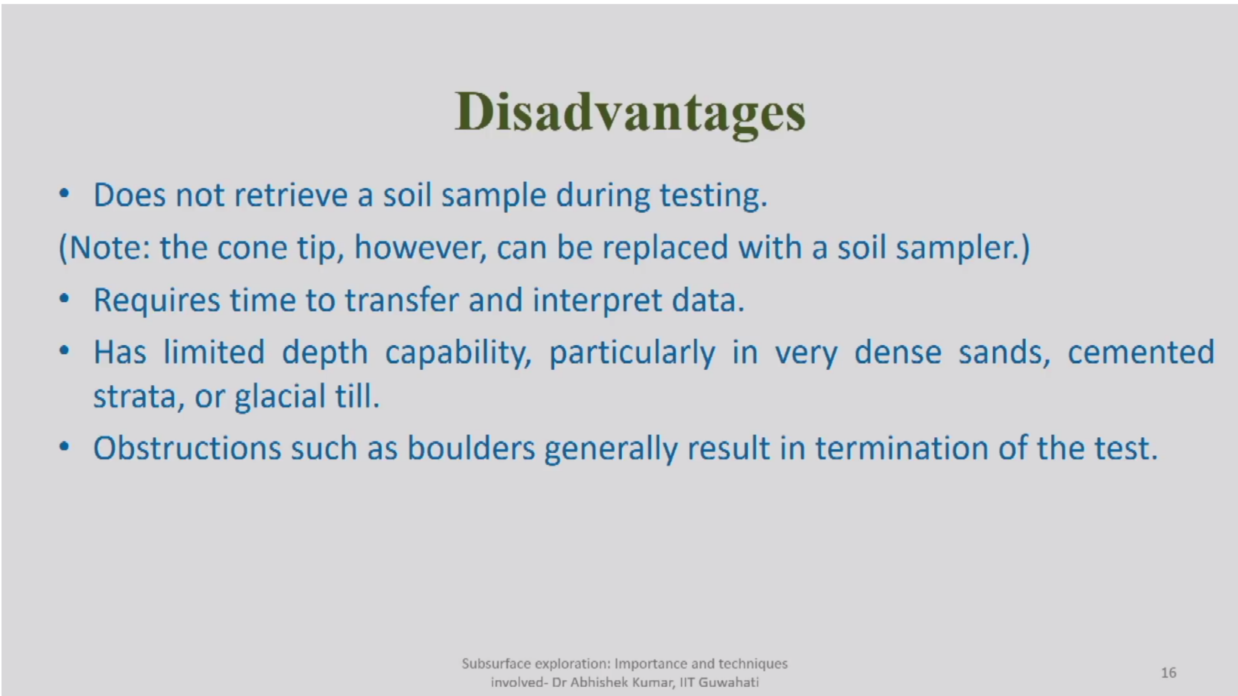
So this is like the value you will get from your field recording itself. Then at the parallel you will have some values of Fs maybe also in KPA or MPA also and then here also it is depth. This is like typical field record I am trying to show you here. Then there also you can have some values like this depending upon how much is the resistance offered along the periphery. Then third one maybe U0 value or pore water pressure again with respect to the depth. How much is the pore water pressure? Again that depends upon how much is the – what is the level of ground water table. You may have similar value or you may have some incremental value or so on and so forth. So these are the three things and then you have FR which is known as Fs over Qc. You determine those values so this FR value with respect to depth depending upon the Fs value and FR value this also you will get it. So I have connected but each of this will be having values measured at 5-5 centimeter interval. So though I have joined each of these points by continuous line but you will not have I mean you will have recording at each five centimeter interval. So this line is composed of joining the points at 5-5 centimeter interval. These curves and so on and so forth for this also. But you remember in mind like you are doing the test at the site of interest from the ground surface also. So this test is not going to give you any kind of so far you have not – you are not aware about any sample you are going to get or not. But this is the information you get once you lower your penetrometer and these are the different kind of measurements you can actually do at the site. So based on this you have to actually interpret different parameters. These are typical field record. Then you start interpretation.



