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Subsurface Exploration: Importance And Techniques Involved

By
Dr. Abhishek Kumar
Department of Civil Engineering
IIT Guwahati

Lecture 7
Geotechnical Investigations

Dr. Abhishek Kumar
Assistant Professor
Department of Civil Engineering
Indian Institute of Technology, Guwahati
Webpage: http://www.iitg.ac.in/abhiak/

Welcome all, today is lecture 7. In last couple of lectures we are talking about geotechnical investigation. So let's further discuss about some more methods which can be used for geotechnical investigation.
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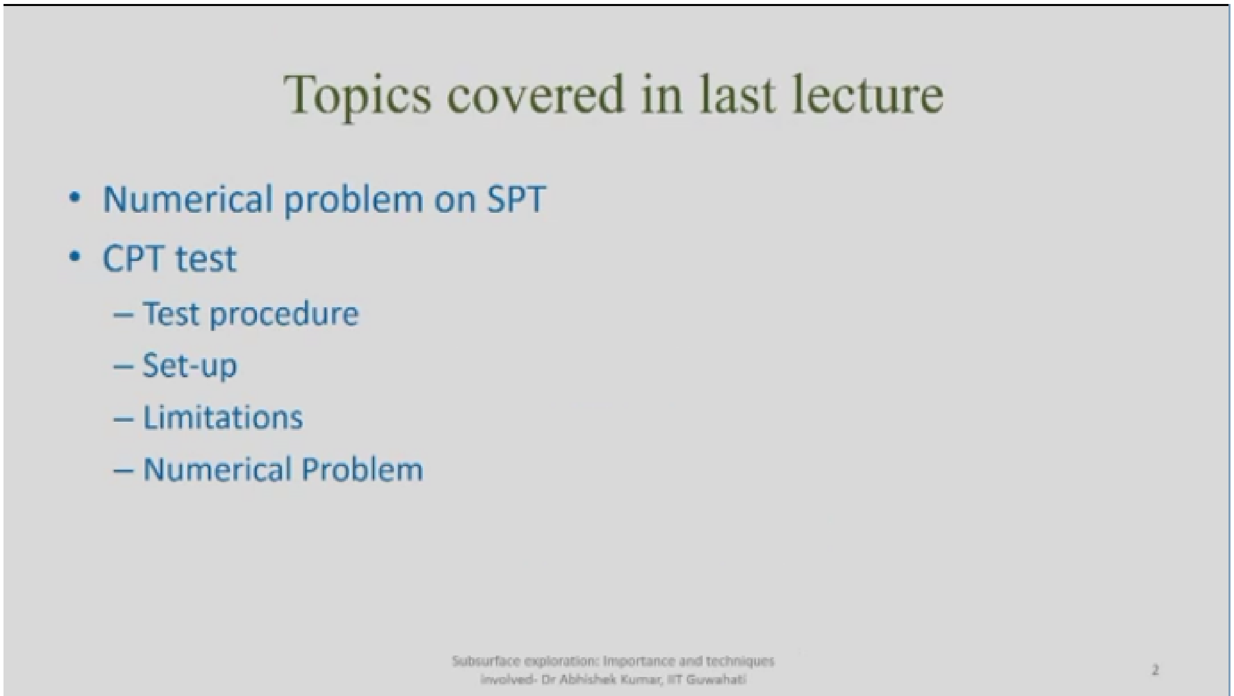

So before going to today's lecture material we'll discuss about whatever topics we had discussed in the last class, so first of all last class we discussed about standard penetration test, how you do the test, how you do the interpretation part, and what are the different corrections to be applied, so based on those discussion and last lecture we tried to solve an numerical problem where N-SPT value at different, different depths were given, and we tried to find out how to approach to find out the correction factors whether it is for overburden correction, whether it is for dilatancy correction, and then based on each of those corrections, how to find out the corrected N-SPT value.

Then we also talk about cone penetration test that is CPT test, so what is the test procedure to be adopted in the field, how you measure, how you lower the penetrometer, what are the different field parameters you have to record at the site of interest including slip fraction and quantitative resistance, and based on these two parameters and at times pore water pressure also based, by means of transducers you measure, by means of each of this parameter we tried to find out though we are not getting any kind of samples, so based on field recording we tried to find out how we come to know what is the in-situ strength, what is the soil type, what is the other parameters which can affect your bearing capacity, search of foundation settlement, design, even consider addition behavior of the material.

Then similar to any other test, what are the limitations of CPT test, as we discussed like the soil which are undergoing failure it is not that type of the cone, but it is a 21 centimeter ahead of the table, which is causing I mean where the passive failure in the soil is happening.

Then based on the discussion on cone penetration test setup and limitation we tried to solve a numerical problem,
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so when we started our geotechnical investigation we talked like there are different methods which can be used and each of these methods can be categorized under semi-direct method, the direct methods were trial pits, test pits where you are actually going to the site, try to dug out the sample where you can actually see the stratification and its natural condition where you can actually see the soil layers in different condition, reported with respect to some nearby structure, reported with respect to the depth and so on and so forth, so those are called as direct method.

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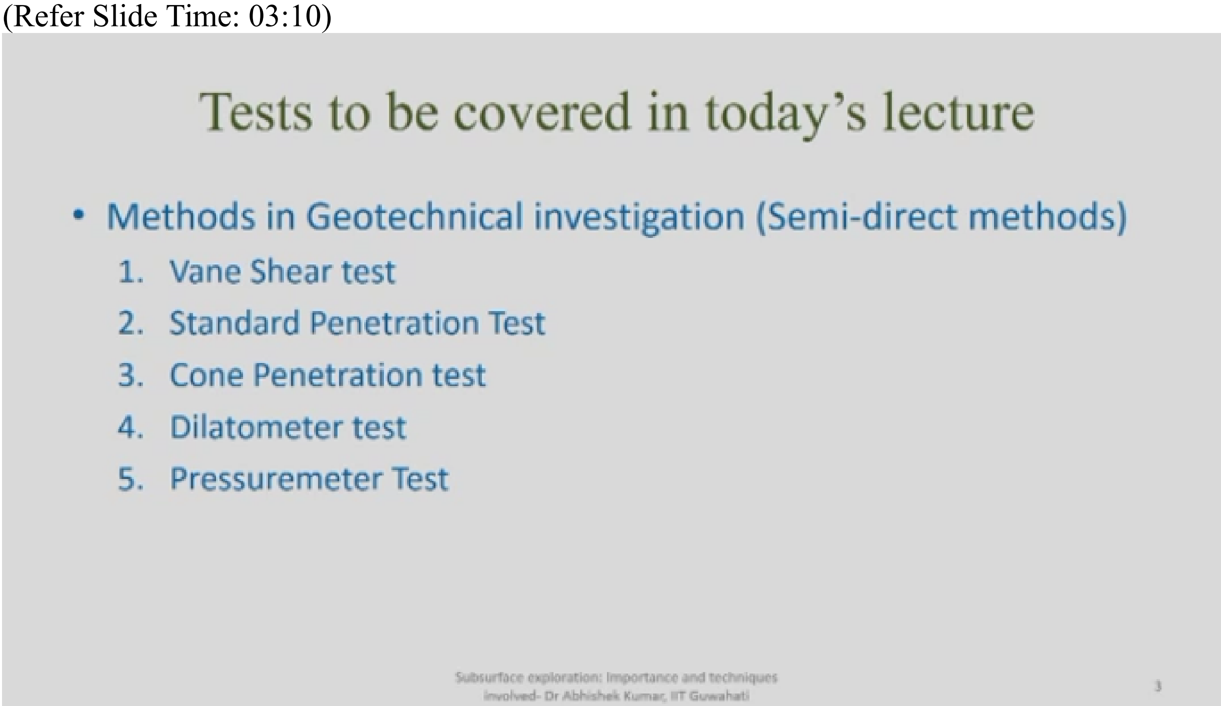

Then geotechnical investigation called as semi-direct method, so we had different methods like vane shear test, standard penetration test, cone penetration test, dilatometer test and pressuremeter test.

