INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

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Subsurface Exploration: Importance And Techniques Involved

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Lecture 5
Geotechnical Investigations

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Welcome all to subsurface, exploration, introduction and technique involves. So today's lecture 5, today also we will be going to discuss about geotechnical investigations.

So before going further to the today's class, what are the topics to be discussed let's review like what are the topics we had covered in the last class.
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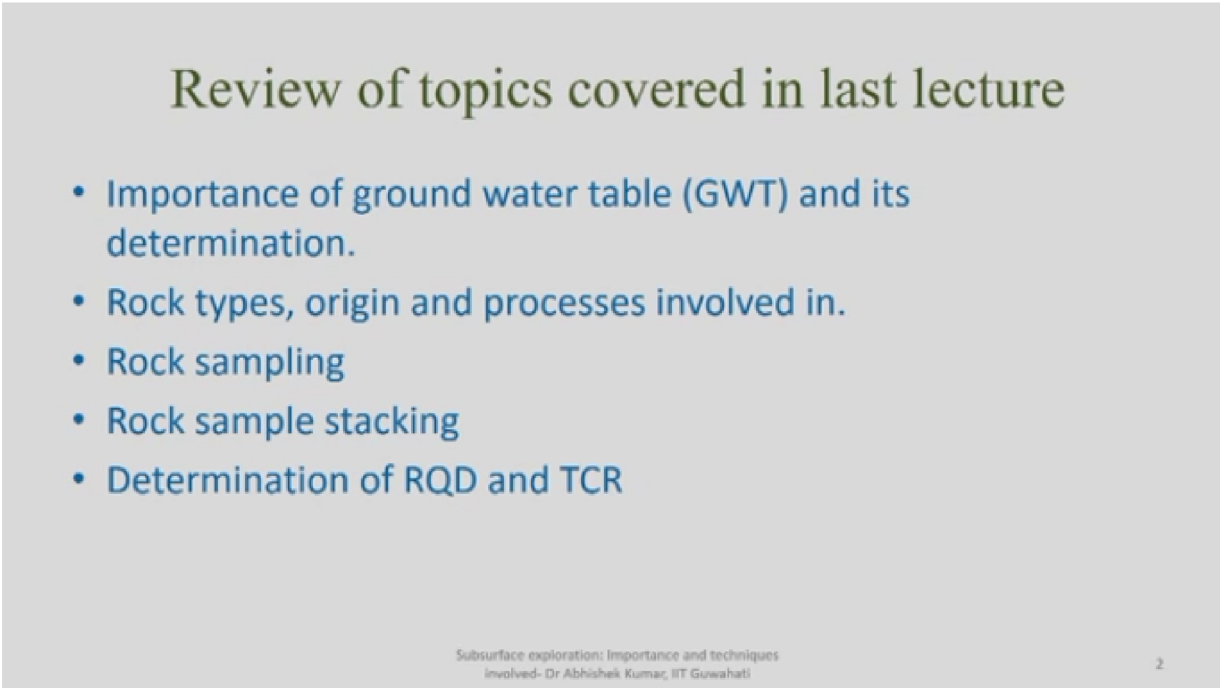

So we try to understand what is the importance of ground water table when we go for subsurface exploration, how ground water table can help you in understanding the soil type, foundation type require, how it can help you in planning for detail investigation, exploration, leaving out the foundation, how it can help you in dewatering if it is required.

And further in order to ensure the safety of the adjoining structures as well, and then its determination depending upon what kind of soil is available at depth below ground water table, you may require few hours, you may require few days also, in order that the ground water table reaches equilibrium and you can report it like this is the equilibrium ground water table at your site of interest.

Then we discussed about rock types, what are the different rock types, metamorphic, igneous, sedimentary, how each of these rocks form, what are the process involved, what are the different agency whether it can be gravity, ice, glaciers, water, ocean and all that, and then how you go for rock sampling, what do you mean by rock sampling once you collect a rock sample from different, different depth, maybe you get an intact sample, you may get a very crushed kind of sample or broken sample, then how you are going to take that sample because finally depending upon what kind of soil or the rock we are getting at different depth, if you are going to analyze the strength property of the rock, we also try to classify the rock based on rock mass classification system, how intact is the rock, what is the average size of the crushed material or sample which is available at that particular depth as resemble through rock sampling.

Then we also discussed how we determine the rock quality, designation and total core recovery which will directly tell you about the quality of the rock you are obtaining from the rock samples.

And then we discussed what are the different bits you can use whether you are drilling in case of soft rock medium, whether you are drilling on a very hard rock medium, so you can go anywhere from carbide drill bit to diamond bit also, so this was the topic what we had covered last time about rock sampling.

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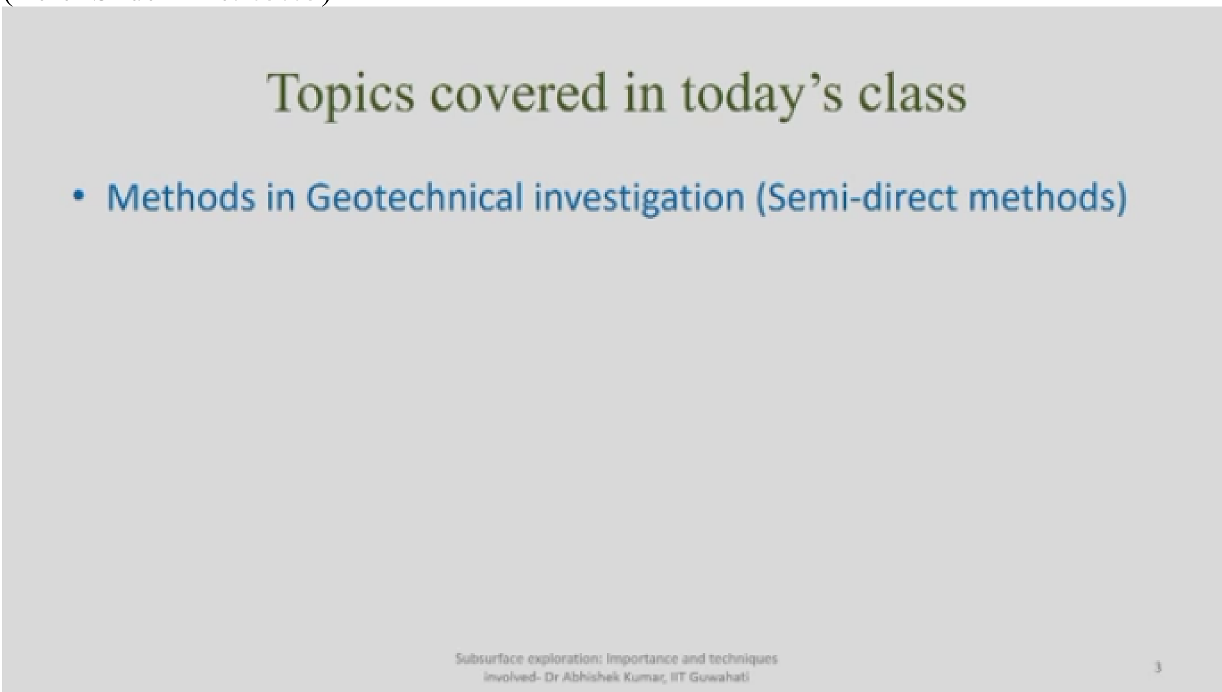

Now when we started about test pits trenches we discussed like those are the direct method because you are actually able to see what are the different kind of soil layer available at different depths, what are their natural conditions, strata position, even moisture content also if you report it properly, so those are called as direct methods, but as we mentioned like such methods those gives you undisturbed sample, but generally we do not go for larger depths, because you have to go for trenching and then as you go deeper and deeper you have to make more and more arrangement, and considering the extent of area you can actually go for digging.

In case of trial pits may not be suitable if you are doing for very larger area, because you have to go for more number of location from which you have to do similar study or subsurface exploration, so you can go for some other method which may not be too much time consuming as well as it will give you relatively good assessment about the rock and soil type available at different depth. Then strength properties of different material available at different depth and so on, so then we come to, those were the direct methods, trenching and test pits.

Now we come to semi-direct methods, so semi-direct method means you are not able to visualize it, you are not able to see it directly, that at the site and at the depth of the interest, but there is some means or other by which you are able to understand the soil type available, it's characteristics in terms of shear strength and other property depending upon what is your interest, as a designer as a field engineer what is your interest, what kind of property you are interested in interpretation, so you have different semi-direct methods.

What semi-direct methods? Particularly in geotechnical investigation, so these are the list of some semi-direct methods,

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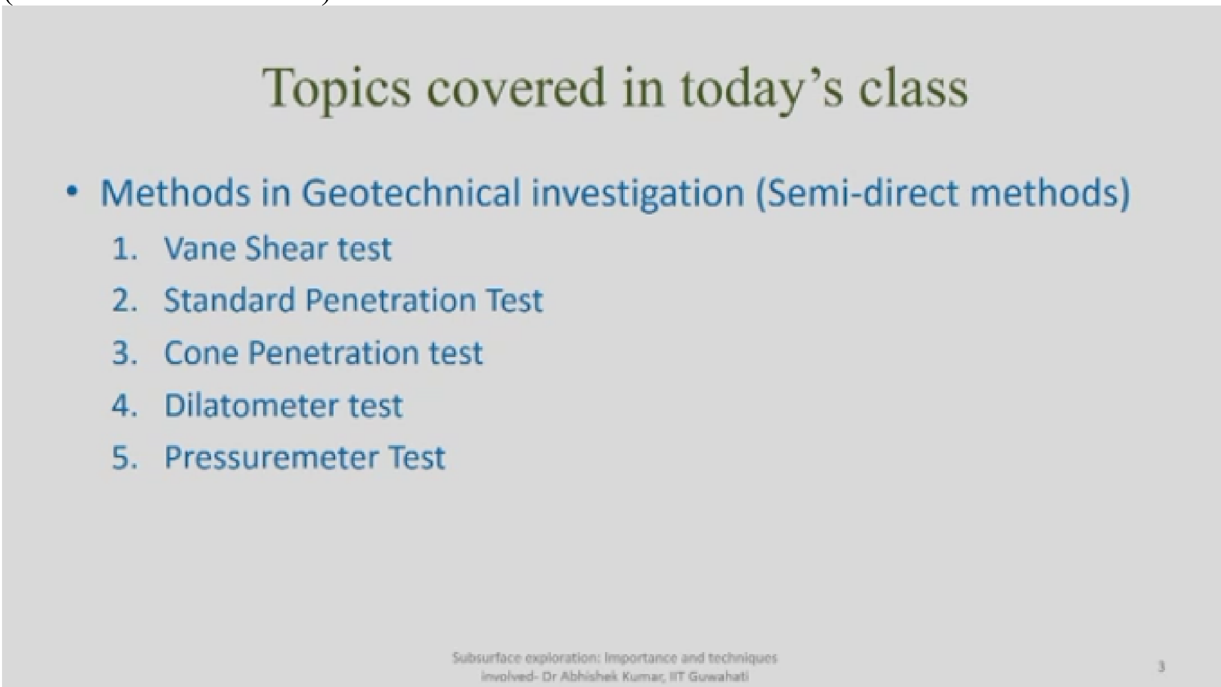

so we have vane shear test, then many of you might have heard about this test, as a name suggest so you have some kind of vane which is your putting into the soil in order to understand the shear strength property, then you have standard penetration test, many of us know with the name SPT test, then so what are this test, we will be discussing, and then interpretation.

Then third one is cone penetration test or CPT test, dilatometer test, pressure meter test, so it is recommended like at the site of interest whenever you are going for any geotechnical investigation, you try to explore, try to validate the finding obtain from one test by another method, so these are the list of geotechnical test or which comes under semi-direct method which are generally used for exploration of soil and rock medium in shallower depths.

Shallower mean in the order of 50 to 80 meters also sometime you can go for, but not all the test will be applicable for all the depth type, so when we go for vane shear test, first one is vane shear test, so in today's class we will be discussing about vane shear test and standard penetration test, rest of the test we will be discussing other in coming classes.

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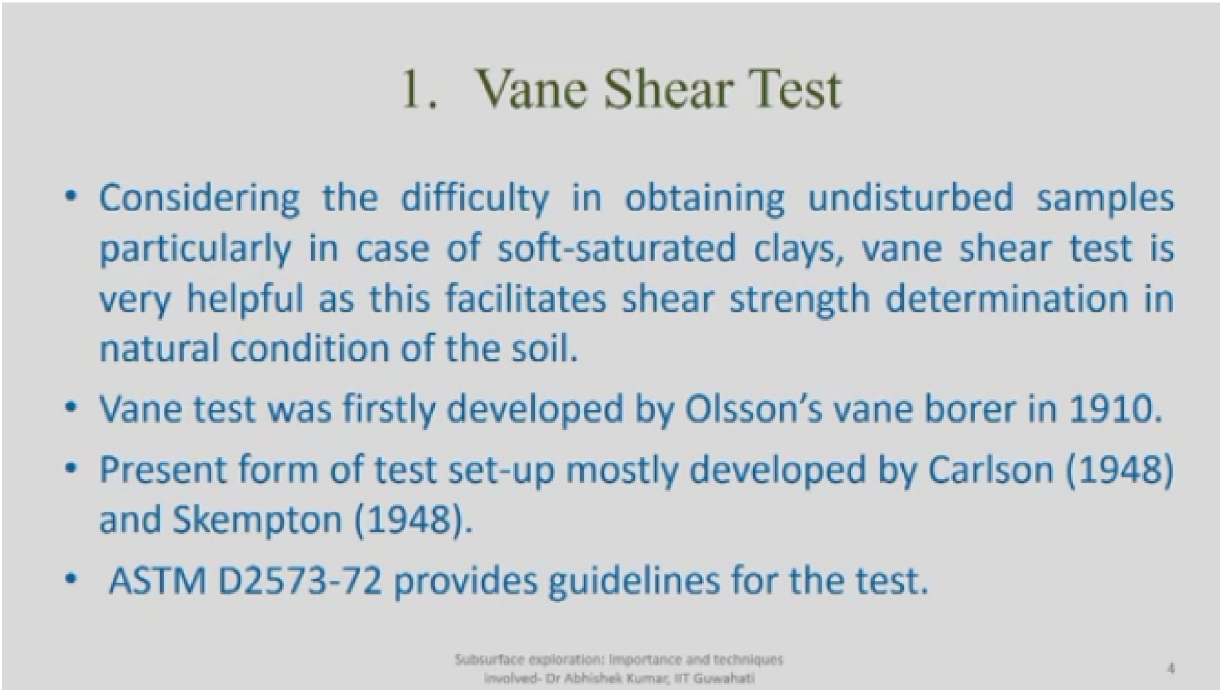

So when Vane shear test, what we have observed particularly in case the soil is very soft, particularly in case of clays and it is fully saturated, so such a fully saturated soft clays, it is very difficult particularly if such test are available at deeper depth it is very difficult to collect undisturbed sample, because whatever will you take into account to collect the sample, first of all there will be partial to more shaking or disturbance will be there in the soil.