Before going to the interpretation we will discuss about advantage because when you go for SPT test particularly so you do generally the test at regular interval of 1 meter, 1.5 meter , 2 meter. Standard is 1.5 meter but again depending upon the designer recommendation you can go for lower rate of sampling or maybe higher rate of sampling. So if some soil layer very small layer is there you will end up in neglecting that soil that will not be reflected in SPT thing but here you can get continuous or near continuous record of soil sample in terms of Qc and Fs value.

Then data are in in situ condition because you are not collecting the sample and bring it onto the surface. Whatever resistance the soil is offering whether it is end bearing or friction it is in its in situ condition very much similar to you Vane Shear test.

Hence better suited. So whatever property you are determining you can directly use it for geotechnical design problems or solution to geotechnical problems quick because you are not unlike your [00:41:12] where you correct the sample, you bring it onto the surface then lower your boring assembly. Then the next step of interpretation you again collect the sample, here you are not replacing the boring and sampling assemblies but you are doing actually continuous recording. So it is quick. It is economical and most another thing is like chances of error also it will be very less because no where you are doing it anything manually.



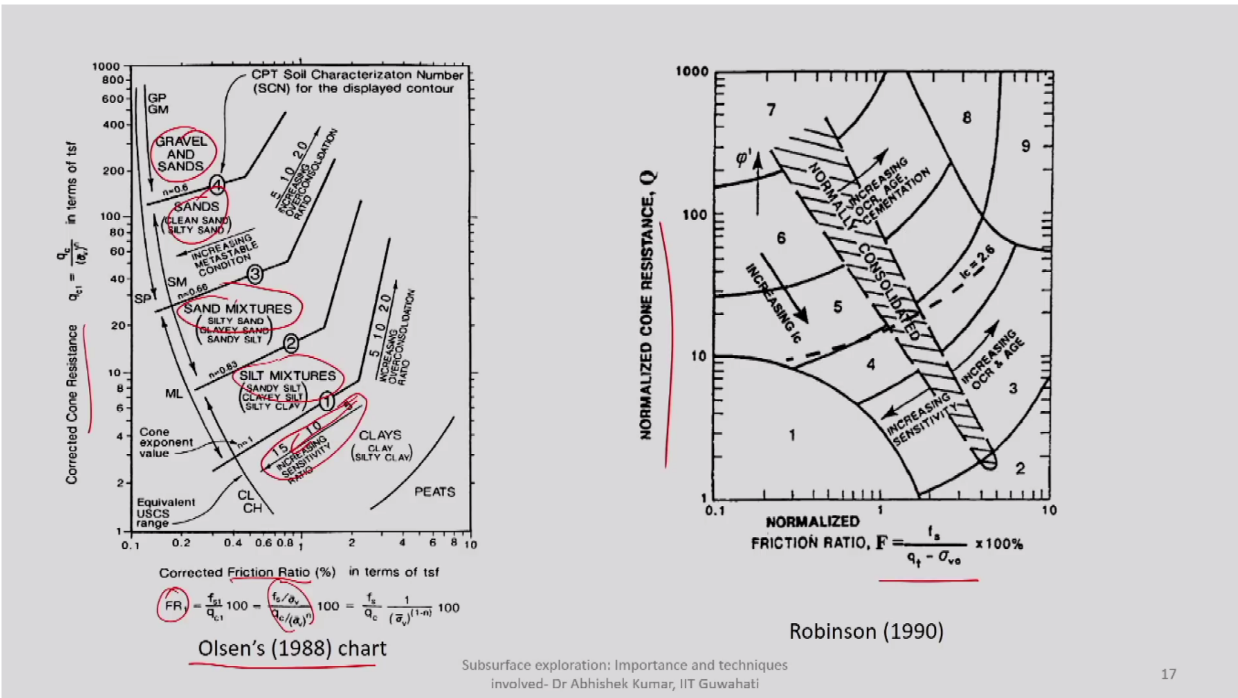
However, there will not always be advantage there are certain disadvantage also. So it doesn't retrieve any soil sample during testing. As I told here because there are transducers which are going to give you how much is the resistance offered by different soil layers at different depths in terms of different parameters but finally it's not going to give you any soil sample. This is particularly you use to get in your SPT test. However, if you require a soil sample you can replace your cone tip by a soil sampler. It requires time to transfer and interpret the data directly whatever data you are getting you cannot use it to identify the soil. You have to actually interpret the data, you have to also refer to standard curves also, charts also in order to come up at different [00:42:35] properties.