So in the last two classes we have already discussed about vane shear test, standard penetration test, cone penetration test, so in today's class we will be discussing about dilatometer test, it is also called as flat plate dilatometer test or DMT,

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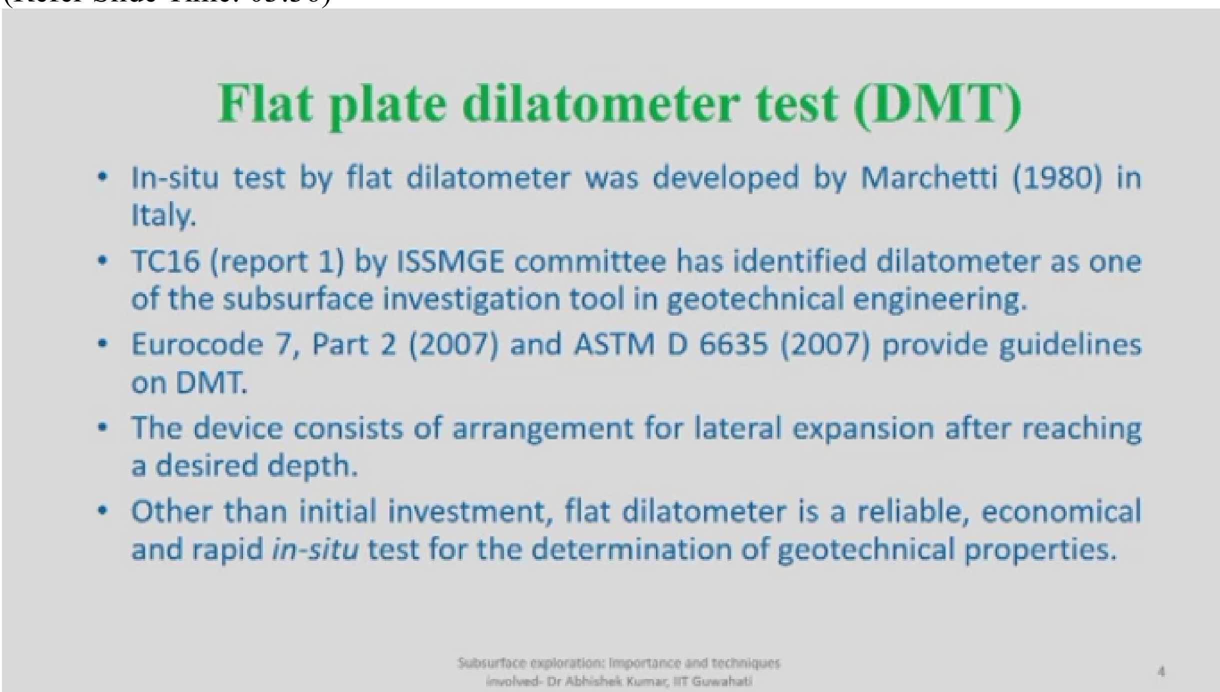

so in-situ test by flat dilatometer was developed by Professor Marchetti in the paper referred as Marchetti 1980 particularly in Italy, so as per the technical committee 16 report one under international society for soil mechanics and geotechnical engineering that is ISSMGE committee has identified dilatometer as one of the subsurface investigation tool in geotechnical engineering, so whatever test we are going to discuss today that has already been identified as one of the geotechnical investigation tool by international society like ISSMGE, so different technical committees are there for earthquake geotechnical engineering for depth foundation, for retaining structures, so this one particularly was recommended by technical committee 16.

Similarly eurocode, another standard guideline provider, like eurocode 7, part 2 in 2007 as well as ASTM D 6635 in 2007 also provide guideline about dilatometer test, how to use a test, how to go for the interpretation, so the device consists of an arrangement for lateral expansion, so there is a device you lower it depending upon the depth at which you are interested to find out the soil characteristics, if you lower the test arrangement at that particular depth and try to find out the soil characteristics by means of lateral expansion.

Other than initial investments the flat dilatometer is a reliable, economical, and rapid, in-situ test for the determination of geotechnical property, so this method other than the initial investment which is particularly for the purchase of the test, it can provide you very reliable information most robust information and numerous parameter you can determine once you do this kind of test at the site of the interest, so it's more economical also and it's because you are going for continuous recording just like CPT test, this test can be considered as very rapid in comparison to other test like SPT where you have to collect the sample at regular interval and bringing it on to the surface, so that's why it has been recommended even in offshore investigation also, DMT also one of the most favorable test or I mean bedrock, I mean bed material exploration in water bodies.

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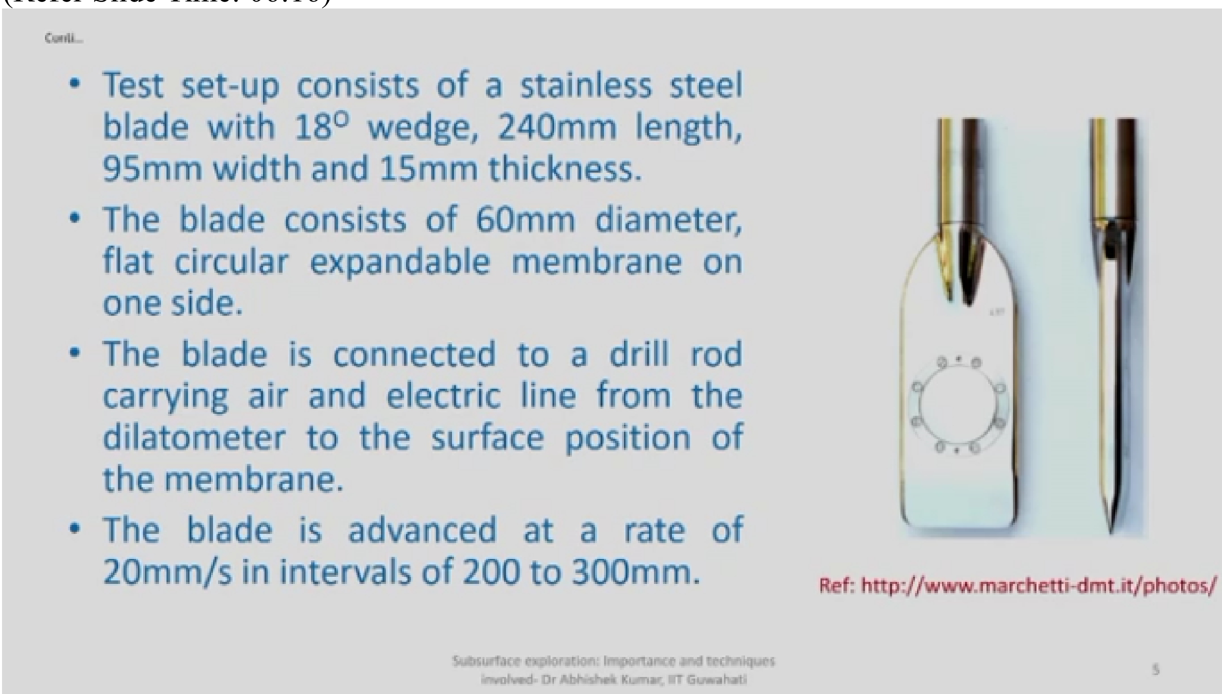

So let's discuss about the setup, so the test setup consists of a stainless steel blade you can see here, there is a stainless steel blade here which is 18 degree wedge angle, 250mm length, 95mm width, and 15mm thickness, so this is the dimension of the blade itself based on the dimension you can understand, so 250mm almost 24 centimeter, 95mm is the width of the base and 15mm is the overall thickness, so this is the kind of blade you can see here on one side of the blade you are having this membrane, and the other side is this side you can see it is flat, so the blade is intact in this position, however you have membrane kind of thing in this location, maybe because in this particular photo the membrane is in contact with the blade that's why you are not able to actually differentiate whether there is a separate membrane which is coming out or sweat curvature is there in the membrane as it comes out of the blade, so the test setup it is consists of this membrane, the blade consists of 60mm diameter, so this is like 60mm dia, flat circular membrane so this is a flat circular membrane on one side,