Second thing, because it is fully saturated, so once you bring out on to the surface there are always chances that there will be change in moisture content in the soil, so it's a very challenging task to collect undisturbed soil sample, in case of soft saturated clays, partially because of disturbance, partially because of change in moisture content, so vane shear test in such a cases when we have at the site of interest this kind of soil, the vane shear test can be very helpful at this facilitates in-situ determination of shear strength, so you need not bring the soil sample, actually if the soil is available at 10 meter depth below the ground surface you need not bring it anyhow on to the surface, take it into the laboratory to determine the shear strength property, you can actually determine the shear strength property there itself in its natural condition of the soil, so because you are not bringing, so there are chances that the soil is not getting disturbed, it's not getting altered, and because you are imparting some kind of strength assessment at the natural ground condition, so whatever is the depth of investigation.

The test was firstly developed by Olsson Vane Borer in 1910, the present form whatever we are doing in the test mostly developed by based on the work by Carlson in 1948 and by Skempton in 1948, so whatever vane Shear test setup, whatever interpretation, whatever standardization we see here mostly based on the work by Carlson and Skempton both were conducted in 1948.

ASTM also provides you guideline in ASTM D2573-72 guidelines to do vane shear test at your site of interest, so if you go for the test setup actually it consists of a drilled rod like supposed this is your ground level, GL, so what you do there will be some kind of drilled rod at your site of interest, so this is called as drilled rod, and then at the end of the drilled rod depending upon your depth of investigation there will be some kind of vanes, this is your drilled rod attached to the vane equipment like this, like this,

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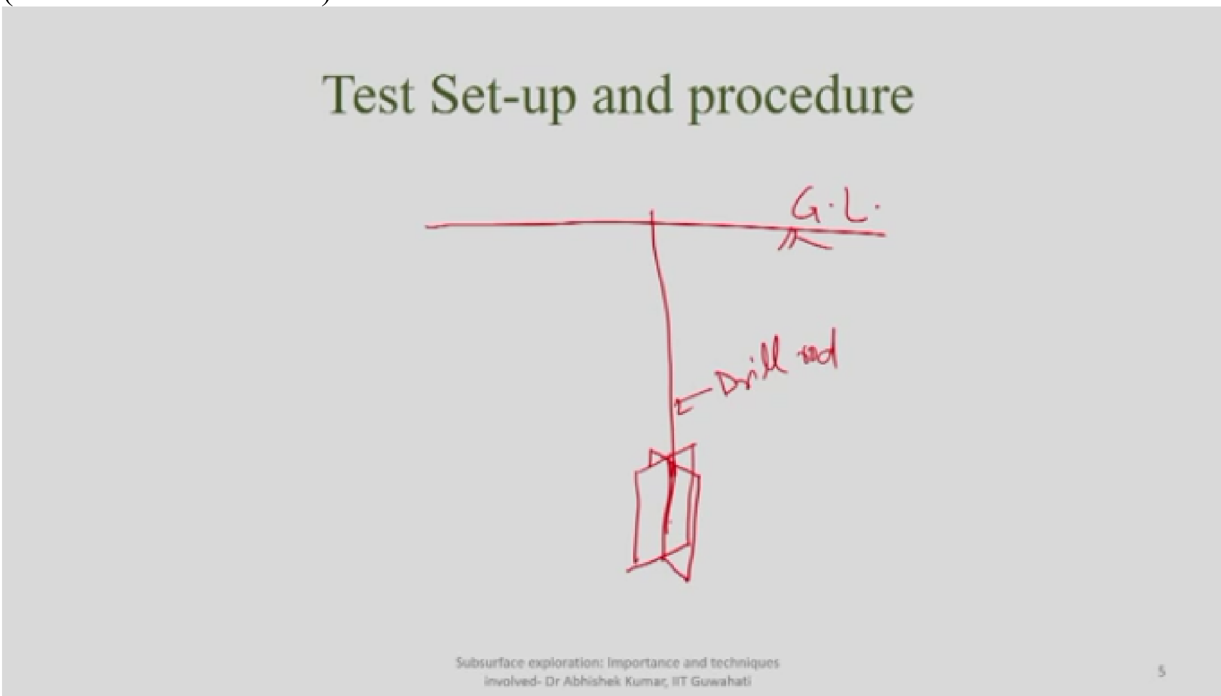

so there will be 4 vane's like these are called as blades of the vanes, the setup itself is called as vane's, and each of these are at 90 degree with respect to each other, so what it does supposed you are standing at your site of interest here, you are actually providing some kind of torque by rotating this drilled rod and depending upon your depth, so actually if you are doing linear deeper depth you will have to have some kind of borehole,

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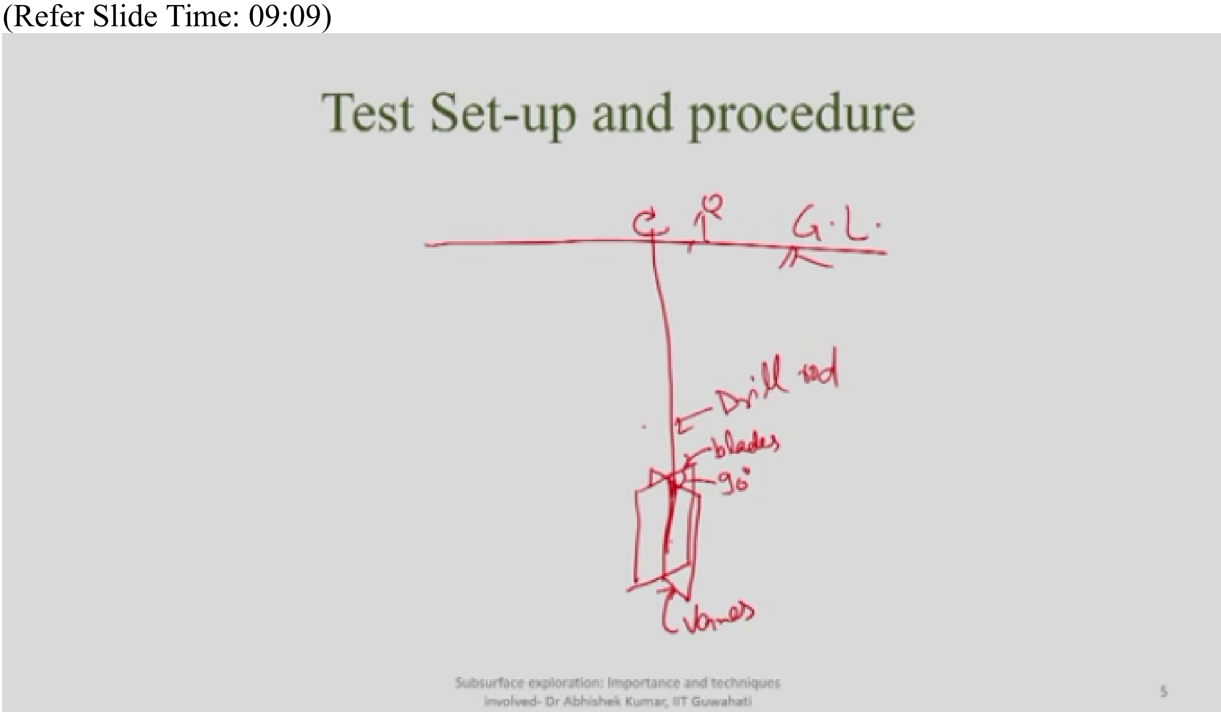

maybe with the based on the borehole you have collected the soil sample up till here or you have reached up till this depth, and then you will insert this vane, so you can see here from this depth onward there is almost no disturbance, so you are actually pushing it, you are pushing in the vane into the site, where the soil is not saturated not disturbed ones, so this is you can call it as undisturbed soil, so because you are doing the test in undisturbed soil, whatever strength property you are getting it is actually sampling, whatever the in-situ strength property at this particular depth so particularly useful for saturated soft clays, okay.

So once you reach in the depth of interest like this is your, may be the depth of interest, you went to this depth just like any SPT test or rock sampling, you are interested to find out the strength properties of the soil here,
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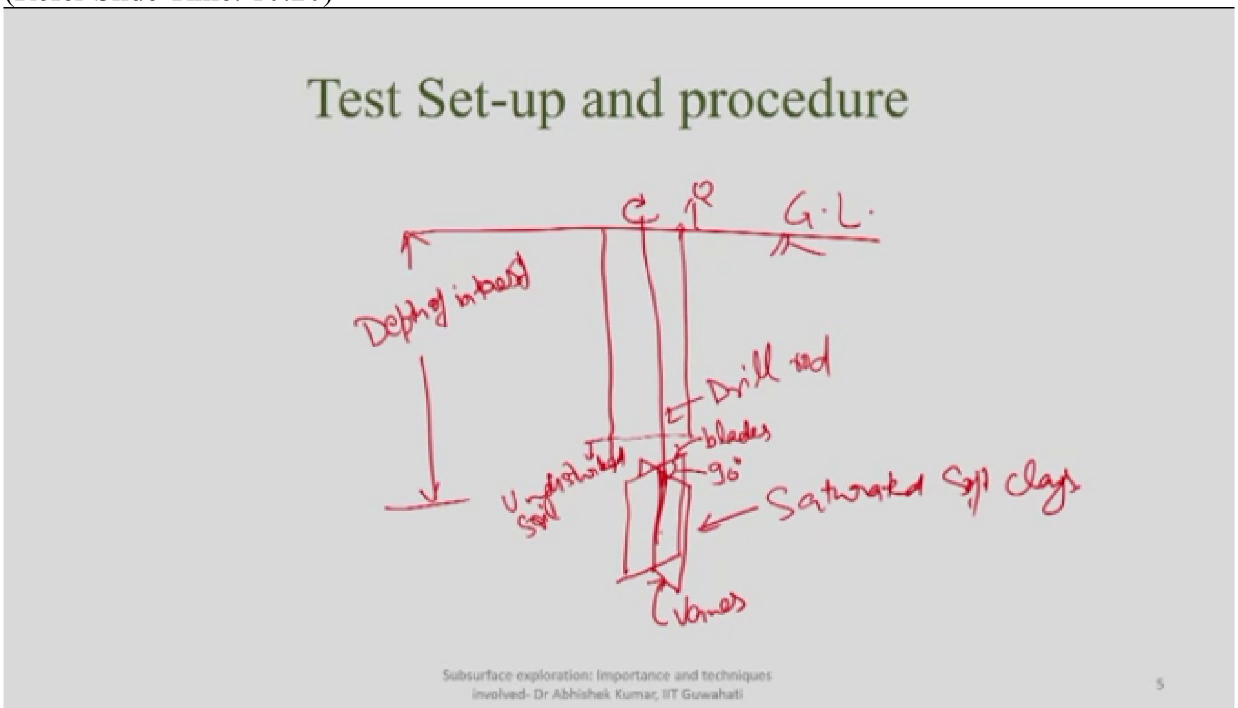

you start rotating it depending upon how much is the torque, so you are having some way to measure, how much is the amount of torque you are applying here, as a result of this torque what will happen? This will also start rotating, once it start rotating now you can see here it's something like this, then you will be having something like this, and then this, so once you start rotating what will happen? As a result of which there will be shear test develop at the interface between the soil and this, because you are actually rotating it,
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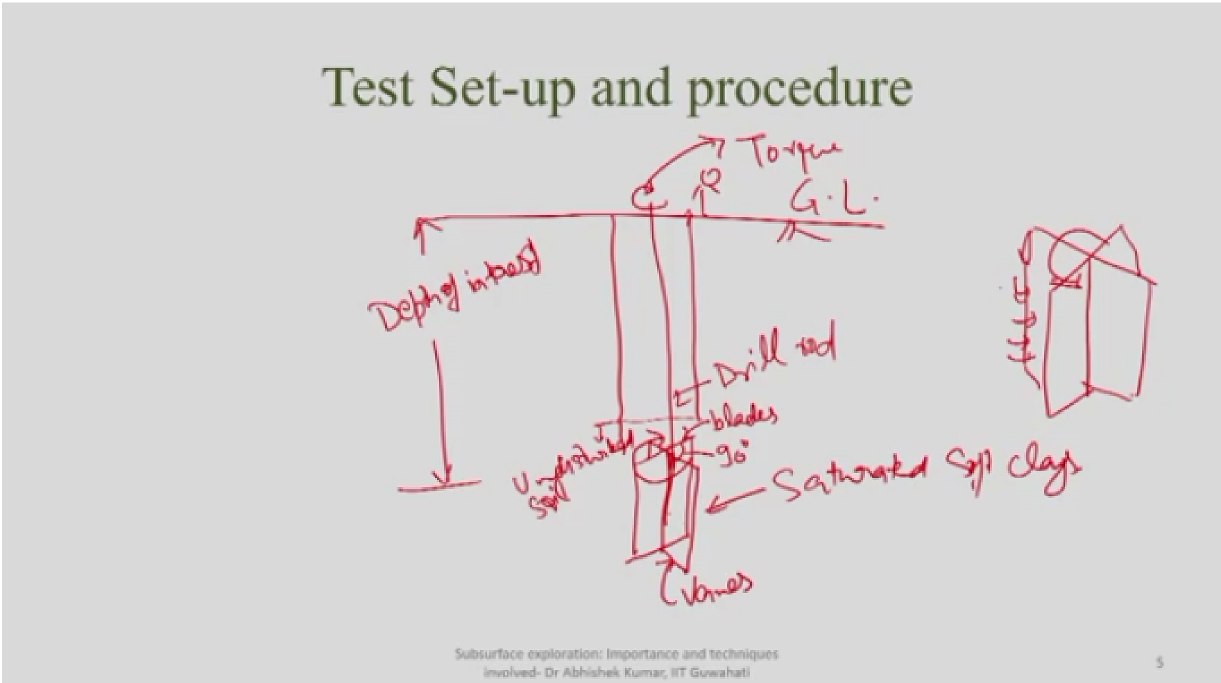

so rotation means this is your blade, this is your soil, so when you are rotating it is actually causing some kind of shear here all along the periphery, all along the circumference here.