So require interpretation require transfer of data as well as interpretation. Has limited depth capacity because finally you are measuring the soil resistance. So you can have, you can go maybe in the range of maybe 25-30 meter maybe in exceptional cases higher depths also but in comparison to other test it has limited capacity in terms of depth particularly in case of very dense sand and cementitious cemented strata or glacial tills.

Obstructions such as boulders which if in case comes in SPT test provided the size of the boulder is smaller than the size of the sampler you can go for SPT test recording but here you cannot use

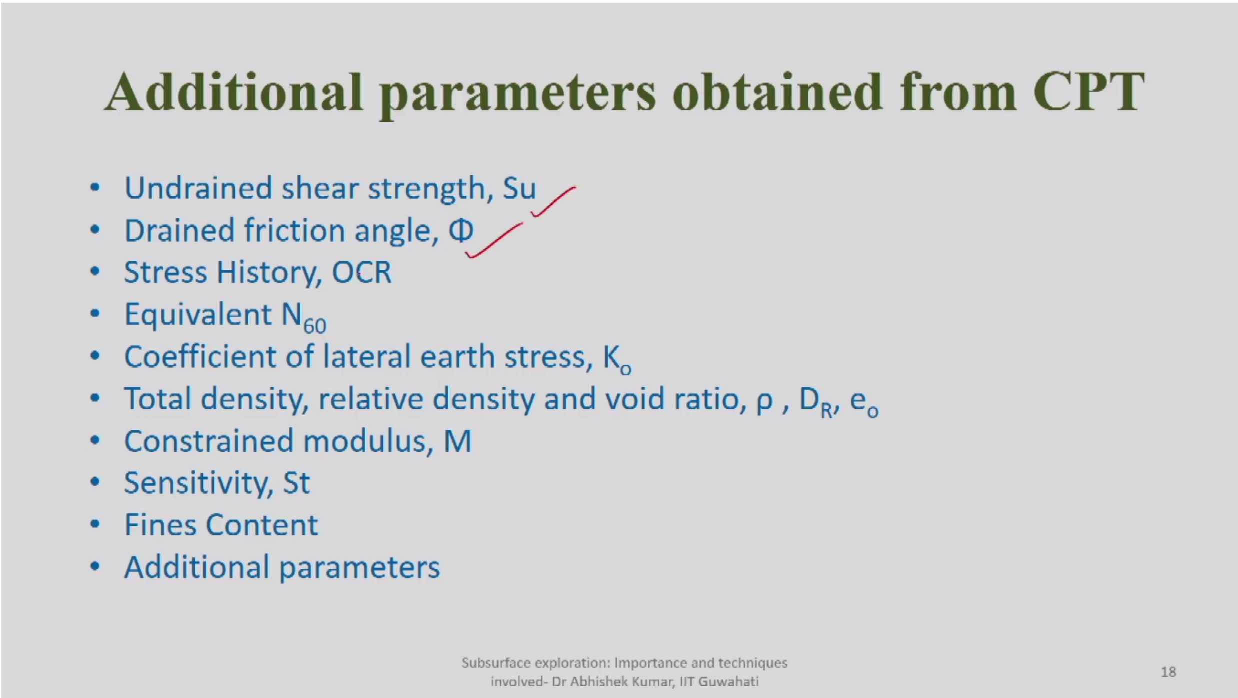
– do it because it is actually measuring the –it is measuring the resistance of our base. So the boulder is there. Actually it is – it will not be able to pass through it.