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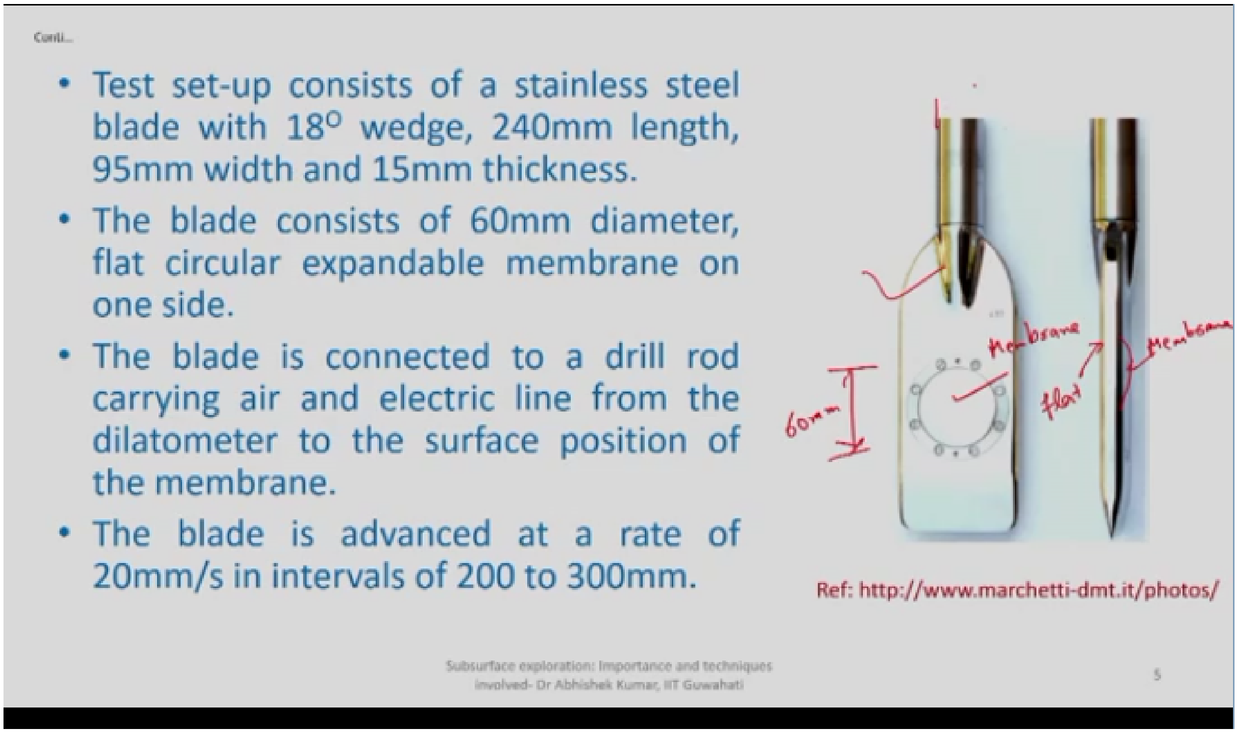

the blade is connected to the drill rod so this assembly whatever you can see on the top that will be again mounted on some drill rod by means of threads, so more and more drill rods as you go deeper and deeper very much similar to your CPT test you keep on adding more and more number of drill rods here.

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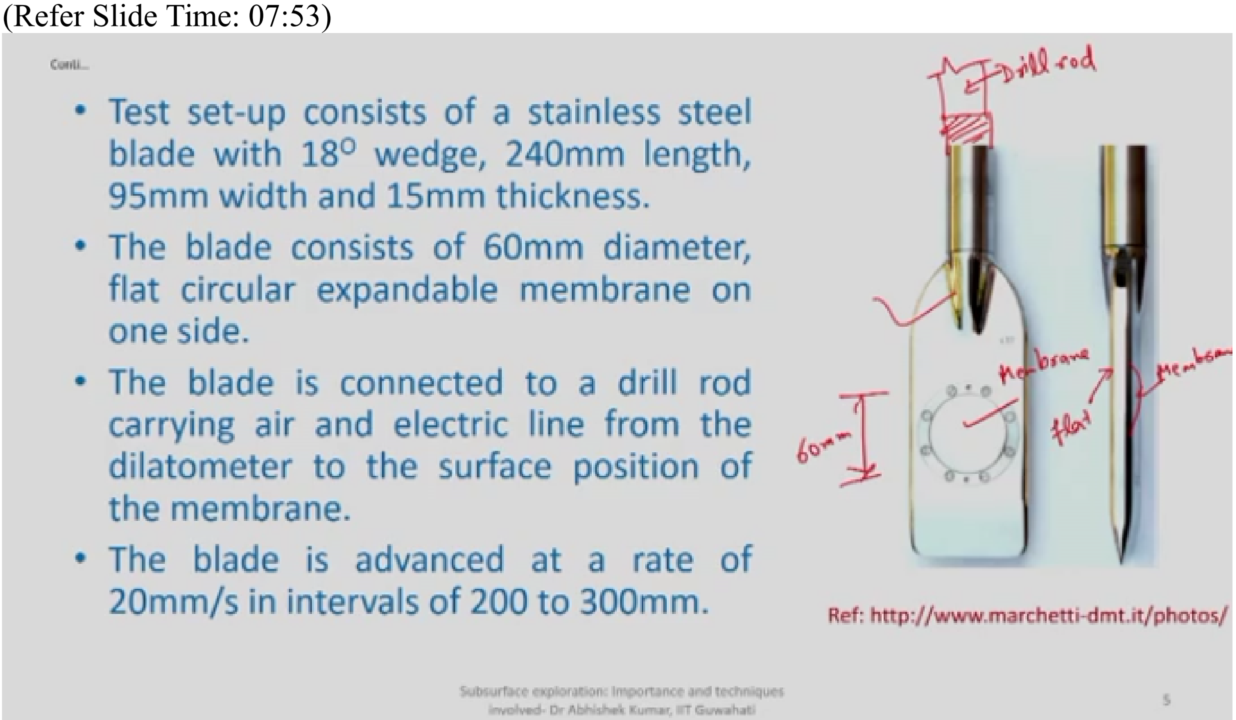

As we had discussed earlier drill rods maybe 1, 1.5 meter thickness because the pressure whatever we are applying at different, different depths so we generally we don’t go for drill rods are too much length, so drill rod maybe of the length of 1 to 1.5 meter length, you can use it connect it, if you are targeting for 20 meter depths accordingly you can count how many number of drill rods will be required.