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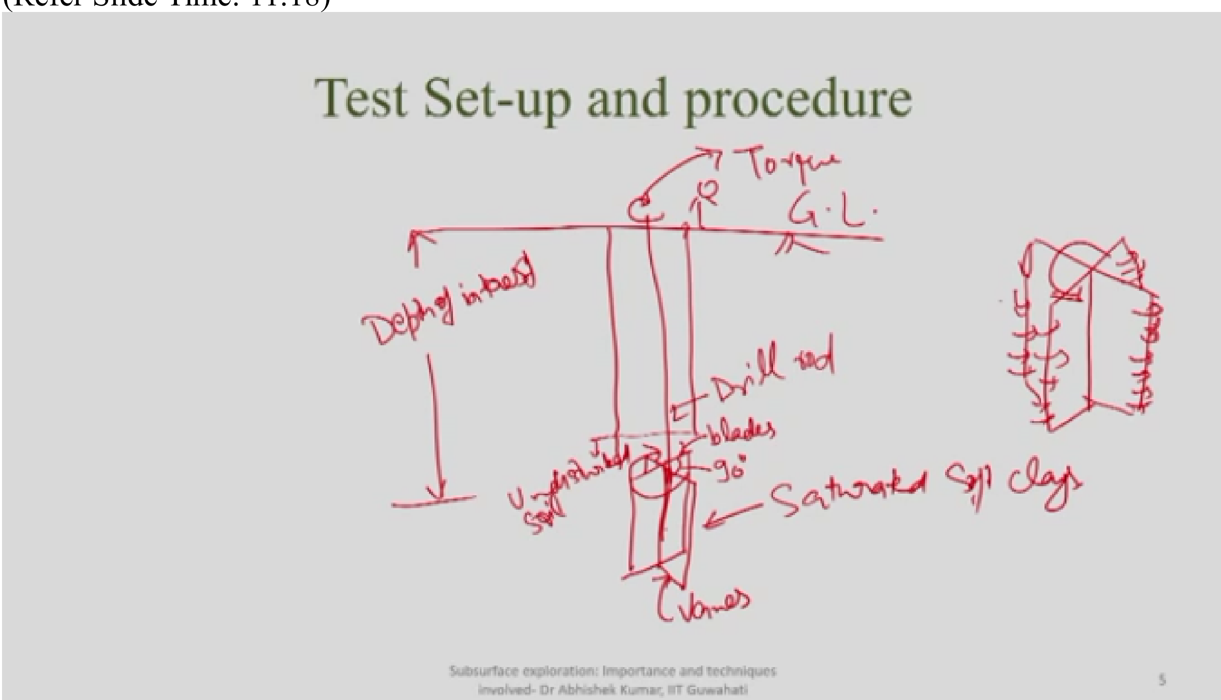

This is about what is happening along the edges, same thing is happening at the top as well as bottom because top is also inserted into some natural soil condition, bottom is also inserted, so what will happen once you are rotating? This is your soil, and this is your rotating, so again at the interface there is some kind of shear happening, so here also you can see some kind of shear happening here, anyway at the bottom also you are having some kind of shear.

So as a result of applying torque at the surface what is happening? You are actually inducing some kind of shear force into the soil and depending upon at what shear force your soil is undergoing some kind of failure that will be indicated by rotation bit, that you will be able to correlate both the things like how much is the external force and how much external force the soil is able to resist before it goes any kind of failure, because the space is induced, the shear in nature so the failure will be called as shear failure, so whatever maximum stress is it is able to take before that stage it will be called as shear strength of the material, so this is the test procedure and this is the test setup.

So generally, now how you go for determination? So as I mentioned here so if T is the torque applied that will be governed by two parameter, one is resistance against rotation or you can called as an moment from the vertical edges + second will be there resistance offered from the top + bottom, since top and bottom both are same, you considered it as two times, so how you will get this rotation?

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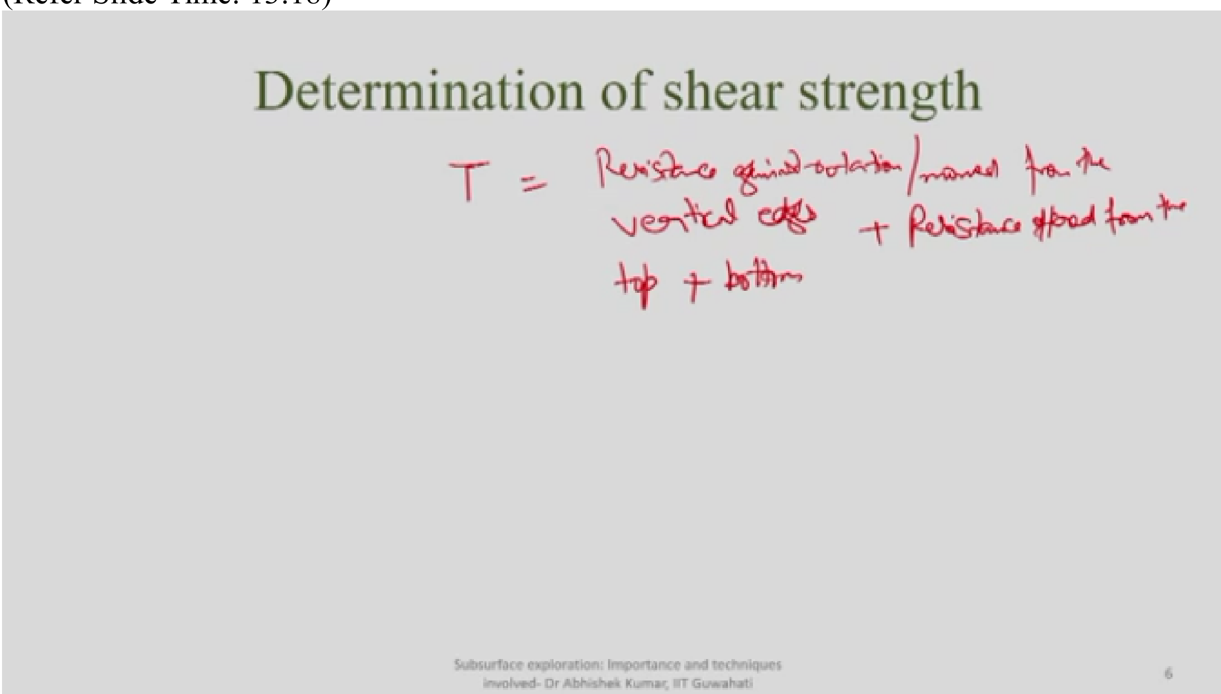

Suppose if you see along the phase it's like complete cylinder is there which is undergoing some kind of shear stresses, so shear stresses are getting developed at this interface along this, so if you consider the height as H of the vane, and diameter is D, how much will be the shear stress along this will be governed by the, what is the circumference or area here that will be equals to pi D, that will be equal to pi times D times H so that will be the area multiplied by, if S is the resistance or the shear strength of the material and then this will be the forth and multiplied by liver arm,

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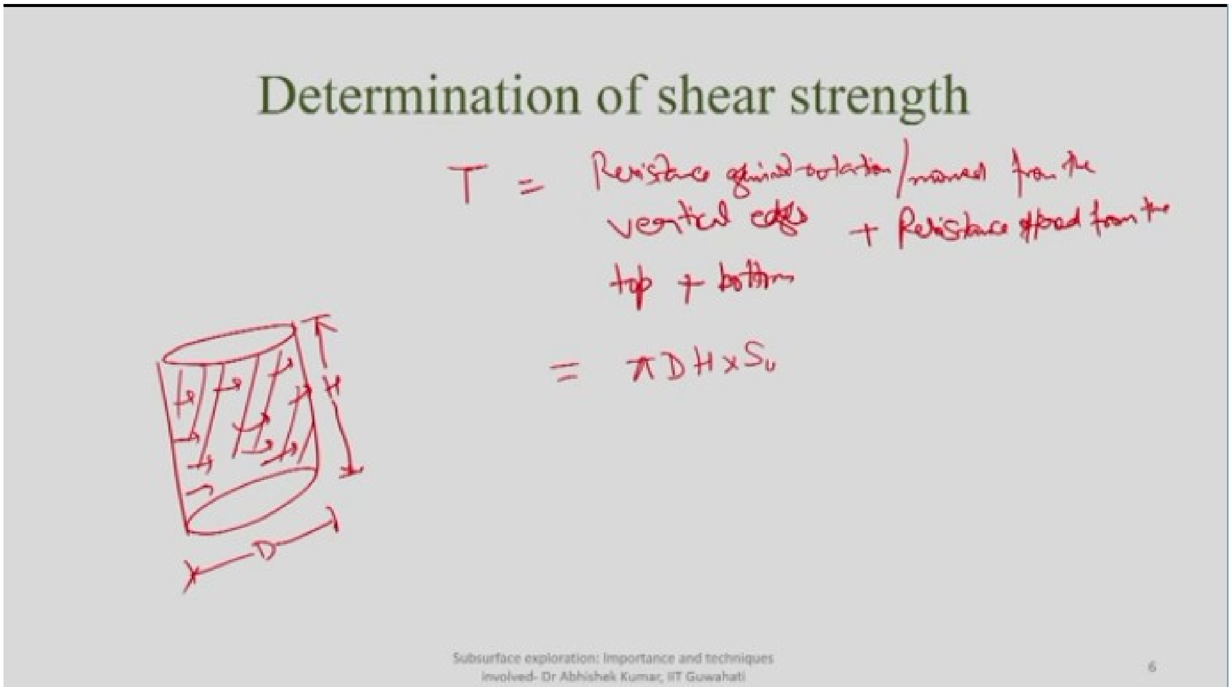

because it will be applying some kind of rotation along this, so this will be called as D/2, so this is about from the vertical phase.

Then you will be having along horizontal phase so I'm putting 2, because it is equal on horizontal, I mean top and bottom, so again when you see on the top and bottom so like this is the entire area consider a small strip which is at R distance, the thickness of the strip is considers DR, so what will be the length of this? This will be equals to 2 pi R, that is the circumference multiplied by DR that is the thickness and then R, and then integrated from 0 to D/2, that's how you will get it.

So integrated from 0 to D/2 we will be able to get it, so if you solve it you will get here pi D square H SU, actually this should be D/2, because that was D square H/2 + this will if you solve it, it will you will get as here as pi, of course and you have to multiply with the SU value, considering SU is the shear strength, so this will give you two times 2 pi S D cube over 24, you can solve it yourself, I'm not going to that much detail because it is simple integration you can solve it, that will be pi R square, you integrated pi R cube/3, then apply the limits you will get to know in terms of D what will be the value, so this becomes like pi/D, pi/2 D square H SU + 4 and then this will become 1/6 pi S D cube this will also be U because this is un-drained shear strength, so this is equivalent to torque.
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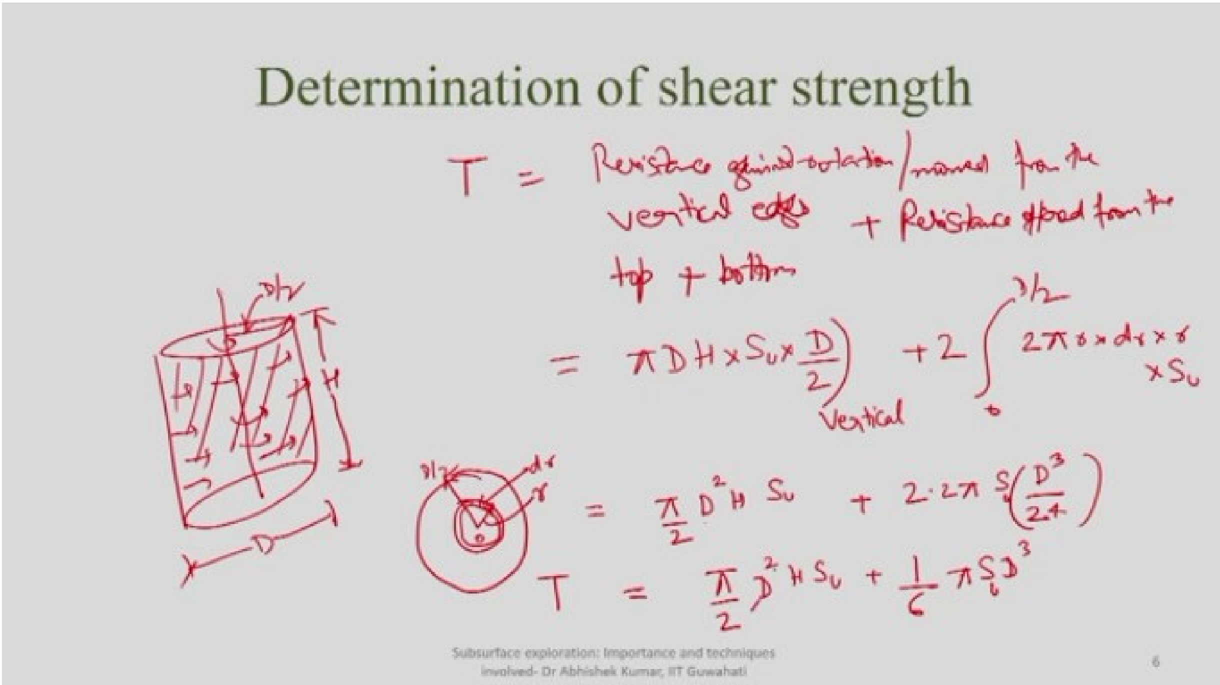