So you have to terminate the test at that particular location either you remove the boulder or maybe you can go for other test locations. So these are the certain disadvantages.

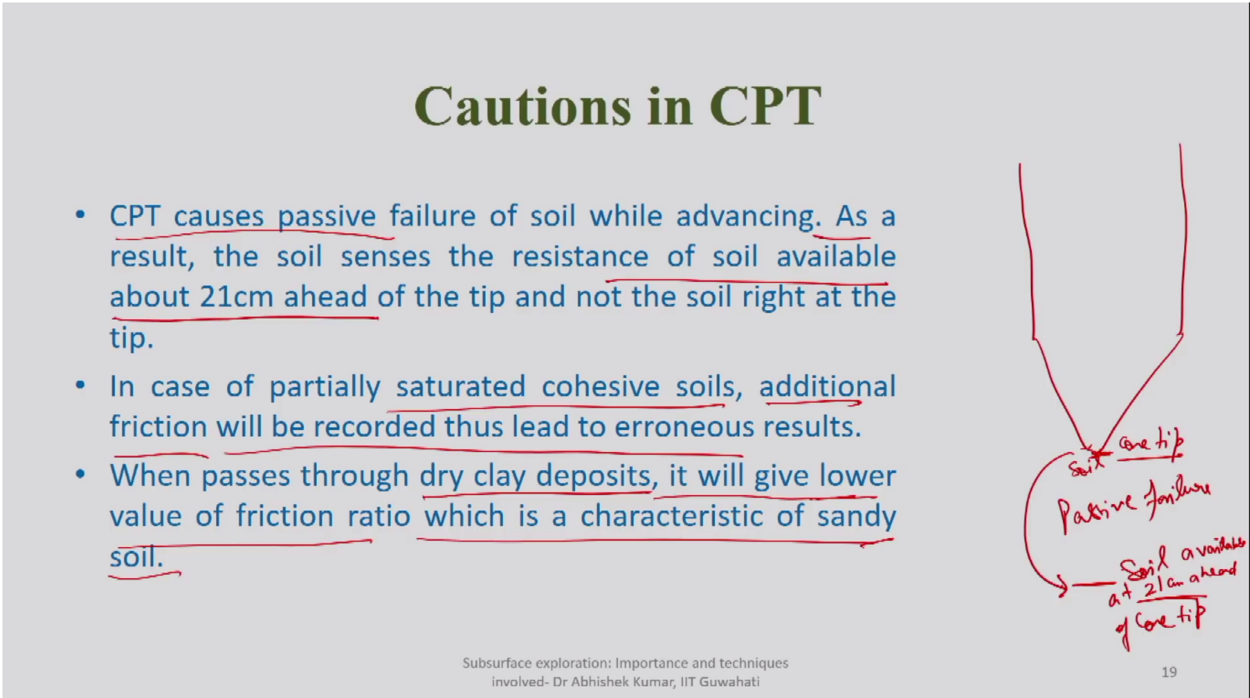


Okay. so you had some values of sleeve friction as well as cone tip resistance based on which you can determine the value of FR if you apply the correctional also with respect to overburden you can get the corrected FR value if suggested of if you are referring to the curve proposed for corrected values. Similarly you can still – once you have the corrected or you have the value of friction ratio and you have the value of cone tip resistance, you can get an idea even without collecting the soil sample whether your soil is gravel, whether your soil is sand, whether your soil is sand mixed with silt sand and clay, whether it is silt mixture, whether it is sensitivity increasing you can see here. In case of clays if it is going in this direction there is increase in sensitivity and so on. So there is a broader classification given as per Olsen in 1988 chart based on your FR value as well as based on your Qc value.