Very much similar to CPT test, you have to understand like what is the depth of exploration because so many number of drill rods, again those are hallow, so there are some kind of measurements, there are some kind of pressure you had to apply from the surface, so every time you put a drill rod you have to actually pass on one or two cables, particularly for pressure application as well as field recording and field measurement.
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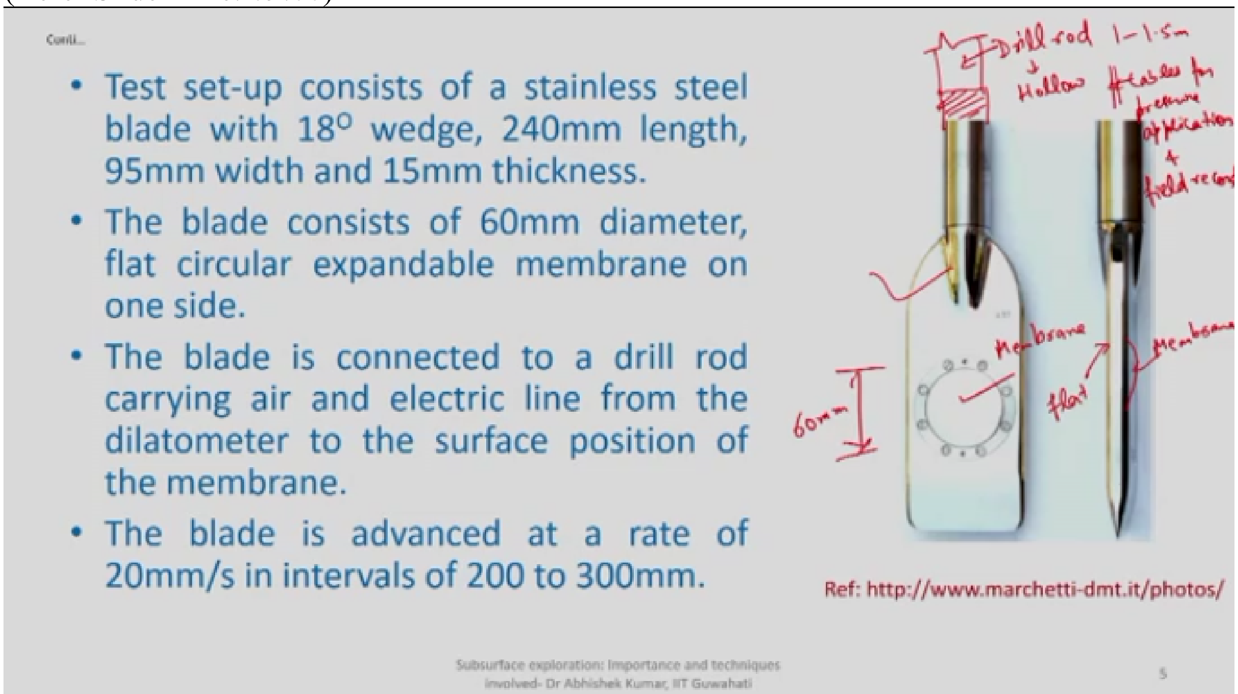

So minimum two cables will be there one is for application of pressure by means of different arrangement and second is whatever pressure is measured you have to get it record on the surface by anyhow, so there will be minimum two cables which will be passing through the drill rods, so in order to, I mean before we start a test depending upon what is the depth of exploration you better pass these kinds of cable through each of these drill rod which are going to be used during the field test, because later on it will be difficult to add more number of rods and then cable will not be connected and you will find difficult in field recording.

The blade is connected to the drill rod as we mentioned here carrying air as well as electric lines so there will be line which is particularly for application of air pressure to the dilatometer from the surface position of the membrane, so this dilatometer will be at the depth of interest where you are interested to find out the subsoil properties, where you are interested to even identify the soil sample and this will be connected from the surface assembly through which we will be applying different pressures, and through which we will be actually measuring the pressures at different, different instances, so the blade is generally advanced at a rate of 20 millimeter per second in interval of 200 to 300mm, so 200 to 300mm continuous push will be there and every 20 millimeter per second there will be some kind of, it is the rate at which you are actually pushing it, so every time you are making some kind of measurements you record it, then you go for next push in the interval of 200 to 300mm again I mean stop it there, then apply some kind of pressure, measure different values of pressure which are required for this particular test and so on and so forth, you keep on repeating the same test procedure up till you reach the desired depth of exploration.

So very much similar to your CPT test, even dilatometer test also gives you continuous recording, continuous in the sense at an interval of 200 to 300mm you will get different, different values, okay.

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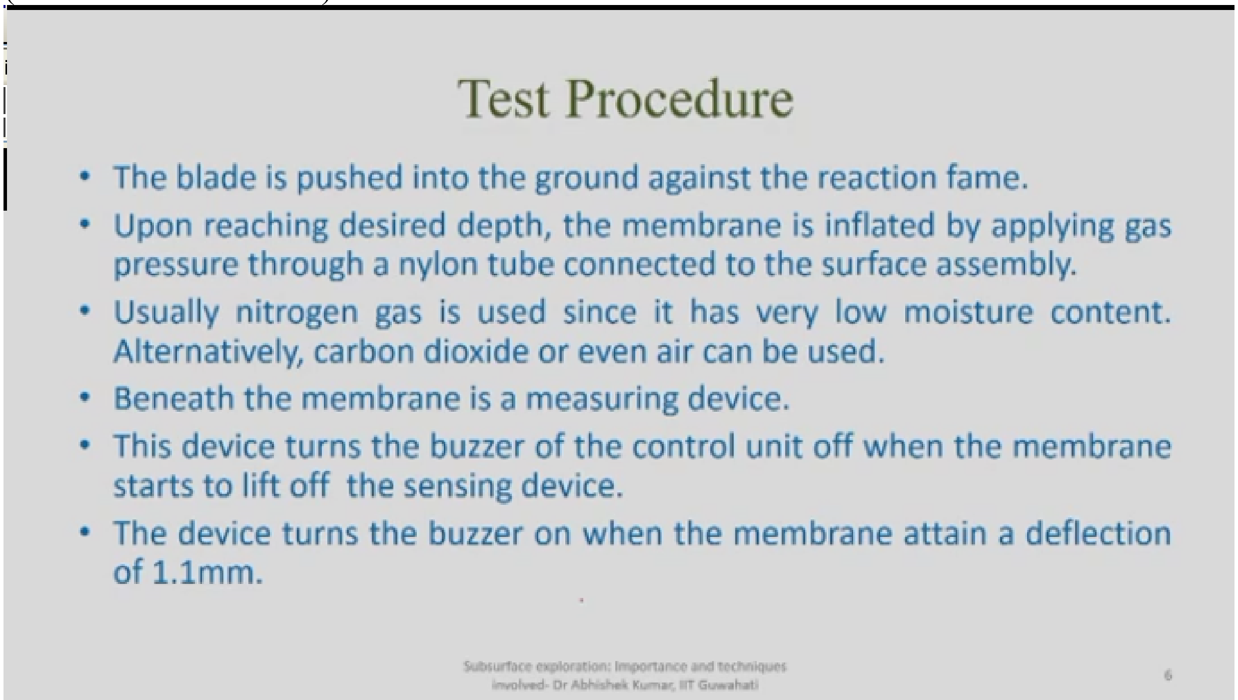

So the test procedure in the last slide I showed you the blade which is consisting of a membrane, so this blade is pushed into the ground against the reaction frame, so in order to push the blade into the ground you have to have some kind of external frame or reaction frame with the offense to which this blade is actually getting pushed into the ground, as you go deeper and deeper layers there will be lot of confinement pressure, so the reaction frame it should be such that the reaction applied by the reaction frame should be much, much higher than the confining pressure otherwise your blade will not be able to penetrate at deeper depth, and since you are not able to penetrate you will not be able to identify or understand how much is the shear strength or resistance offered by soil at different depth, so the reaction frame again you have to choose very carefully.

Again once you reach a desired depth the membrane is inflated by means of glass pressure, so you apply actually glass pressure into the membrane that the bulge portion on one side, still membrane so there will be nylon tube which will be connected to the dilatometer through which you will be applying pressure.

This pressure will be controlled from the surface assembly through the nylon tube the pressure will be this applied pressure will be transferred to the dilatometer, and in the dilatometer one side you are having the membrane as we will see more in the coming slides, so usually nitrogen gas is used since it is having very low moisture content, alternatively you can also go for even carbon dioxide or air can be used, but depending upon what gas you are using there will be some pros and cons, okay.

So beneath the membrane is a measuring device, you saw the membrane, below the membrane there was a measuring device which actually senses how much the membrane has moved other or towards the blade, so the device, this device turns the buzzer of the control units, so there will be control unit at the surface at different instances of the membrane movement, the buzzer will turn on or turn off when the membrane will moves either, when the membrane comes in contact with the blade or when the membrane is pushes away from the blade, so whenever it starts lift off again there will be some buzzer sound at the surface because finally you are measuring different kinds of pressure values even at the, I mean at the surface, and this test is happening at particular depth of interest.