So if you know the torque, for known values of D, known value of D which will be the setup property, known value of S height of the vane, and this you are getting from the field recording from field record, so you will be able to understand the value of how much you have, how you are going to get the, so once you know the value of T and other parameter you will actually get to know what will be the value of SU, that is un-drained shear strength of soil, okay,

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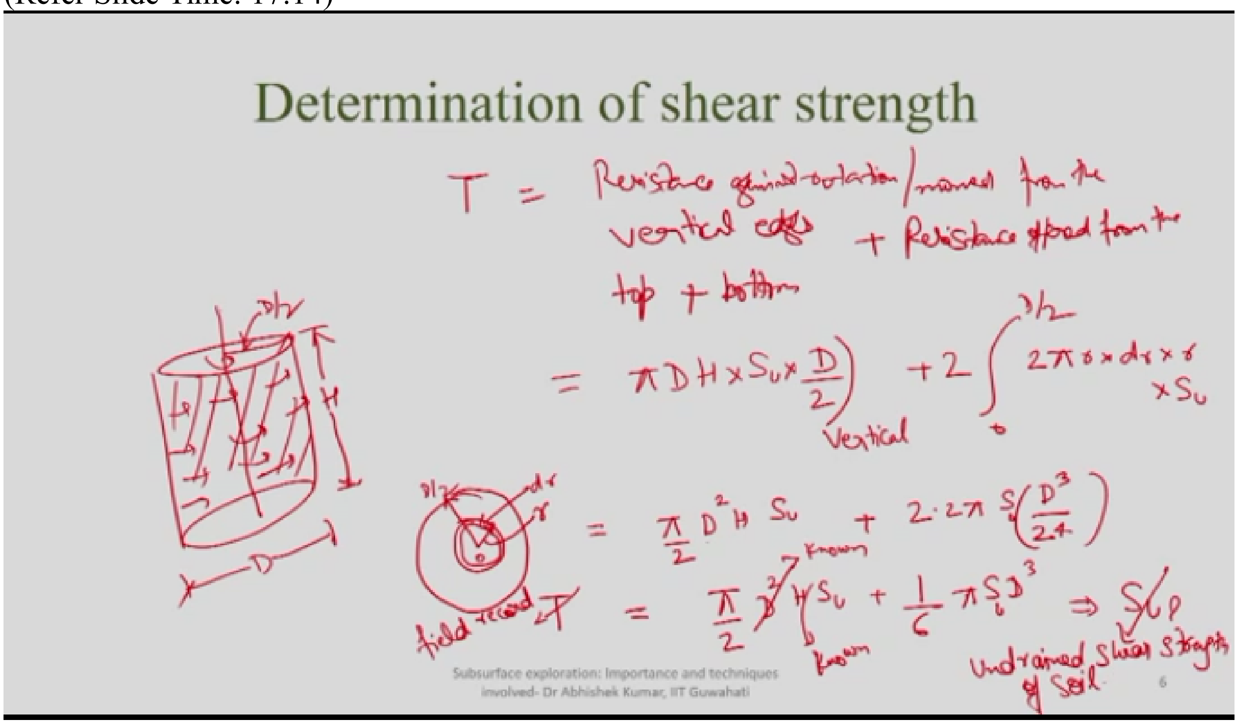

this is how you can get an idea about this thing, okay.

So and most of the time whatever you see in setup, generally the H value is equals to two times diameter, this is known, I mean more or less in many of the setup whatever you are developing in the practice by different industry we generally maintain this ratio of height to diameter is 2, so if you put this again this equation can be simplified further.

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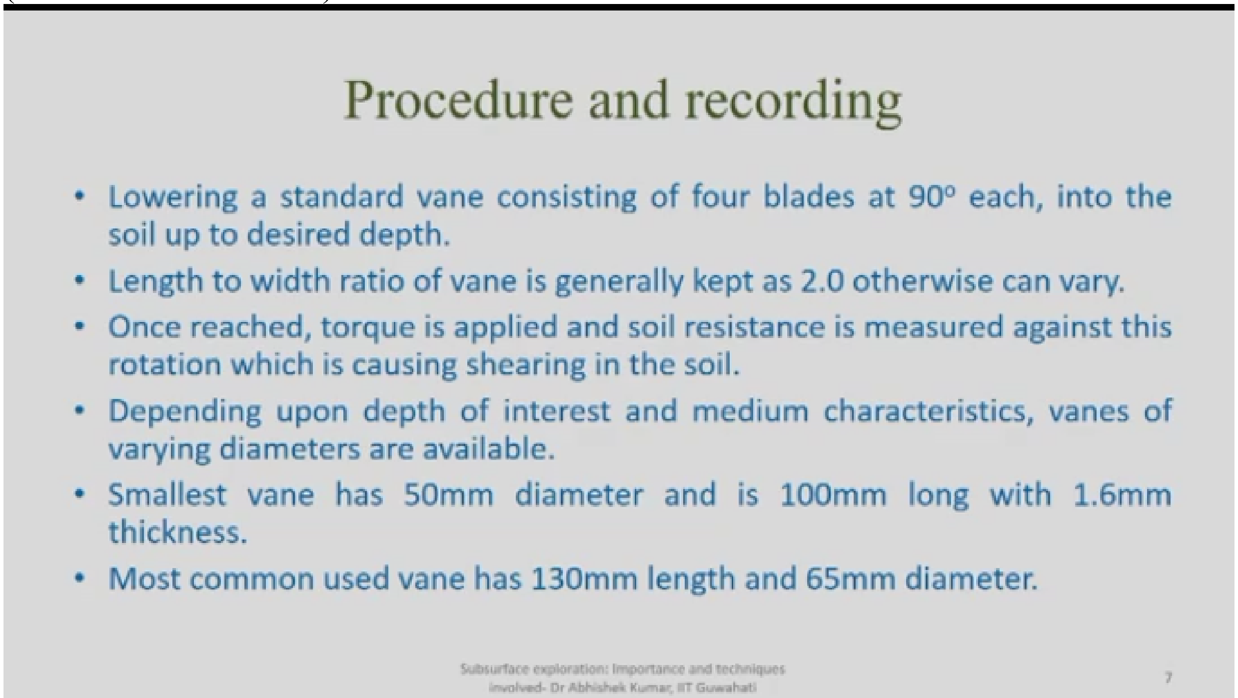

So procedure as I suggested here so once you know the torque you know the diameter of the, diameter in which the shear failure is happening and then the height of the vane you will be able to understand based on the torque how much will be the un-drained shear strength, so procedure was like depending upon the depth at which you have to understand or you have to determine the strength properties of soil you have to actually lower the vane, so vane consists of four blades as I suggested in the figure which are at 90 degree to each other, you insert that vane into desired depth of your interest, length what is the ratio of the vane is generally kept as 2.0 otherwise it can vary.

Once you reach your desired depth torque is applied and the soil resistance is measured against this rotation, this is causing shearing in the soil, so remember when you go for vane shear test you are actually inducing some kind of shear forces by means of torque by rotation and the resistance offered will give you an indication how much is the shear strength of the material, in-situ shear strength of the material.

Now depending upon the depth of interest and medium characteristics, vanes are varying diameter are available, of course the setup of the vanes is of uniform size, but as you go deeper and deeper you keep on adding more and more number of rods, drill rods, so smallest vane which is available is of 50mm diameter and 100mm length and 1.6mm thickness, so this is the smallest vane which is available in the market, and most common is 130mm length and 65mm diameter vane, so as I mentioned here like after this Skempton and Carlson work,

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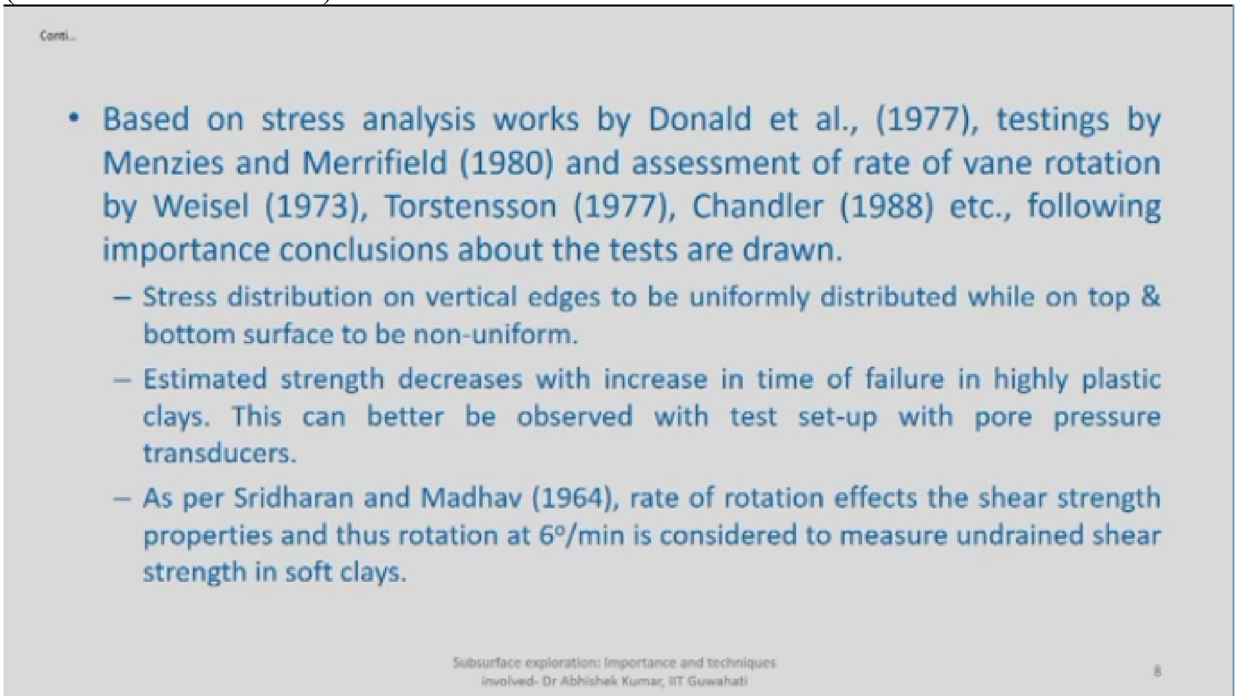

lot of work has been done towards standardization towards stress analysis also, so some of the work which were particularly done by Donald in 1977, and Menzies and Merrifield in 1980 and assessment of rate of rotation by Weisel, Torstensson and Chandler in 1988, some important conclusion about how actually the stress induced happened and what will be our interpretation in general, so it has been found like stress distribution along the vertical edges, along the vertical edges to be considered uniformly distributed while on the top and the bottom surface it is non-uniform.

Then second one, estimated shear strength depending upon how much time it is required for failure if you, the estimated, I mean more is the delay in failure that will have decreased shear strength so you will be actually underestimating the shear strength of material, this can better be observed with the test setup with pore pressure transducers, so if you apply the rotation very slowly what will happen? You will get additional resistance based on the pore pressure, because pore water as it is the case of fully saturated soil, if you rotate it very slowly then pore pressure generation will be dominating and that will induce additional resistance to rotation that will be, that will give some additional component to the torque you are measuring, and that's why you will end up in overestimating or underestimating the finer shear strength, because you are actually not quantifying the pore pressure induced with respect to the rate of rotation, so at the end it will end up in underestimating the shear strength of the material.

As per Sridharan and Madhav were conducted in 1964 the rate of rotation can also effect the shear strength properties, so first one, the previous one was based on the pore base and induced related to the rate of rotations and this is telling like depending, if you rotate it very quickly then you will end up in underestimating, if you rotate it very slowly then you may end up in, I mean vice versa, so the standardize and then suggested like 6 degree rotation in one minute can be considered as optimum, or it can be standardize when you are going for measurement of un-drained shear strength of soft clays, so this is some kind of standardization based on the work by Sridharan and Madhav they have done after 1964, so people can take up this as a guideline and then once they are doing this kind of test setup at the site of interest this is the guideline typically they can choose to determine to ensure whatever values they are determining it is actually indicating the true shear strength or un-drained shear strength of the material at the site of the interest.