Same here Robinson in 1990 proposed if you know the value of friction ratio, normalized friction ratio and cone tip resistance this way also you can get an idea about sensitivity and whatever properties you can determine for in situ site.

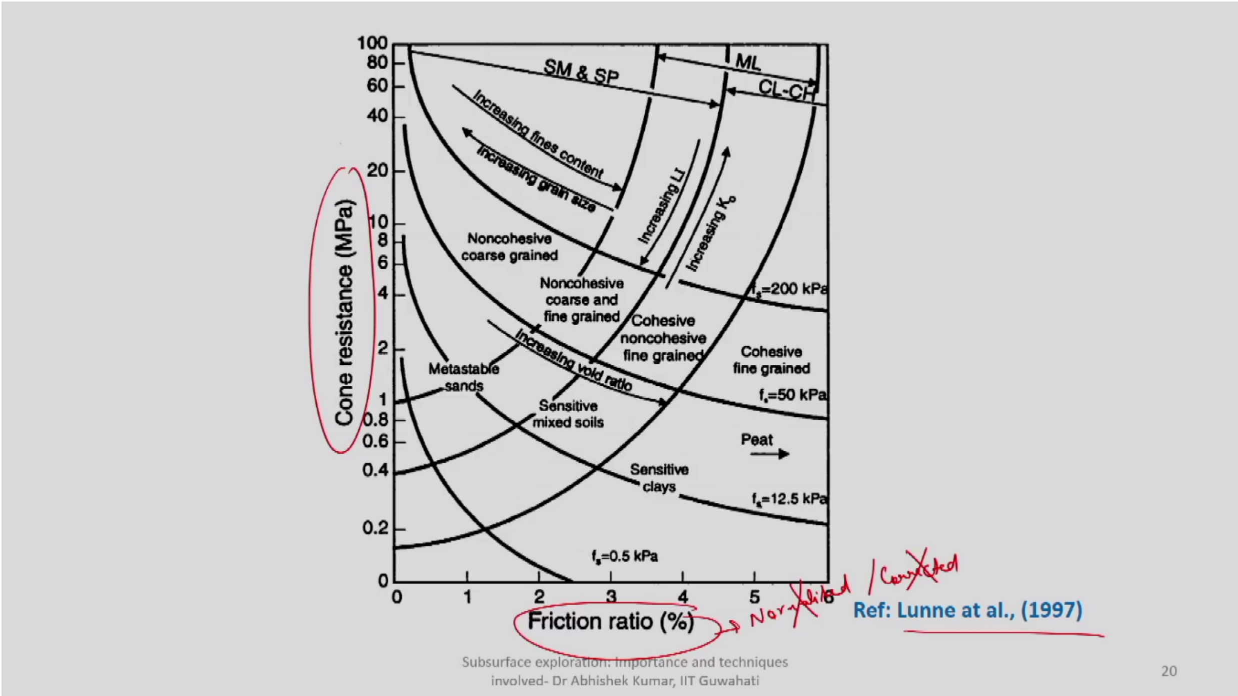


Same way you can actually determine so many parameters. One is undrained shear properties. Drained angle of internal friction. Then over concentration ratio equivalent standard penetration test corrected for 60% hammer energy. Then coefficient of lateral earth pressure you can determine. Then total density, relative density, and void ratio you can determine. Constrained modulus. So many of those parameter you can determine simply by measuring two parameters one is skin friction, one is cone tip resistance.



Caution, one important thing which has to be highlighted here is because once you are pushing the cone into the soil it is suppose to cause some kind of failure but issue here is though it is causing the failure it's not causing the failure at the tip. This is cone tip. So in order to push it into the ground it has cause passive failure. But it has been observed this passive failure is not happening at the soil which is available next to the cone tip bu at the soil which is available at – soil available at 21 centimeter ahead. So whatever resistance you are making in terms of cone depression it is actually indication of resistance offered by the soil 21 center ahead. That's why it is written here. So CPF causes passive failure in the soil while advancing as a result of which the soil sensor are resistance of soil. Sensory is the resistance of the soil available at 21 center higher. So it's not going to give you the resistance offered by the soil at cone tip at 21 centimeter ahead of cone tip.