So device, in the device turns the buzzer on when the membrane attains a deflection of 1.1mm, so the membrane is there you start applying some pressure because of which the membrane will start, I mean it will start pushing the soil, so this is the membrane, this is the blade and behind the membrane there will be soil, so once your membrane start pushing the soil and till the time it reaches 1.1mm the buzzer will be off, once it reaches 1.1mm push of the soil, the buzzer will be on and this buzzer on will indicate that it has reached 1.1mm displacement of the soil.
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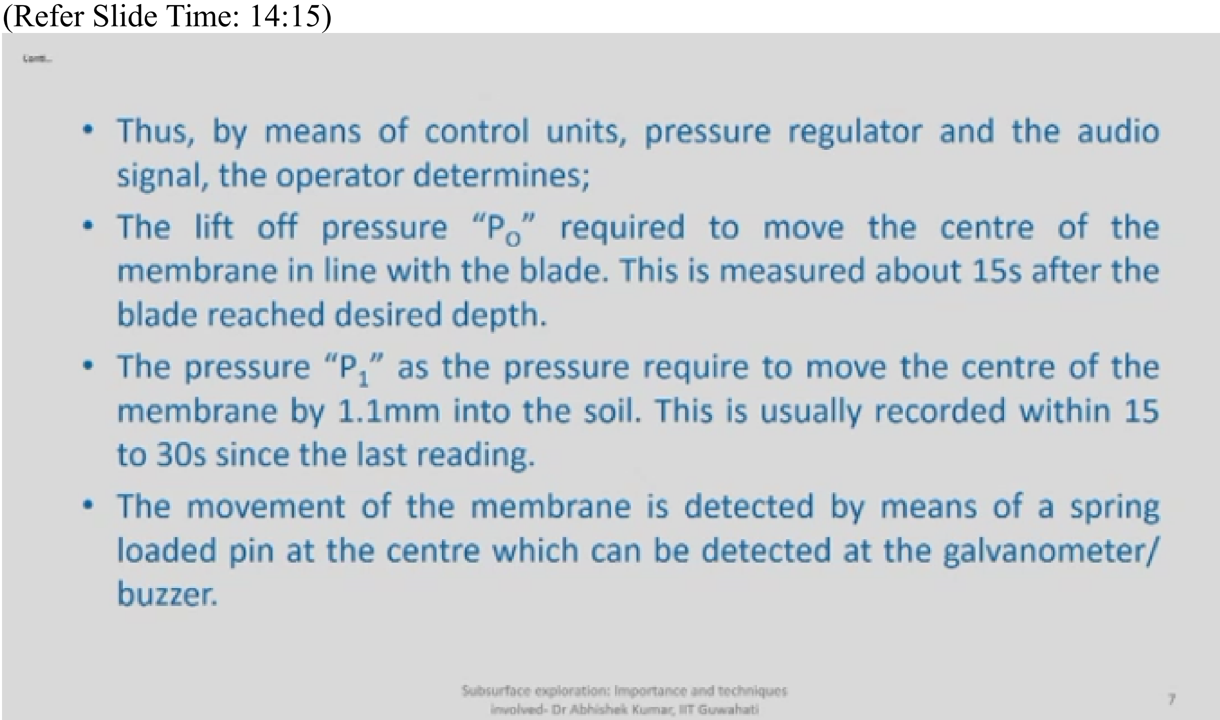

So that is one among many observation you have to do it during field testing, thus by means of control unit pressure regulators and the audio signal the operator determines, so these are like you are having control unit which will control how much pressure you are applying, you are having pressure regulator which will actually measure the pressure applied, and the third one is buzzer, so based on audio signal maybe once the buzzer sound is on that will indicate okay, if necessary movement in the membrane has happened, now you can measure the pressures, so based on these things you can measure actually the lift of pressure also known as P naught, which is required to move the centre of the membrane, whatever membrane you are having in line with the blade, so the membrane was initially it was like this, slightly curved, so how much is the minimum pressure required to bring the membrane in contact with the blade, this is measured about 15 seconds after the blade reaches it desired depth, so once you start it lowering your dilatometer once it reaches a desired depth you apply some section pressure because you have to bring the membrane in contact with the blade, so you apply some section pressure and I mean wait for 15 seconds and then measure how much is the minimum pressure required to bring the membrane in contact with the original line with the blade.

The second pressure that is P1, this is second measurement you have to do at the depth of interest, so it is defined as a pressure required to move the centre of the membrane, so in the first part when we are measuring the P naught value we actually bring the membrane in contact with the blade, so it is kind of flatting the membrane.

In second one you are actually pushing the membrane away from the blade such that the deflection in the membrane, the centre of the membrane will become 1.1, indicating that 1.1mm you have actually push the surrounding soil, that will be some kind of measurements, some way you are actually measuring how much the soil offers resistance again this constant deformation of 1.1mm, so this is usually recorded within 15 to 30 seconds since the last recording, so last recording means 15 second, I mean you recorded P naught value after that you started pushing the membrane into the soil and then maybe 15 to 30 seconds it will take depending upon what depth and accordingly how much pressure you applied, so 15 to 30 seconds you applied the pressure and then measure how much is the value of P1, of course there will be pressure gauges at the surface which will actually help you in getting how much is the pressure you applied, whether it is for inflating the membrane or whether it is for deflating the membrane.

The movement of the membrane is detected by means of a spring, so because the membrane is moving of course in order to make sure the membrane moves in a control environment, this is connected by means of a spring, loaded pin at the centre which can be detected by a galvanometer or buzzer, so the arrangement is such that every time the membrane moves either in line with the buzzer, in line with the blade or away from the blade, some maximum displacement has been fixed because of, after which the buzzer will be turn on, so when the buzzer is turned on you understand like this is the maximum pressure which was required in order to even bring the membrane, in contact with the buzzer or for 1.1mm deflection of the membrane towards the soil, so two pressures are required, okay.
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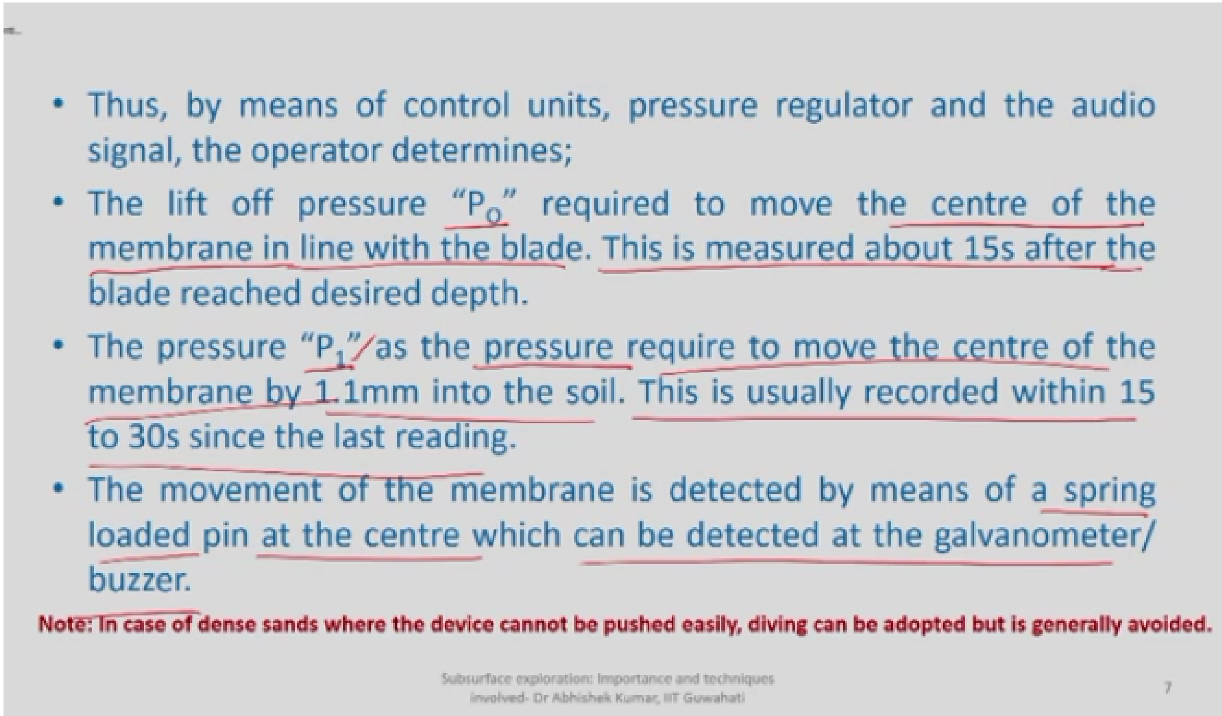