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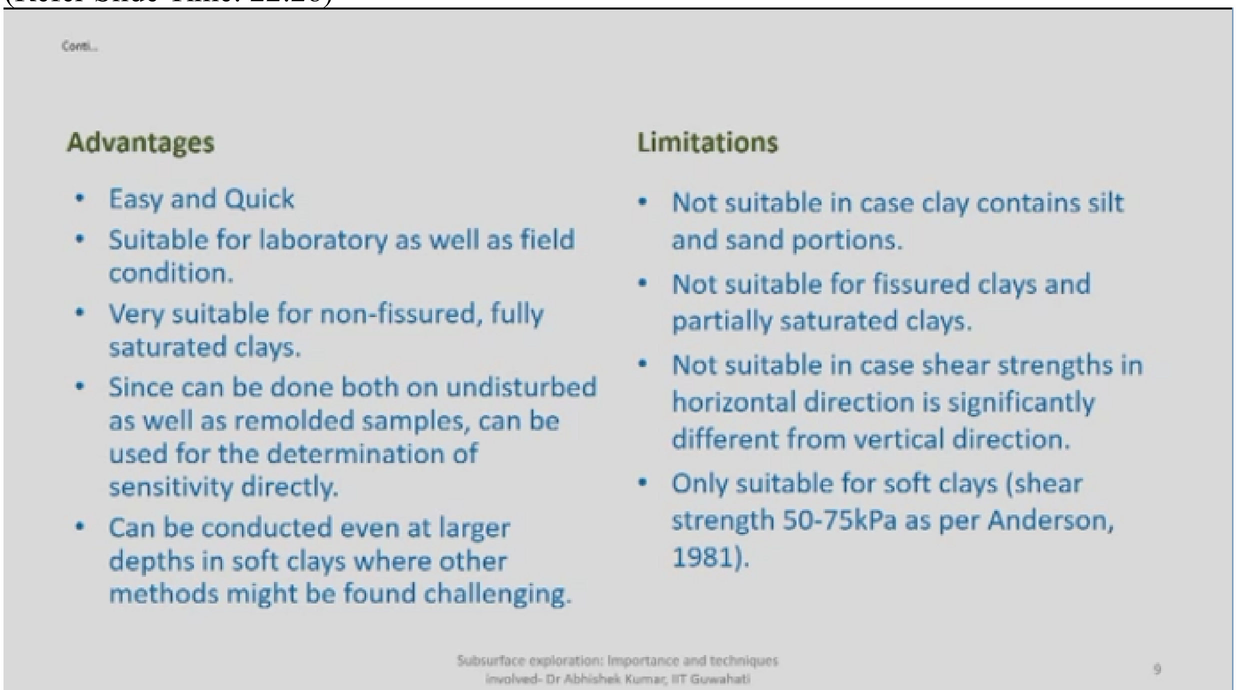

Of course just like any other methods or technology we use, even this method has certain advantage and disadvantage. Advantages are it is easy, it is very quick you simply lower the torque, vane, start measuring it then bring it on to the surface, next level whenever you are interested to driven the shear strength you proceed to that depth maybe by boring, then again remove the boring setup put this brainy setup and then again measure the rotation and followed by the shear strength determination, so it is very quick, it is very easy also determination, the chance of error very less.

Suitable you can do the test in the field as I told you, if you are able to get big chunk you can also determine the sample or if you are particularly doing on remolded sample you can actually determine the same thing in the laboratory also, you cannot use this test, I mean it is very useful for non-fissured fully saturated soil.

And since that test can be done both on natural condition or if you are creating a remolded soil sample in the laboratory so it can be able to determine the shear strength of both remolded as well as undisturbed soil sample, so you will be able to determine the sensitivity of the clays directly, you need not go for any other testing, undisturbed soil sample you are getting from the field, you are able to determine the shear strength, then remolded soil sample you are able to create at the site of interest or maybe once the soil is undergone some kind of failure at the site of interest itself you again do a vane shear test that will give you how much is the in-situ shear strength left in the soil which is already undergoing some kind of disturbance, so that’s how you can get the idea about the sensitivity, either of the combination of laboratory and field investigation or from the field investigation alone.

It can be conducted even at larger depth when other methods where you have to actually collect the soil sample, bring into the site, bring it into the laboratory or conducting the test it may be challenging, but this test you can even conduct at larger depth, again depending upon the depth your force applied or the torque application range will also increase, so we have to apply, we have to think and make ready with that kind of arrangement, if you go deeper and deeper the torque apply may not be possible manually you can go for some make any other arrangement also if possible, so these are the set in advantages what we have discussed.

Now we will be discussing about the limitation, so this test is most suitable for cohesive soils, it may not give very true indication when the soil is mixed with silt and sand portions, it is not suitable in case fissured clays is there or when the soil is partially saturated, and it is again not possible when the shear strength variation or the shear strength properties in horizontal as well as in vertical direction is significantly different, because as you saw the equation this is the one equation we are using for determination of shear strength, so if both in horizontal which is as a shear failure happening in horizontal because of top and bottom plate, and vertical direction because of vertical edges is happening, so if both are not equal then possibly this formula whatever we have used may not be useful, you have to have some kind of coloration correlating these two things, then possibly you may be able to use, but not in general because it's giving you collective information, because rotation even at the site will not be possible if the resistance under top is different and vice versa.

And the third, and the last point is it can only be used for very soft clays, so the shear strength ranges from 50 to 75 KPA as per Anderson 1981, so it cannot be used for very stiff clays or other materials, particularly for partially saturated also you cannot use it.

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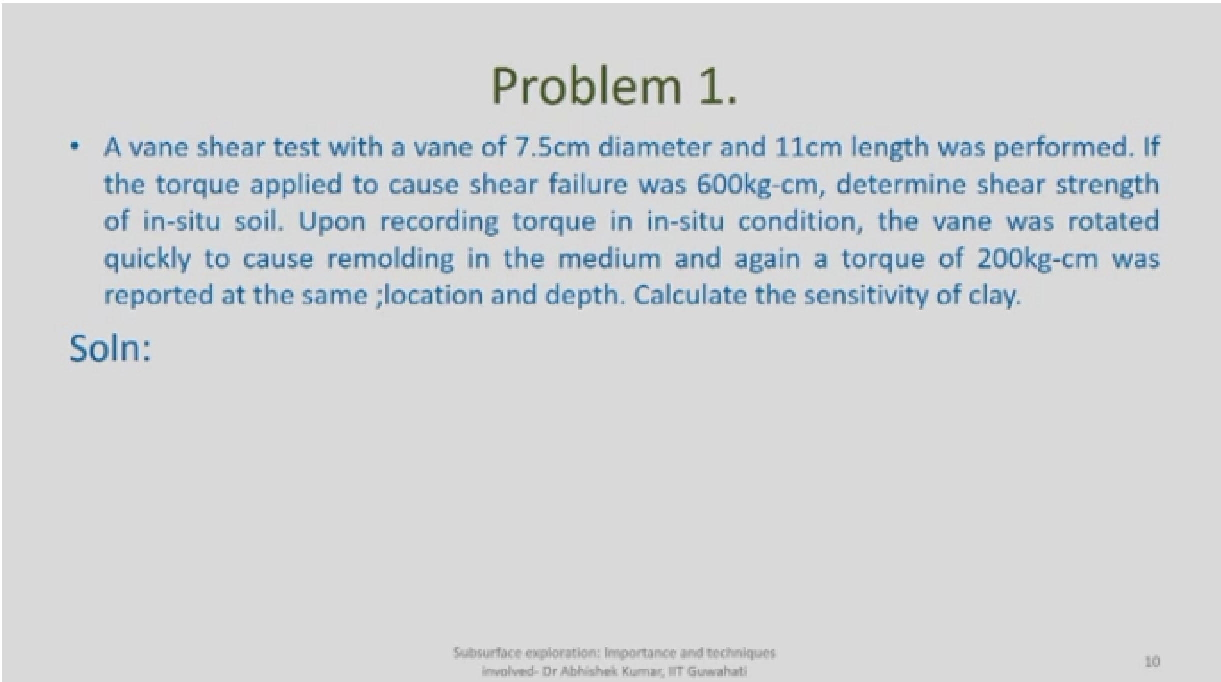

So with this background of our vane shear test, today we will be discussing about another numerical like how the information given from field investigation can be helpful to determine the shear strength properties, so here is the one numerical which says like or vane shear test setup with the vane of 7.5centimeter diameter and height of 11 centimeter length was performed, if the torque applied to cause shear failure was 600 KG centimeter determine the shear strength of the in-situ soil.

Second thing upon recording torque in in-situ condition the vane was again rotated quickly to cause remolding, so you started rotating it very quickly, it will cause disturbance and the soil sample whatever will be left there will be called as removal with soil sample, and again the torque was measured so it was 200 KGs centimeter, you can understand because initially we were doing in natural condition then you rotate it very quickly, so two things it gives you because it is not remolded, so shear strength will be lower and second thing the effect of rotation, if you rotate it quickly you will end up in underestimating the shear strength, I mean that the material property will change.

So at the same location, so you have two values of torque one is when you are rotating it at standard rate and other one when you are rotating too quickly, so based on these two you will be able to determine what is the shear strength, so first one will give you the shear strength in its natural condition, second one will give you the shear strength in its remolded condition.

And finally you will be able to determine what is the sensitivity of that particular clay material, so we are going to discuss this, so let’s list out what are the parameters given here, so first one is given, so you have H that is 11 centimeter, then you have diameter that is 7.5 centimeter, then you have torque that is 600 KG centimeter, okay, so you should be able to determine what should be the value of SU, SU should be how much.

Let’s go here by, so this is particularly when you have undisturbed soil, so T will be equals to that is 600 as we discussed earlier also will be equals to pi D square H times S/2 + pi D cube, this is SU, this is also SU divided by 6, just put the values here you will be able to understand pi/2 times D is 7.5 square times 11 times SU + pi/6 times 7.5 cube times SU that is shear, since all are in given in centimeter I’m not going for any unit conversion, so that way you will be able to get how much will be the value of this, if you solve this you will get to know 1943.86 SU divided by 2 + 220.98 SU equals to 600, so if you solve this equation you will get to know SU as how much? You will be able to get SU = 2.53 KG per centimeter square, this is the unit of because it is strength that will be having the unit of stresses.

Then second one will be remolded soil, so again H, D, everything will remain same but your T value will become 200KG centimeter, so use again the same formula you will be able to get 200 equals to same thing you will get here, whatever was mentioned 1943.86 SU/2 + 220.98 SU, and that’s how you will be able to get SU remolded = 0.16KG per centimeter square.

Now sensitivity, how you define sensitivity? So undisturbed, SU of undisturbed/SU of remolded, so this is called as undisturbed, so this will become just put the values whatever you have estimated so 0.53 divided by 0.16, so that will give you the value of 3.31 so this is called as sensitivity of the clay at your site of interest depending upon what depth you are targeting to assess the value.
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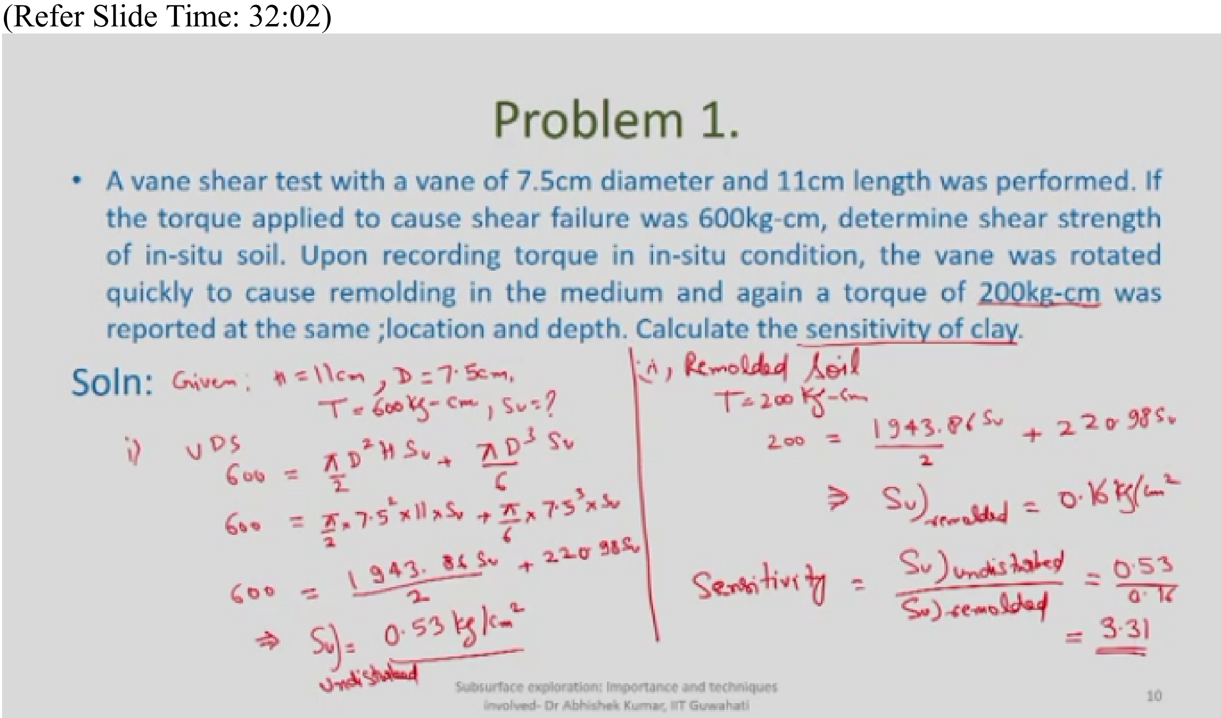

Now this is about vane shear test setup, so same way depending upon the depth you will be able to determine how much will be the shear strength properties at different, different depth, which you generally get from CN 5 values, and the sensitivity of the clay, so keep on doing the same test at different, different depth you will be able to get just like a bore log of what will be the value of shear strength property at different, different depth, this is about vane shear test.