Second thing in case of partially saturated cohesive soils additional friction will be recorded because it is partially saturated and which can lead to erroneous results. Third one, and more important here is when passes through dry clays now dry clays it will offer, it can offer resistance in terms of friction but as we know because it is clay it is not suppose to. So at times even though it gives you lower value of friction which is the characteristic of sandy soil. So when passes through dry clay deposit it may give you lower value of friction ratio. So low friction ratio can be you can get either in terms of dry clay or you can get in terms of sandy soil. So once you are getting it you have to be more careful whether the soil interpretation is correct or not.



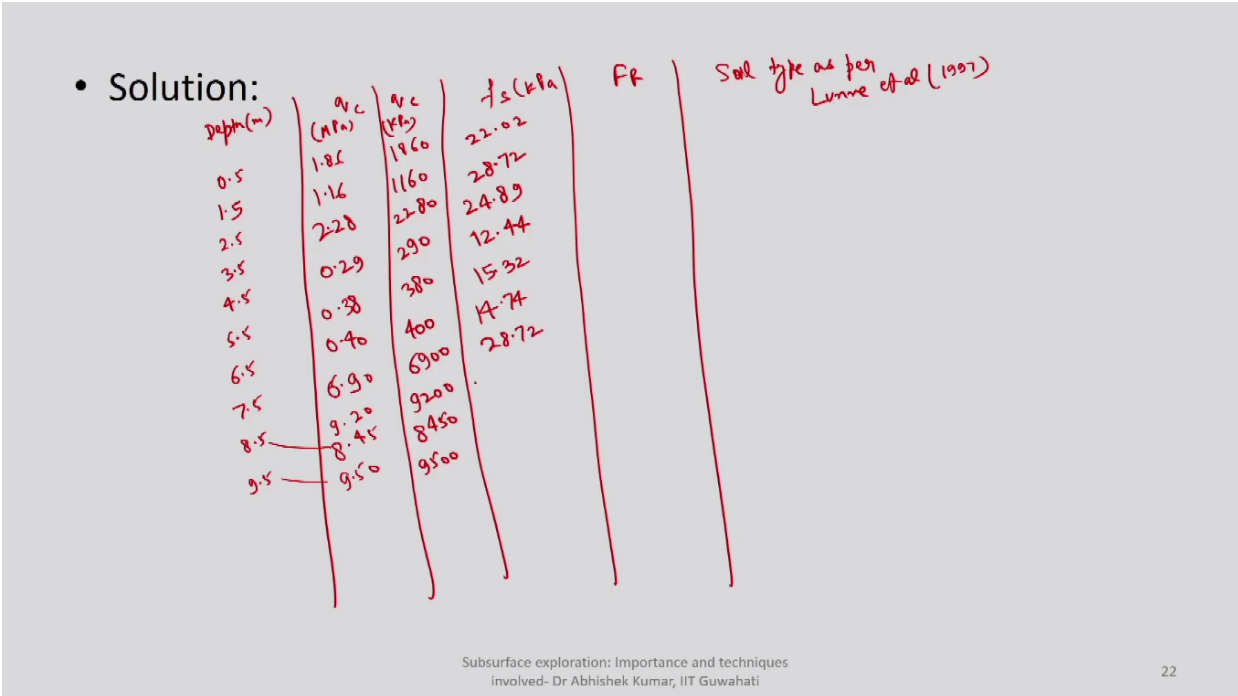
Okay. this is another graph given by Lunne in 1997 among many popular graphs. So once you know the cone tip resistance once you know the friction ratio you can actually classify which kind of soil you are targeting or which kind of soil you have encountered at that depth of interest. Now here you are not getting any – you are neither getting normalized value as where there were in previous graphs nor you are getting corrected values. So you can directly use this chart to find out the values obtained from the field recording.