There is a note here, in case of dense sand where device cannot be pushed easily like continuous flooring cannot be done, driving can also be adopted, this should be driving can also be adopted but is generally avoided because it can also cause some kind of damage to the membrane and to the blade itself, so it can be done but if the impact load is too high then it can cause some kind of damage so I mean there is some clause, you can do but again in working condition, so this is about membrane which we had discussed,

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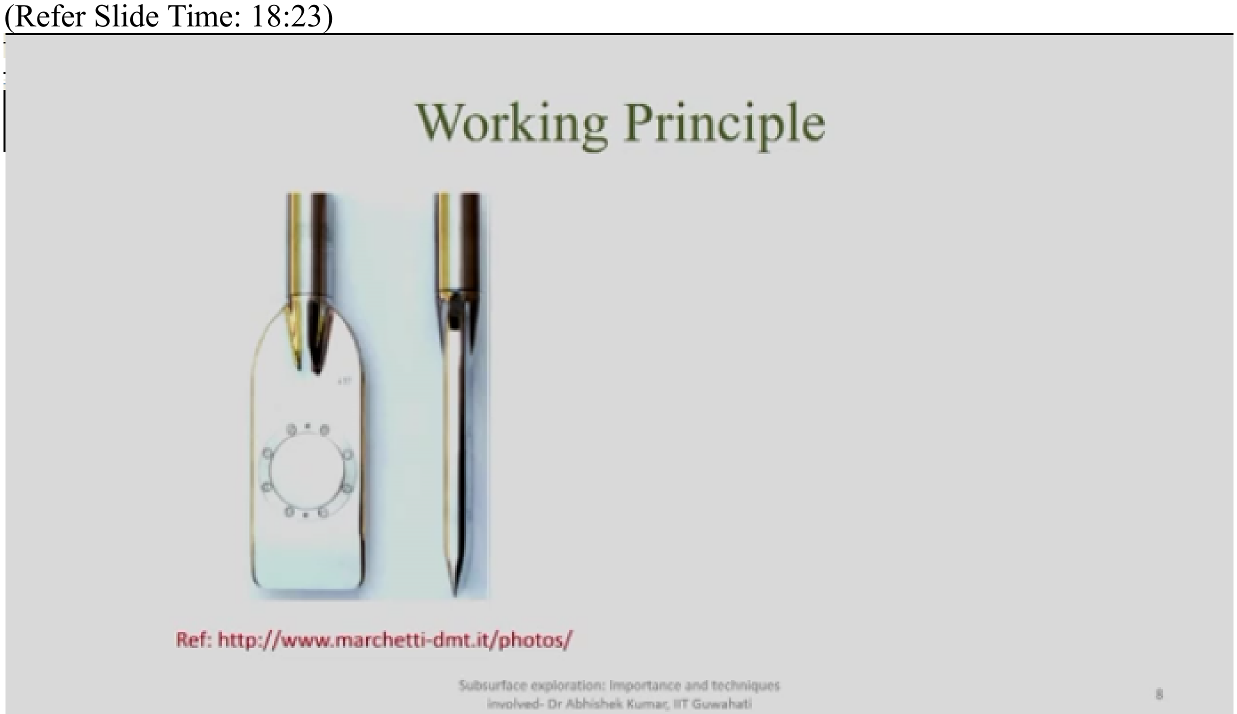

this is called as the blade and this is the membrane,

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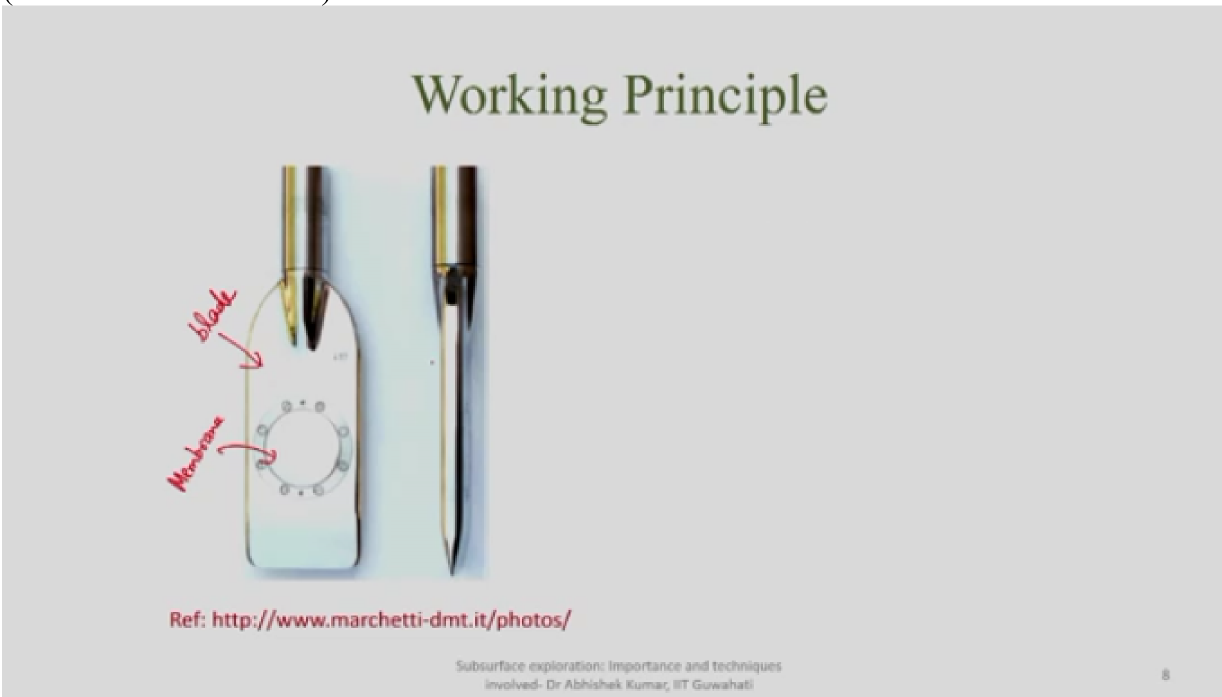

but in order to ensure or in order, so now we will be discussing how this membrane works, so if you take the cross section of this blade, so you will actually see some kind of arrangement like this, so there will be a spring which is connected to some assembly here, and this assemblies again connected here and there will be additional assembly, I'm going to nomenclature each of this assemblies here whatever I'm drawing for better understanding.