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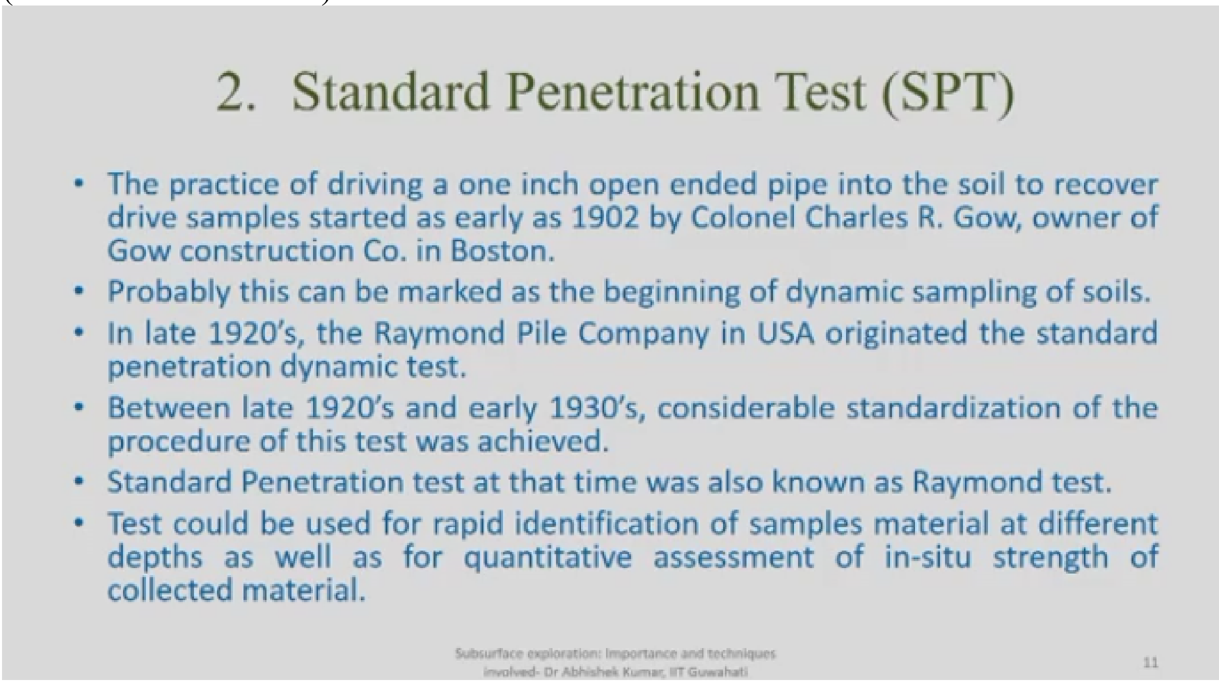

Now we'll go for another test, as we discussed earlier, so this test is called as standard penetration test also known as SPT, so the practice, before going into detailed about what is the test setup and how you do the test and interpretation let's see about what is the history of this. So the practice of driving of one inch diameter, one inch yeah diameter open ended pipe, so pipe into the soil, so you are actually driving some pipe into the soil so that you will be able to recover or you will be able to bring some sample from that particular depth on to the surface, this was first practice in 1902 by Colonel Charles R. Gow, he was the owner of Gow Construction Company in Boston, probably this was, this is marked as the first and then when dynamic sampling of soil had started.

So in late 1920 the Raymond Pile Company in United States of America originated the standard penetration test setup between 1920 to 1930 lot of work has been done towards standardization of this first test procedure and even now also whenever we go for any new sites or whenever we try exploring any older sites particularly like even nowadays also and maybe earlier days also like 10, 15 years back also if you start collecting the data, most of the data what you are understanding about the soil type about strength property of the site you are getting based on the samples collected from standard penetration test, so this test can be used because of standardization happened between 1920 and 1930 that time the test was also known as Raymond test, so it can be used as for rapid identification of sample material at different depth as well as for quantitative assessment, you will be able to get some value of quantity, some quantitative assessment of in-situ shear strength of the material, so vane shear test was giving for fully saturated soft clays, this also giving you some indication about shear strength property of the material.

So it can be, it is most commonly used for in-situ soil sampling because so far whatever test we had discussed whether it's our boring, wash boring, other than rock sampling which is particularly use for fractured rock, weathered rock,

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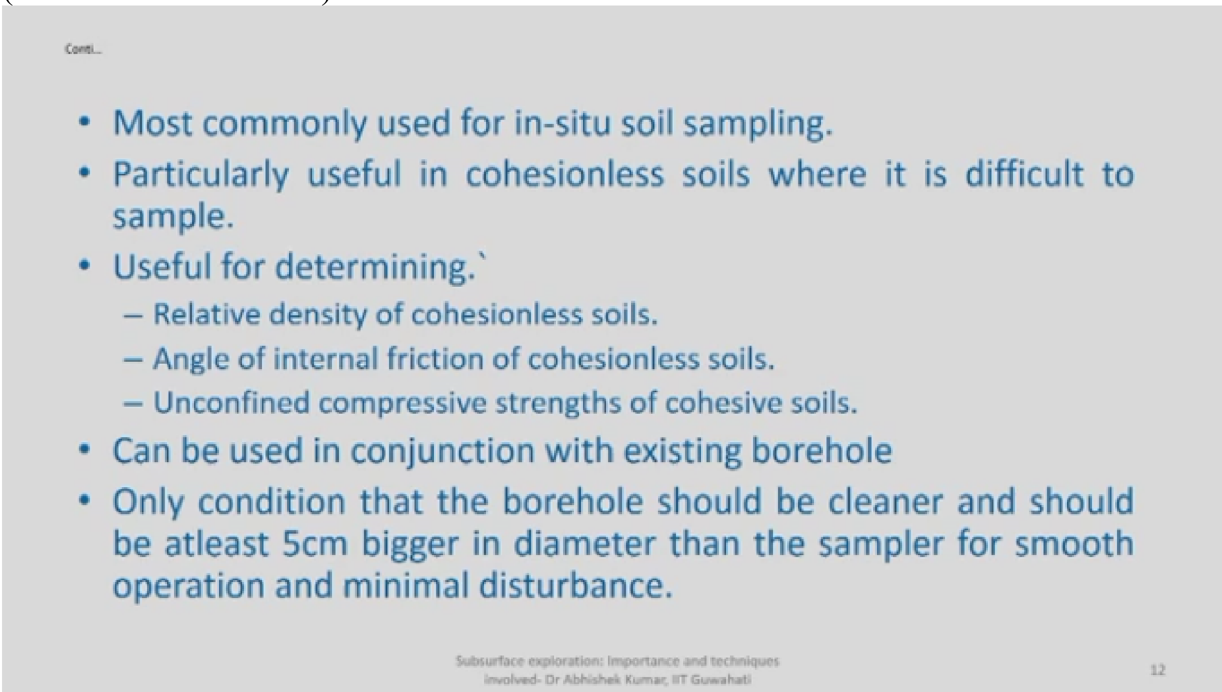

intact rock, SPT test we cannot use it there, but this is the most commonly used test where actually you are collecting the soil sample, so this is probably the first test so far, we have discussed where actually you are collecting the sample from that particular depth of interest you bring it on to the surface.

Earlier we had discussed the sampling for rocks, so particularly useful for cohesionless soil where actually you will be, you find it difficult to collect the sample otherwise so this way you can may be able to determine the in-situ strength properties of the soil, it is very useful and determine the related density, it's particularly useful for cohesionless soil, then angle of internal friction again for cohesionless soil, and then unconfined compressive strength for cohesive soils, so angle of internal friction, then relative density for cohesionless soil you can determine then unconfined compressive strength you can determine for cohesive soil, it can be used in conjunction as I told, I have been telling from time to time like when we go for boring, when we go for sampling it's like simultaneous one after the other you can do the exercise, so if you're designer and you are feeling in recommends you have to collect the sample at maybe 1.5 or 2 meter interval, so you need not go for continuous sampling you can do boring, and once you require the undisturbed sample or a sampling to be done, you can remove your boring assembly lower your sampling assembly at that particular depth, once your sample is achieved replace again your sampling assembly with the boring assembly and keep on doing the same exercise until you reach the desired depth or otherwise you face some other kind of material where SPT or boring method which you are using is not applicable, so then you can go for other test depending upon what is the usability or what is the suitability of each of those test considering the soil type available at the depth.

So it can be used in conjunction with existing borehole, only condition that the borehole should be cleaner, and also the borehole should be cleaner and should be at least 5 centimeter bigger in diameter, so if the borehole is of same diameter of the sampler, then what will happen the walls it will first of all there will be chances of wear and tear, and second thing when you are trying to measure the in-situ strength in terms of resistance offered by the soil, but some component based on the reference of the borehole wall in contact with, which is in contact with the sampler you will get additional resistance so you will end up in overestimating the soil resistance.

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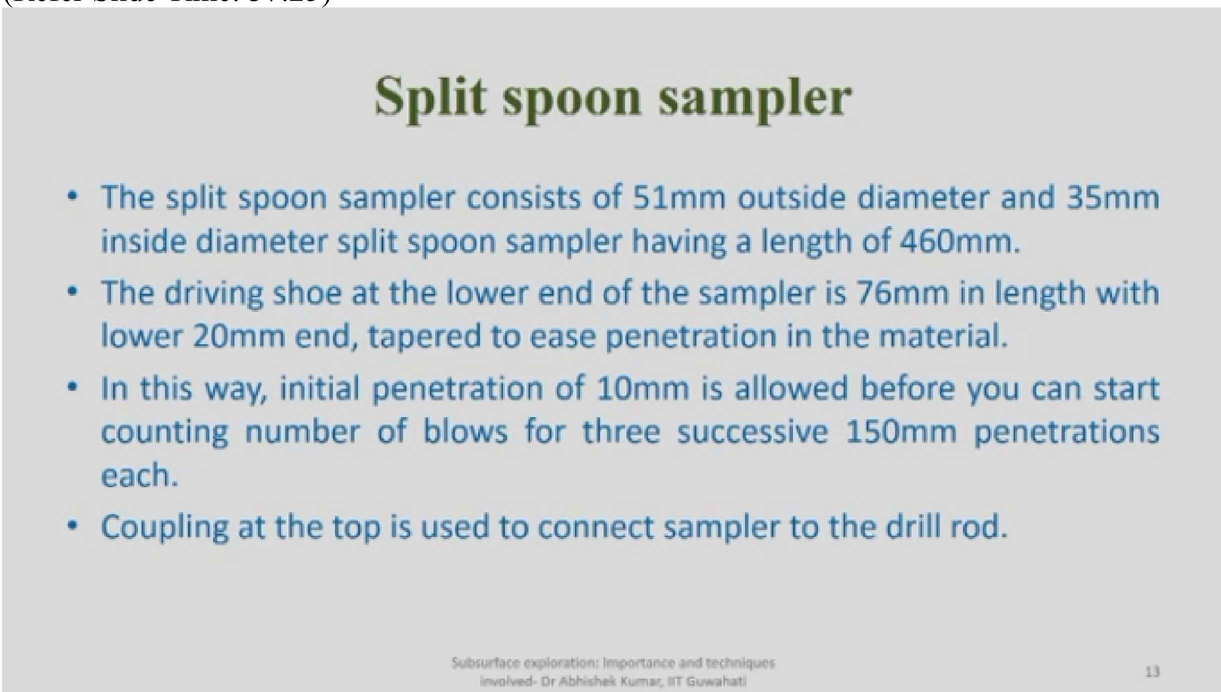

So for smooth operation, for minimum disturbance generally it is preferred that the diameter of the borehole should be at least 5 centimeter bigger in comparison to the sampler diameter, so we have been saying sampler but what is the meaning of sampler, so actually it is known as more precisely at split spoon sampler, so as the name suggest split it is actually once you get the sample from a particular depth you are actually able to split it, so it can open into two halves, so either of the half will be containing the soil sample, you can collect the soil sample from there, store it in the plastic bags or other where you are able to, so that you can contain the moisture contain particularly intact as you had collected from the site.

So what are the properties of that sampler at same distance, because you are putting it into the soil and bring it on to the surface so it's just like some kind of spoon, you are putting it and you are bringing it on to the surface and then you split it, so as the name suggest, so there is a spoon which is particularly used for sampling, and once you bring it on to the surface it will split it, so once you split it will be able to get you the soil sample, so the sampler is 51mm outside diameter, 35mm internal diameter with the total length of 460mm, so 460mm when tube is there internal diameter of 35mm, outside diameter 51mm, 460mm is the total length, and this tube is such that on the top, on the bottom you are having a driving shoe, at the lower end of the driving shoe which is 76mm in length, lower end is actually tapered like this, so when you push it into the soil it will be ease for penetration into the soil, so that's how you can actually push the sampler into the ground.

Then initial base, initial penetration of 10mm is allowed before you actually start counting the number of blows because in 10mm you will, even your test setup will based into some kind of disturbance, at times you may have some, I mean weathered material also available or some local concurs and small, small stones will be there which are actually not the part of in-situ soil very precisely to be told, and then you start the counting the number of blows required to drive the sampler to certain depth in three segments, that is 150 centimeter like 10 centimeter you removed or do not count the number of blows 10, 10mm and then you put your sampler then start pushing it under the impact load, so once it reaches 150mm penetration from the head of driving shoe you will count how many number of blows you had imparted for this 150mm, and then do it for another 150mm and another 150mm that will give you like 3 readings, N1, N2, N3, then you will be having because you have to apply some kind of impact load, so you have to have some kind of coupling with which you can actually connect your drilled rod, so drilled rod will be there at the top which is connected to the sampler, maybe available at 5 meter, 6 meter depth, so from the sampler to the top surface you will be having a drilled rod at the top of the drilled rod you will be having some mechanism which can actually apply impact load.

So sampler as I told here, so split spoon sampler it consists of something like this, something like this is one half, and then there will be another half here, something like this, so this is like once you connect it, it will be like this tube kind of thing you can see some hairline crack here, split wave which will indicate like you can actually split into the two parts, so there are side this will be some kind of coupling, so there will be some threads here, and then this other side there will be driving shoe kind of this, so this will give you an indication, you can actually push from this side into the ground, so this is same thing is on vertical phase, and then you have drilled rod depending upon whatever is a depth of interest it should be of consistent in diameter, drilled rod and this is your depth of investigation, this is ground level and this is a borehole, this is a borehole which is, as I suggested earlier also borehole which is at least 5 centimeter bigger in diameter then sampler, so this is about, what is happening below the surface then on the top you will be having some assembly which can actually impart some kind of impact load.