Problem 3.

- Given data is obtained from field during CPT investigation. Indicate soil type at different depths and plot CPT data including FR variation with depth.

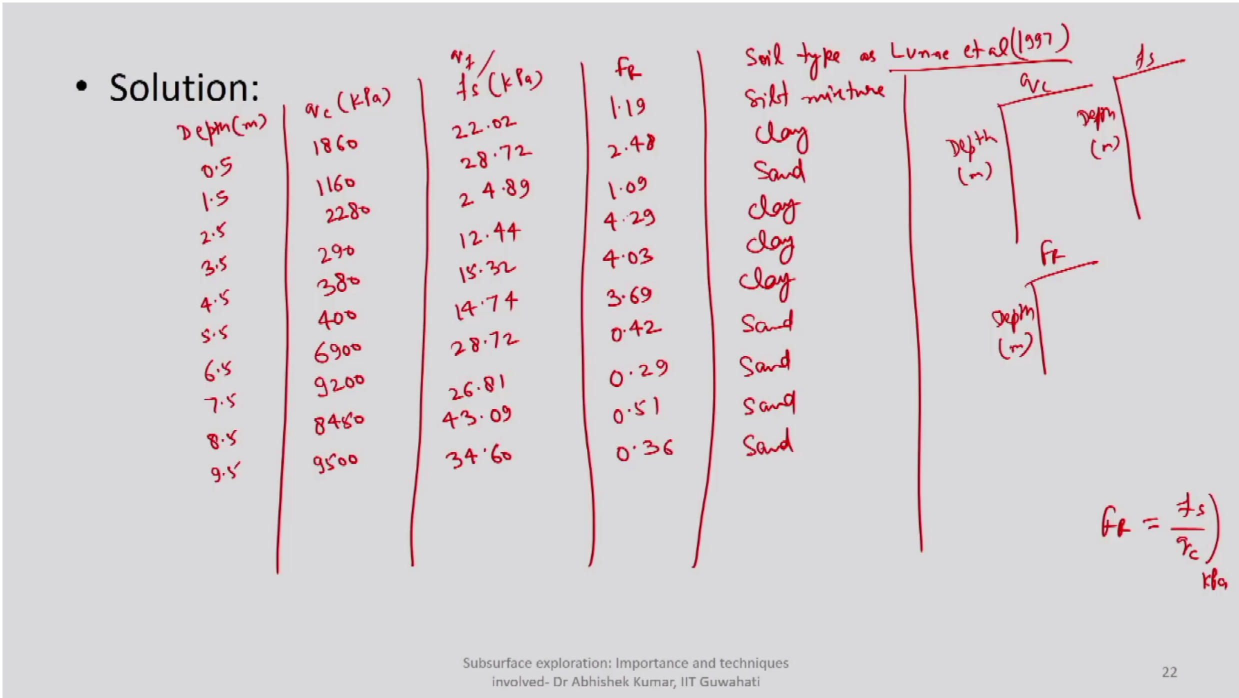
Depth (m)	qc (Mpa)	qs (kpa)
0.5	1.86	22.02
0.5	1.16	28.72
2.5	2.28	24.89
3.5	0.29	12.44
4.5	0.38	15.32
5.5	0.40	14.74
6.5	6.90	28.72
7.5	9.20	26.81
8.5	8.45	43.09
9.5	9.50	34.60

So in order to discuss this I have brought one numerical problem you can see here. Given data is obtained from field during CPT investigation. Indicate what kind of soil is available at different different depth and also plot the CPT data including FR variation with respect to depth. So FR is actually friction ratio. So with respect to depth you have been given the value of Qc and you have been given the value of Qs or Fs and you have to determine the value. So in order to identify the soil type as highlighted in the previous graph here, once you know the value of Qc, once you know the value of FR you can directly use this graph by Lunne, 1997 and classify whether what kind of soil is available if this kind of data is given to you.