This is just to understand like why buzzer, how the circuit works or what mechanism is happening at this location, and then you are having this membrane here, so you can see this is called as membrane, this is your blade, main blade assembly, then you are having this as flexi glass cylinder,

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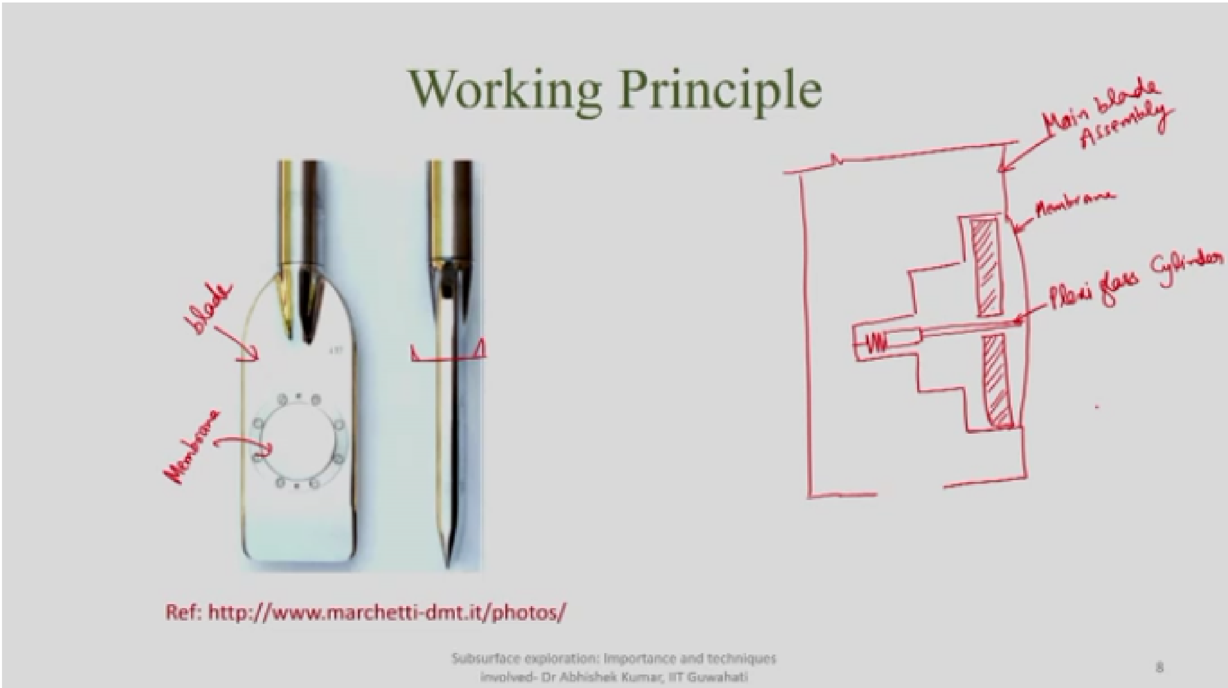

and then you are having insulated you put here insulated plastic here, so there will be actually, this will be connected to, and then this will be also connected, so you are having some positive here, so you are having one anode, one cathode here which is indicating like some kind of electric circuit is getting complete, then this is called as stainless steel cylinder, this is called as spring,

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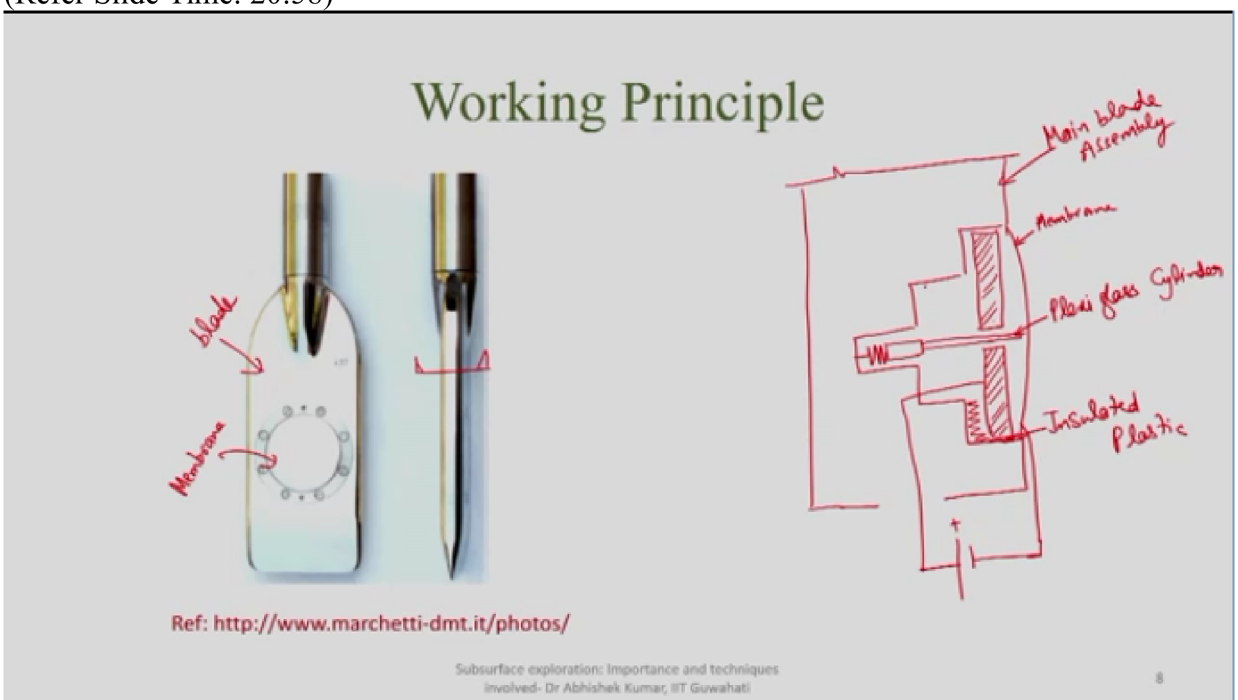

as we have been discussing like the movement of the blade will be detected by the spring this is called as again stainless steel cylinder.

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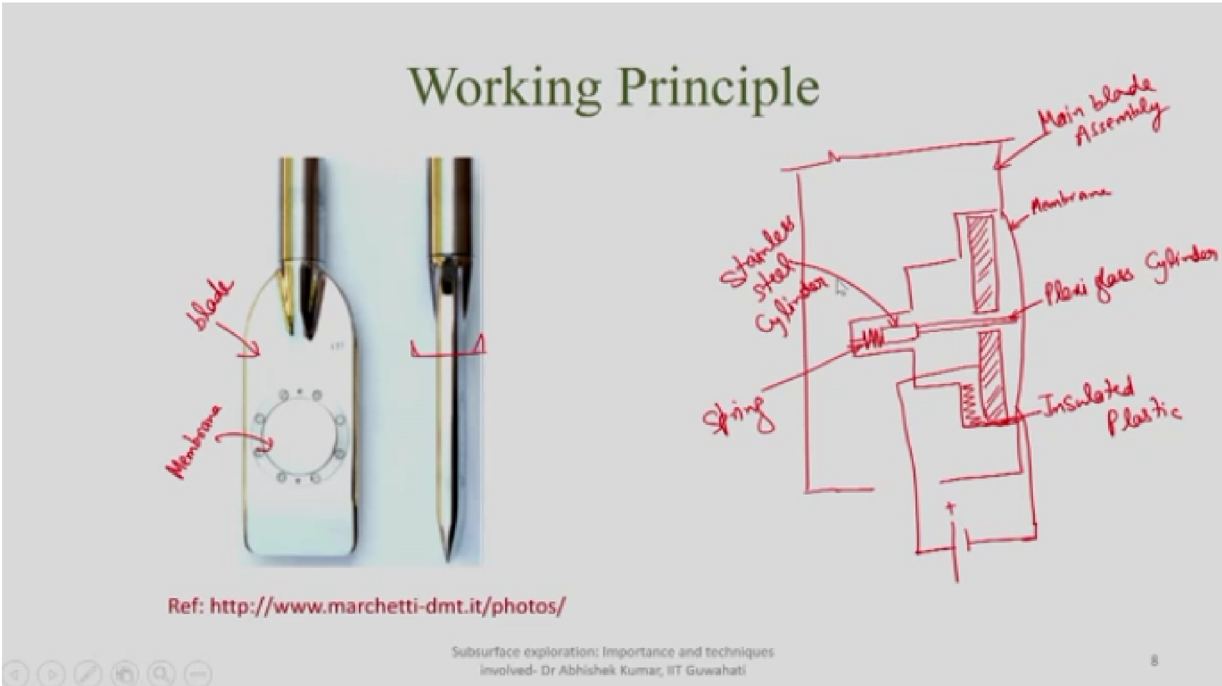