Now every time you apply some impact load or some push this will actually push into the ground and the next time there will be some more push, some more push, finally when this entire push will be equals to 150mm which you can actually imply from here like this, so 150, 300, 450 which can actually mark here, so that you will be able to understand here also or and same thing here also,
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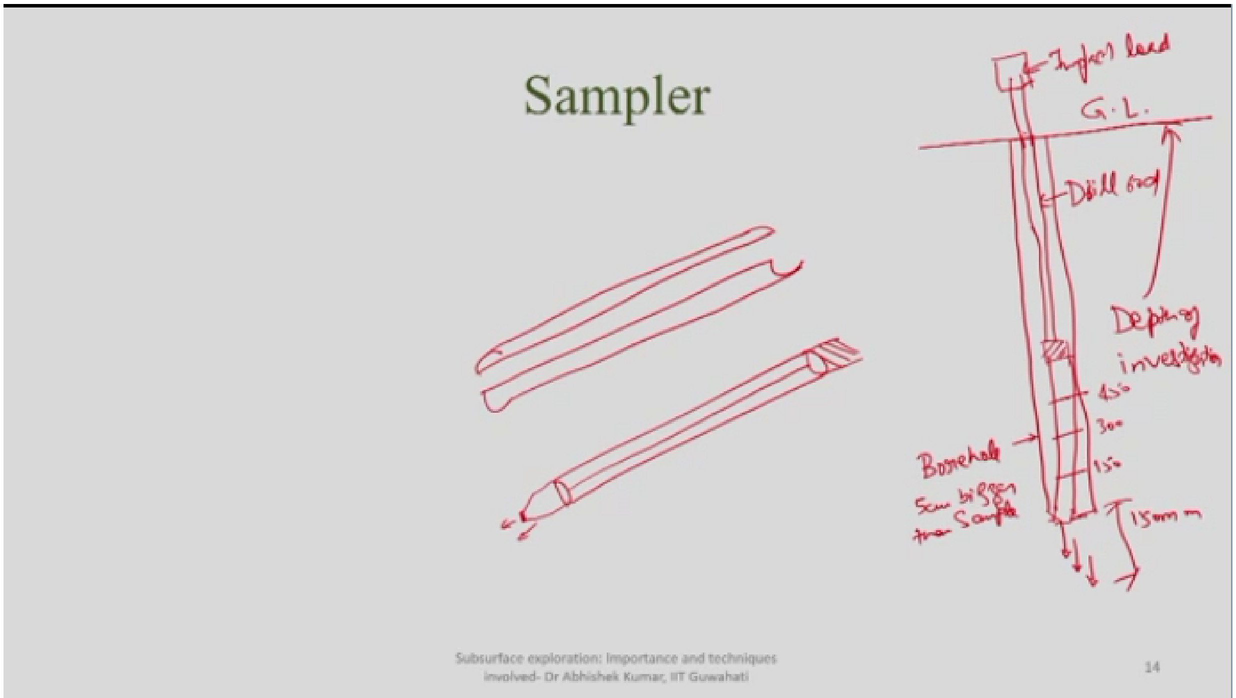

because this will be below the ground surface, so you can actually apply here, 3 markings of 150, 150 interval, that will give you once, when your sampler has pushed 150mm into the ground you mark how many number of blows are there, so this is about the sampler, this is called as split spoon sampler.

So once you bring out on to the surface there actually you will find some kind of soil sample depending upon, the condition of the soil you may get, small sample you may get entire area once sample like this, you collect the soil sample into some plastic sheets, wrap it, so this is like plastic cover, you wrap it and then you will be able to understand you can test it further in the laboratory, further take to laboratory, so you will be getting sample as well as you will be able to understand the resistance offer.

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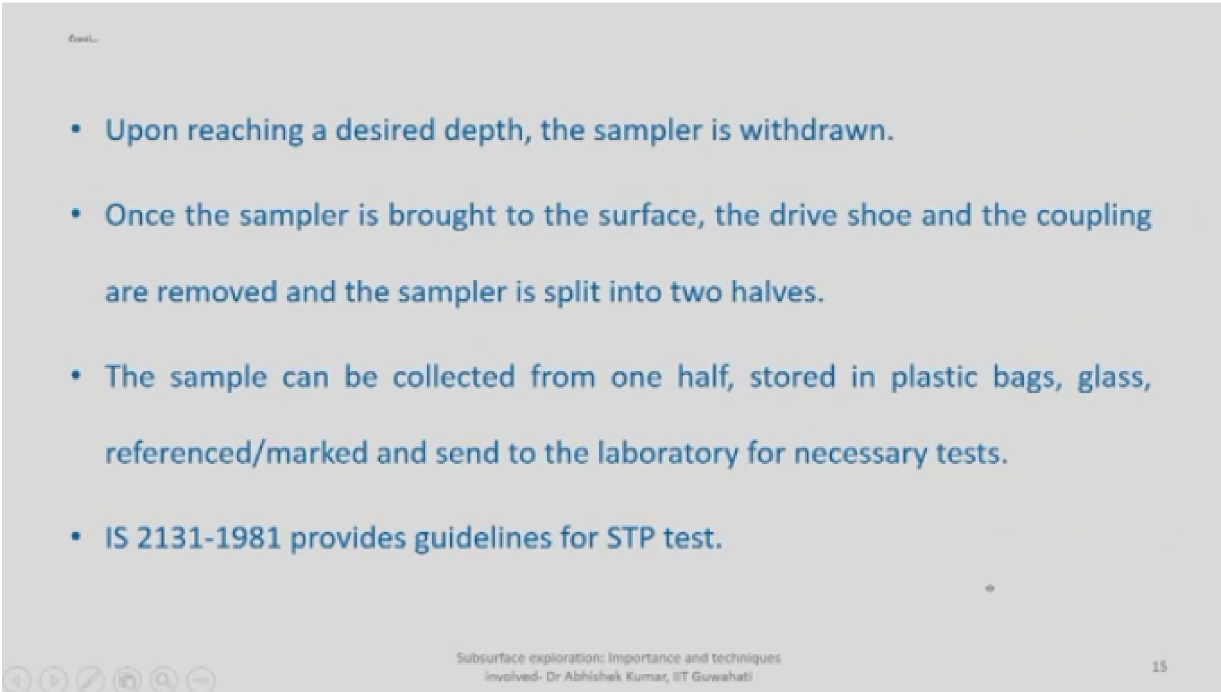

So upon reaching desired depth, the sampler is withdrawn, once the sampler is brought on to the surface the drive shoe and the coupling are removed so that the sampler can be split into parts, the sampler can be collected, the sample can be collected from one half stored in plastic bag, glass, referenced, marked you can put the date, borehole coordinates also if you are collecting number of boreholes information at same stacking setup, and then send to the laboratory for necessary investigation, so IS 2131-1981 provides guideline for SPT test.

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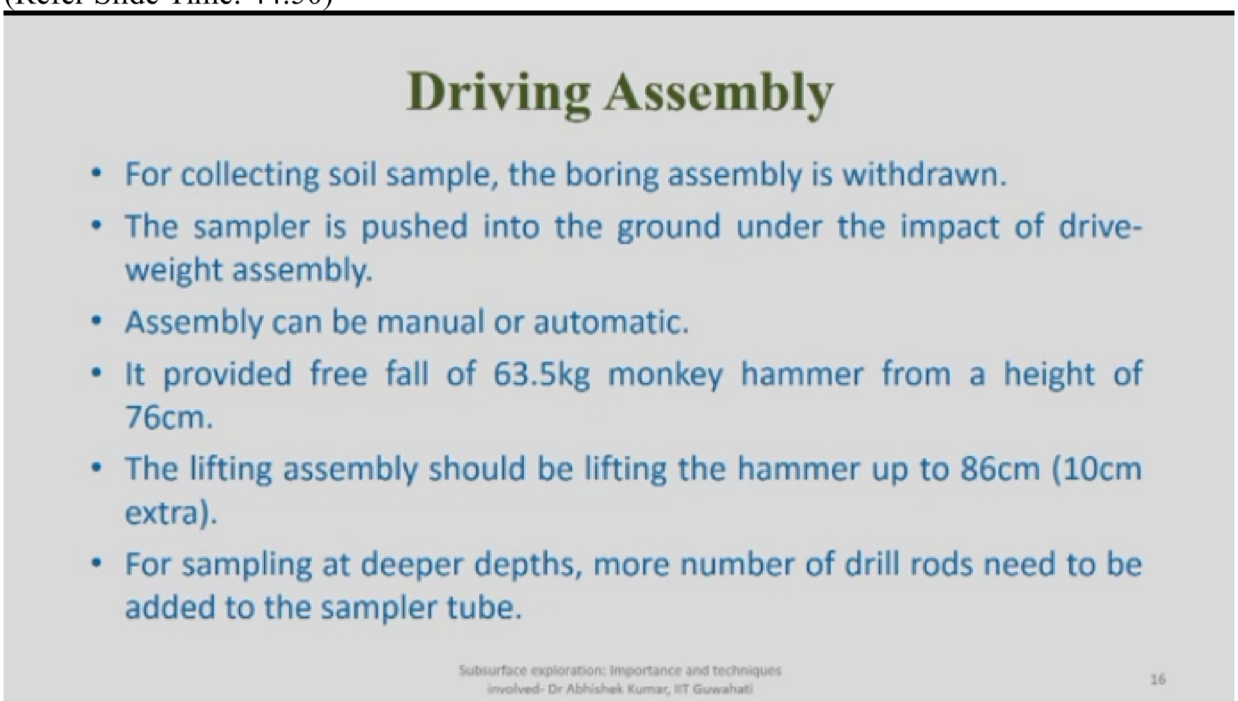

Driving assembly, for collecting the sample the boring assembly is withdrawn, the sampler is pushed into the ground under the impact of driven weight, assembly can be manual or automatic, you can use automatic or driving weight, so assembly is such that it should provide your free fall of 76 centimeter, because it is after all impact load so you have to have some kind of free fall that is 76 centimeter, and 76 centimeter you are dropping a hammer which is of 63.5 KG called as monkey hammer, the lifting arrangement that's why should be capable of lifting the hammer, 76 centimeter + 10 centimeter extra, in order to make sure it is able to lift otherwise what will happen if it is just 76 centimeter and you are pulling it, what will happen is, actually it will sometime pull the sample also towards the ground, so in order to make sure that thing should not happen, while doing a particular set of measurements you have to have some 10 centimeter extra.

For sampling a deeper depth more number of drilled rods, so you keep on applying depending upon the length of the rod and depending upon what depth you are actually exploring the soil sample you keep on adding more number of rods so that you can penetrate deeper depth and then do a test.

Markings as I told here, suppose this is your drill rod, this is your ground level you actually mark 3 locations here, so that will tell 150mm, 300mm, 450mm, so you start pushing when ground level, when this thing will reach there you will stop counting N1, when this will reach here you will stop counting N2, when this will reach you will count N3,

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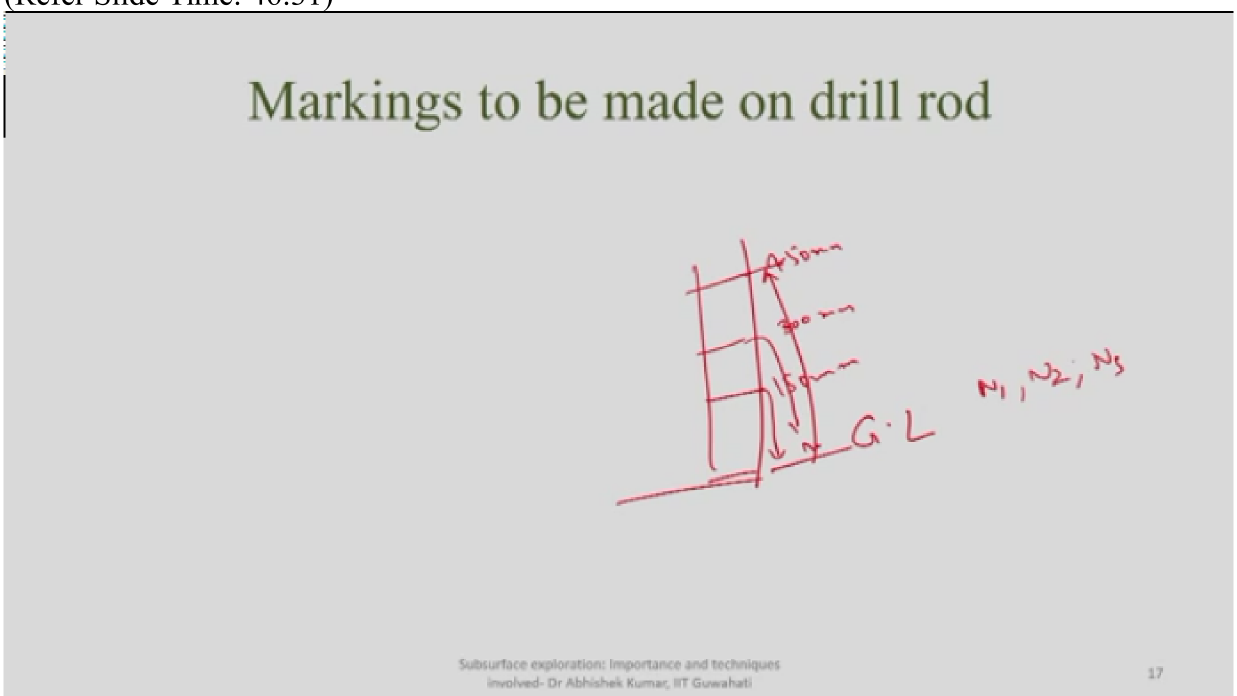

so for every 150mm centimeter so generally people mark it by chalk or maybe marker, for easy like otherwise because it is pushing into the ground otherwise how you'll get to know like it has reached 150mm penetration.