So to start with you can actually determine what will be the value of so this is like you can start here with depth in meter. Then the value of Qc given in MPA. Then Qc value you can convert into KPA because other value of Fs is also given in KPA. So Fs KPA then based on this you can determine the value of friction ratio and then you can determine the soil type. So when you are referring to soil type you can also very precisely mention here as per Lunne at al 1997. So if you go here you have data given at 0.5, 1.5, 2.5, 3.5, 4.5, 5.5, 6.5, 7.5, 8.5, 9.5 meter and how much is the value of Qc given here? 1.86, 1.16, 2.26, 2.28, 2.28, then 0.29, then 0.38, then 0.40, then 6.90, 9.20, 8.45, and 9.50. I think there is some overlap between the values of this is corresponding to this. This is corresponding to this and so on.

Then you convert it so you will get one value 1860, 1160, 2280, 290, 380, 400, 6900, 9200, 8450, 9500. This is the value of Qc we will be getting here, then the value of Fs is given as 22.02, then 28.72, then 24.89, then 12.44, then 15.32, then 14.74, then 28.72, then 26.72 so it was 26.72 and so on.



So to start with the problem let's first of all write what are the values given here. So you can write here depth given in meter then the values of Qc given in I am going to write the value directly in KPA because the value of Fs is also given in KPA. So you can write here Fs KPA is I have given here also QF, then the values of we are trying to find out how much will be the value of FR and then based on the value of FR what will be the soil type.

So when you are defining the soil type it will be better if you can write using which methodology based on which [00:52:38] you are referring to to convert this field recording FR or Qc value based interpretation about the soil type. So this is soil. This 0.5, 1.5, 2.5 so these are the values given in the numerical problem. 5.5, 6.5, 7.5, 8.5, 9.5, and so I mean it is given up to 9.5. Let's see how much is the value of Qc given. 1860, 1160, then 2280, then 290, then 380, 400, 6900, 9200, then 8450, then 9500. These are the values given in terms of KPA converted. So don't get confused. Original values are given in MPA, I have converted into kilo pascals. Then the value of Qs or Fs is given as 22.02, 28.72, 24.89, then 12.44, 15.32, 14.74, 28.72, 26.81, 43.09, 34.60. These are the values given then you determine the value of FR equals to Fs over Qc. Both are given in same unit. I am using it in KPA. So how much is the value of Fs you will get it will be 1.19, 2.48, 1.09, 4.29, 4.03, 3.69, 0.42, 0.29, 0.51, 0.36. Now you have the value of FR and you have the value of Qc go to the previous slide this one so based on the value of FR here this is the value of FR and this is the value of Qc read what will be the soil type from this. So for your understanding I have just classified the soil type here. I am writing here directly. You can check with the graph given by Lunne et al. It's like silt mixture. Then you have clay, you have clay here. This is you are having sand. Then you are having clay. Clay. Clay. Then you are having sand in other depth. Sand. And then sand. So you can see here even without collecting any soil sample just by measuring the cone tip resistance as well as skin friction you determine the value of FR make sure the value of both the resistance are in the same unit. You will be able to determine the values of FR and based on this Lunne et al paper you can directly classify what kind of soil is there. So this is one part of the question where you have to identify what kind of soil is available at different depth and then putting these values of FR versus Qc so this is depth then Qc value. Then depth versus Fs value and depth versus FR value. You can actually draw using maybe Excel sheet you can use this value you can actually draw it. So that will complete your second part of the work whatever is asked here.

So this is all about cone penetration test. So today we discussed about how we interpret the data. How we apply correction when you are going for standard penetration test data. Similar way if you are doing cone penetration test though we are not retrieving any kind of soil sample but still based on the field recordings in terms of typical two or three measurements we can identify the soil type and using the different correlation given by different people you can also determine the value of different parameter like over concentration ratio, coefficient of earth pressure at rest, [00:57:39] strength and so on and so forth. So this is about the today's class. Thank you so much.