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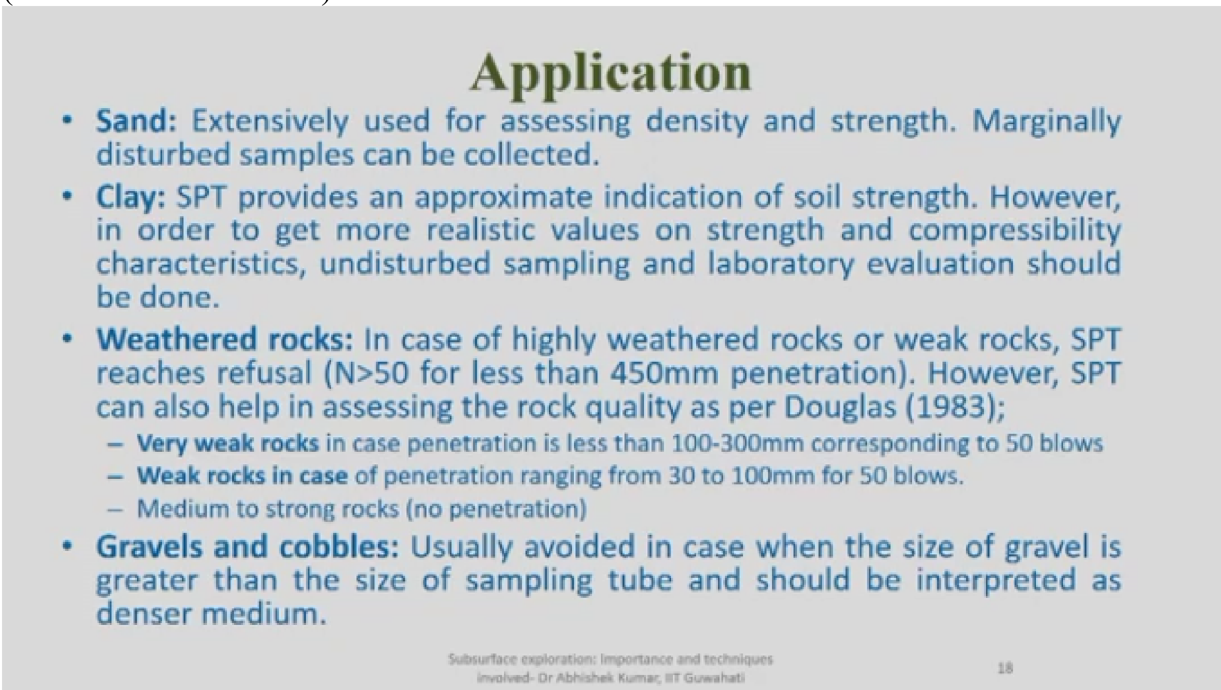

Then application it can be extensively used for assessing the density and strength of sands, even you can get marginally disturbed samples, clay it can provides approximate indication about the strength properties, however to get more realistic value of our validation you have to collect the samples by other means and test in the laboratory, weathered soil you can use it in case of only highly weathered rocks, even you can use it for classification of rocks like when you are getting 100 to 300 penetration only for 50 number of blows you call it as very weak rock, when for 50 number of blows you are only able to penetrate 100mm, that means this rock is lesser, weak or it's not very weak, and then no penetration then you refer it as medium to very strong rock.

Cobbles and boulders also you can do the test but provided the size of the gravel is not greater, otherwise your sampler will not be able to contain any sample, and that's how you will not be able to do the test in cobbles and boulders, so once you do the test depending upon your average N value so when you go for final N value reporting, you will report N2 + N3.

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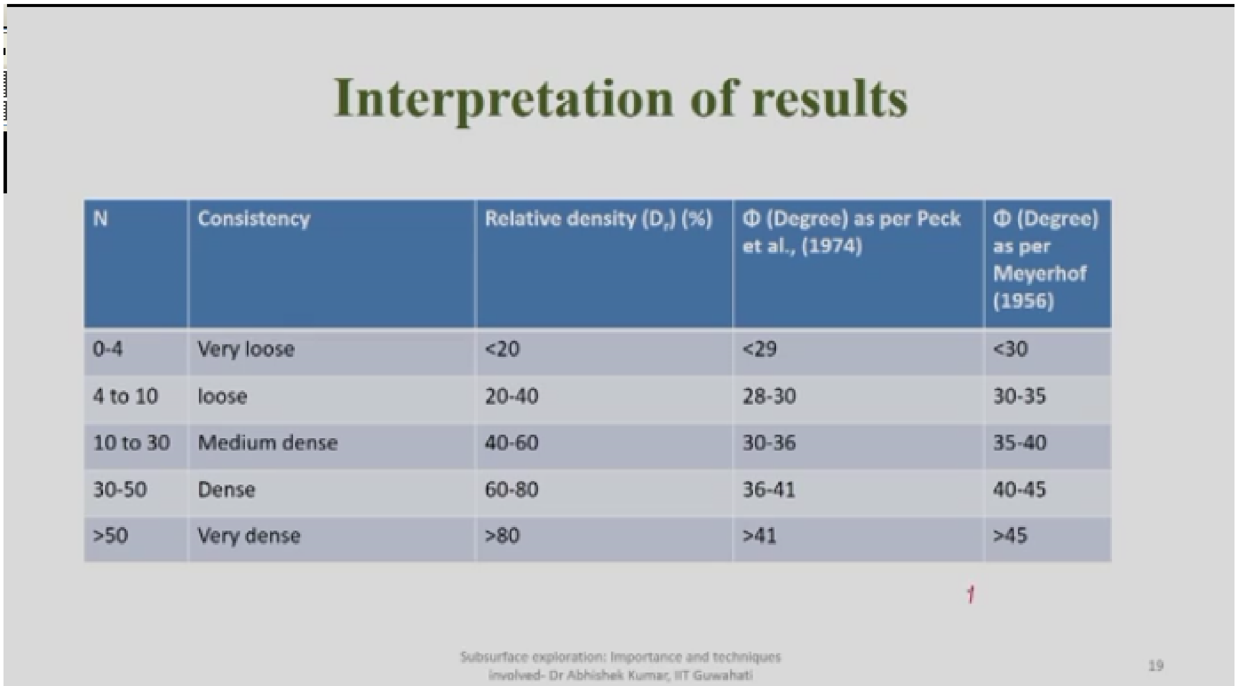

First N1 you will not considered because that the depth in which you are first, that you are penetrating 150mm for the first time that will depth mostly contained vegetation and other filled up material and other things, so generally we go for reporting next to number of blows, for next to 150, 150mm penetration, so once you know this you can get, first of all get to know what is the consistency whether it is very loose soil, loose soil, medium dense soil, dense soil are very dense soil, you can also get an idea about what is the related density like 4 to 10 if the SPT N value will say it is very loose soil, having density in the range of 20 to 40.

Similarly Peck Et Al in 1974 provided reference based on your SPT you can get idea about 5 value and then same by Meyerhof in 1956, so that's how you can actually get an idea other than number of blows you can also get an idea, what is my consistency, what is the relative density and what is the 5 value of the soil.

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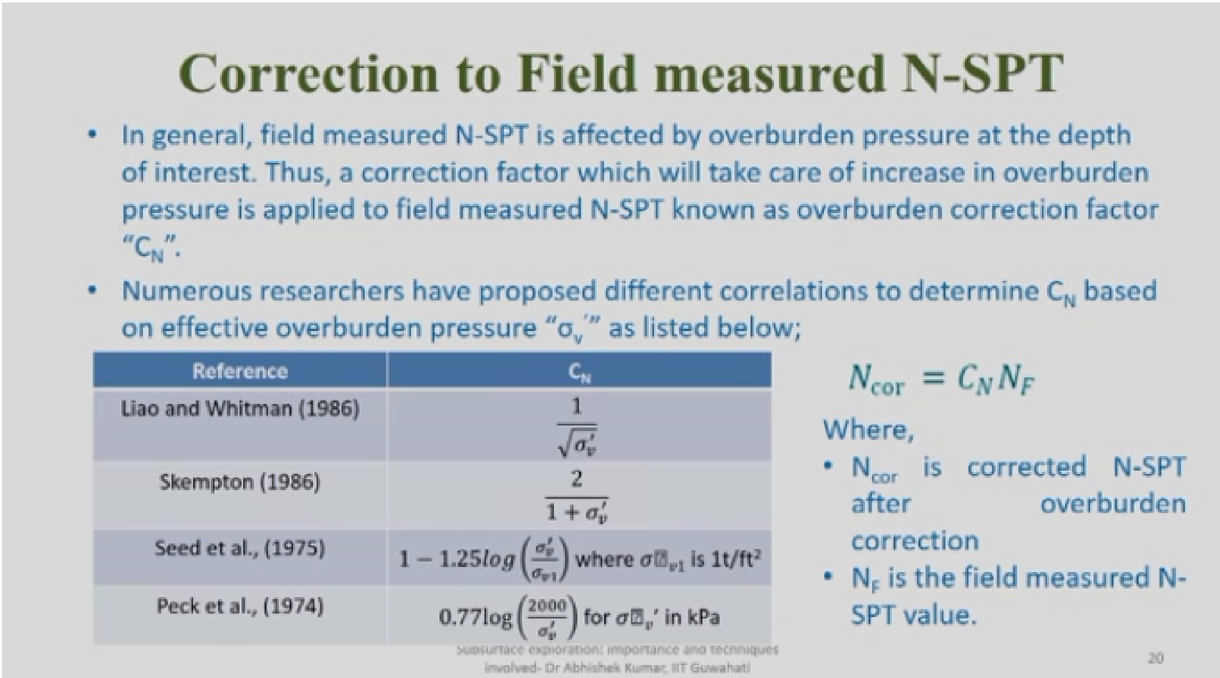

Field measurements, once you collect the soil sample as we all know, as you go deeper and deeper there will be more confinement because of overburden pressure, so in order to apply correction, in order to correct the field measured value with respect to borehole diameter, with respect to the depth at which you are correcting the soil sample you have to go for some kind of correction known as overburden correction, so this is like this and corrected will be equals to overburden correction multiplied by field recorded SPT N value, so different people have given different values of overburden correction factor, where sigma VF, this is a effective stress at that particular depth, you put it here you will be able to understand what will be the value of CN, apply it to the field recorded SPT you will correct, you will be able to get corrected N-SPT for overburden correction.

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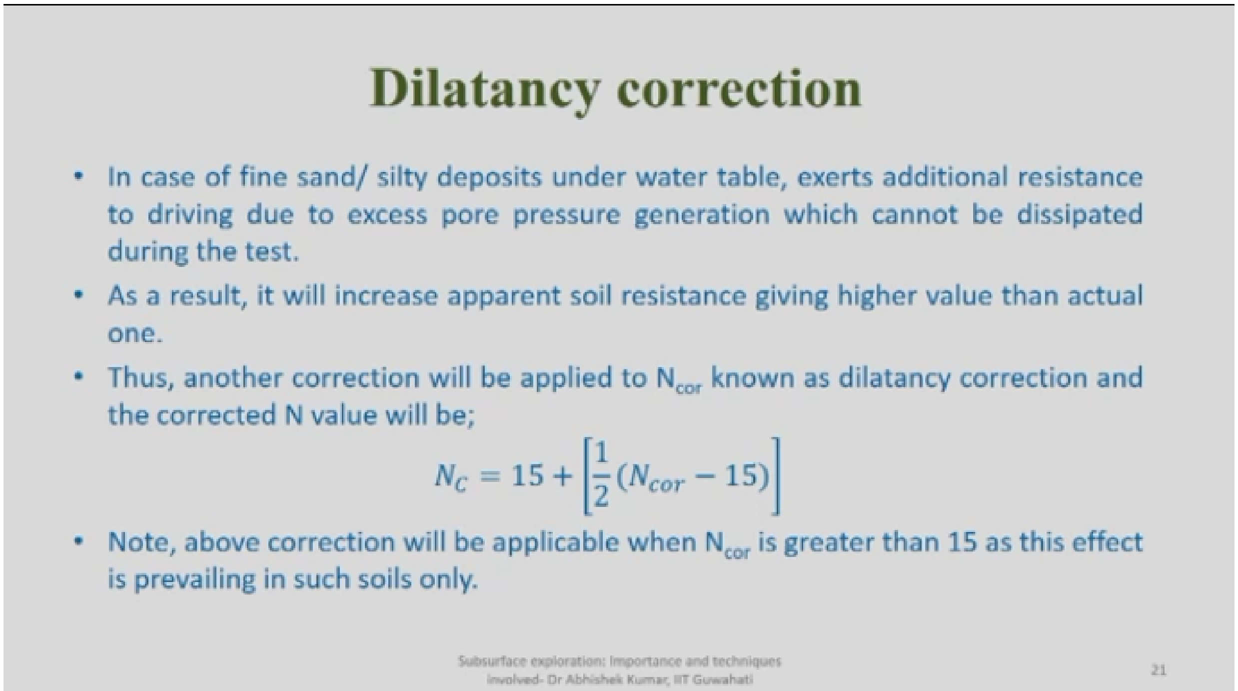

Then second it has been observed like when a particularly in case of fine sand and silts that the permeability significantly lesser in comparison to cores and soil because of high rate of loading, what will happen? Particularly underground water table there will be additional pore water pressure generation, because you are lowering, you are providing some kind of impact load and water is not able to dissipate within that small instance of time, so as a result of which this pore pressure will apply additional resistance or additional force on to the sampler which cannot be dissipated quickly during the test as a result so you are having some resistance of weather soil plus some resistance additional which is called as apparent resistance which is because of pore pressure generated, so you have to apply some additional correct, it has been applied if the corrected N-SPT for overburden correction, if it is greater than 15 and the soil is fine grain sand or silt then only this correction due to dilatancy is required, so this is the correction factor 15 + half times, actually this correction this should come here, not here, half times N corrected and 15 were difference, that’s how you can apply, so finally the correcting, this is the final corrected in N-SPT value, which is corrected for overburden as well as which is corrected for dilatancy correction.

So we’ll stopped today here, in the coming class based on this SPT interpretation we will discuss one numerical problem also like once you know SPT test and at required depth how you apply different corrections, and then how you interpret the data, so thank you so much. We’ll meet in next class.

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