Now what happen, if you remember in the last slide we discussed like at the depth of the interest we are going to measure two kinds of pressure, so what happens here initially you try to bring the membrane in contact with the blade, so this is like initial position of the blade, okay, so when you bring this membrane this is actually, it should be extended till here, in the same way it is extended till here, okay, so what will happen here, yeah,

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- Upon reaching P_1, the membrane is quickly deflated and the blade is pushed to the next test depth.
- The blade can safely withstand a pressure of 250KN while pushing into the ground.
- Determines at-rest lateral stresses, elastic modulus, shear strength of sand, silt and clays.
- The fixed displacement system ensures that the membrane expansion will be 1.10mm±0.02mm regardless of the care of the operator.
- Two pressure gauges, audio buzzer, electrical-pneumatic cable are the components of the control unit kept at the surface.

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so what happens here like initially when you go for bringing the membrane in contact with blade, so that means you're actually bringing this membrane at this location, you can call this

location as A, so the pressure require, so once you bring this membrane from its initial position of membrane, so initial position means when the membrane is in original deflected position,
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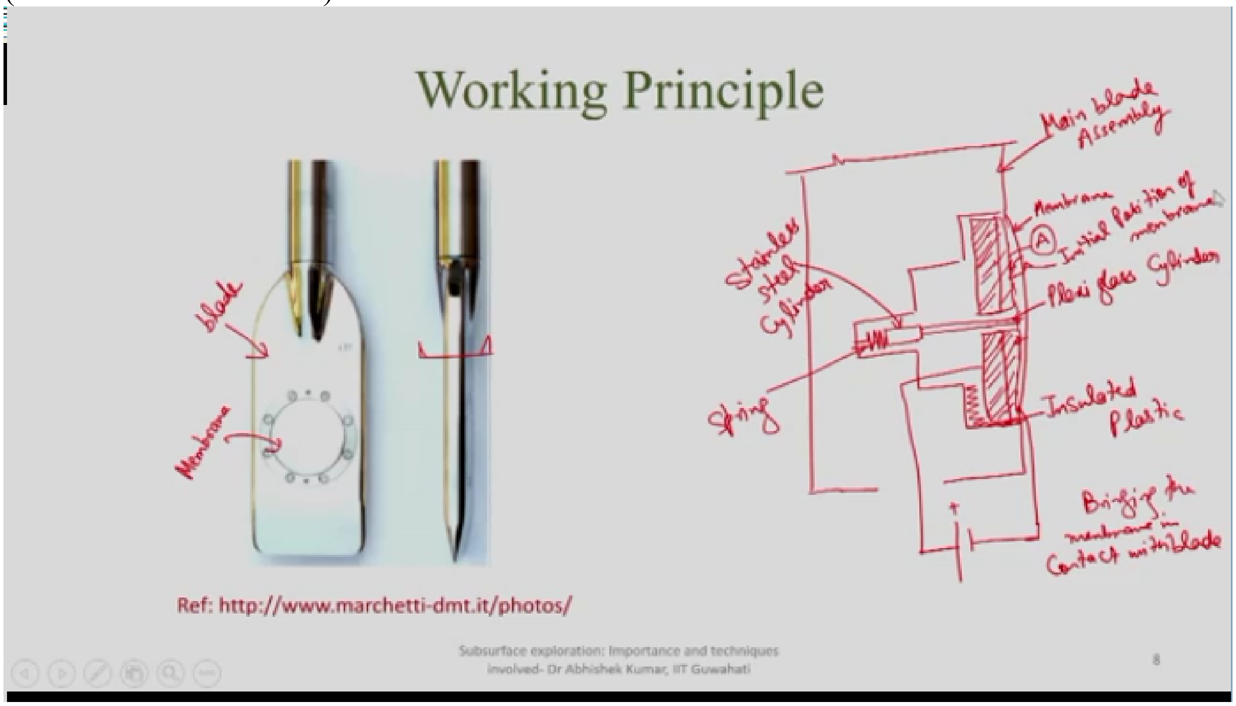

you started applying some section pressure so that the membrane will move towards the blade, so what will happen when it comes in contact with the blade it will become almost in contact with the blade and then in that case it will touch this sensing disk, so this is called as sensing disk.

So you connected to the sensing disk, so what will happen? The sensing disk is connected here with the cathode and other part which is connected to the blade, when the blade is comes in contact with the sensing disk, the circuit will be complete and that will be indicated by the buzzer sound, so inflate, deflate, buzzer will be on indicating your, so you will hear some buzzer sound indicating like whatever section pressure you had applied, now that the blade is in contact with the, membrane is in contact with the blade because the circuit is complete.

Second one what will happen here, you applied some kind of pressure from moving the membrane outside, now as the membrane moves out there will be release in this, the spring will actually get released, so when it will get release what will happen? For a moment of 1.1mm the maximum moment it can do, so what will happen after 1.1mm this part will come in contact here, this part will come in contact here, so it will come like here, again so this will, so the cathode was carrying the charge from here and once this sensing disk, the steel cylinder comes here after 1.1mm displacement again the circuit will be complete you can understand because once this part touches here, so there will be I mean, this part even contact with this and because of this assembly which is connected to the steel cylinder it comes in contact with the membrane.

So again for 1.1mm that is inflation or movement by 1.1mm, so initially we applied some section pressure because of which it inflated and how much of, because of this inflation the membrane comes in contact with the sensing disk, the circuit will complete and the buzzer sound was on.

Then you started pushing the membrane back into the soil, actually because you are interested to find out how much is the maximum pressure required for 1.1mm displacement of the soil, so in order to make sure like 1.1mm you are measuring correctly you have to start with zero, so in order to start with zero you have to first bring the membrane in contact with the blade, after that whatever movement is there it is actually pushing the surrounding soil here, so second time when you push it 1.1mm because of the release of the spring, the circuit will again get complete, the steel cylinder will connect one side with the sensing disk, other side it will connect with the membrane, so because of which again the buzzer sound will be on, indicating 1.1mm deflection has happened to the centre part of the membrane or indirectly it is telling like 1.1mm you had actually pushed the surrounding soil, so whatever is the pressure required to bring in the membrane first in contact with blade you call it P naught, second one the pressure required to push the centre of the membrane 1.1mm you call it as P1, this is at the base.

So I mean these are the two field measurement you have to do at any depth of interest at any site of interest, again once you get these two value you will actually again deflate the membrane again push it to different, second depth and so these are working principle upon reaching maximum, upon reaching P1 value the membrane is quickly deflated, and the blade is pushed to the next step again there you measure how much is the pressure required to bring the membrane in contact with the blade.

Second how much pressure is required to push the membrane 1.1mm into the soil and so on and so forth, every time you do the test it gives you, it keeps giving you two values P naught and P1 values or the, yeah value of course you have to apply certain corrections later stage, we will be discussing so the blade can withstand whatever blade you are using now you can understand, you are able, you are actually pushing it into the soil so the blade itself should be strong enough, so it should be such that it should withstand the pressure of 250 kilo newton while pushing it into the ground, so the based on this two measurement you are actually able to determine at rest lateral pressure, elastic modular, shear strength properties, and even you can determine over consolidation ratio and so many other properties just by measuring these two parameters at the site.

So the fixed displacement system ensures that the membrane expansion will be 1.1mm + -0.2mm regardless of the care, so it is like independent of whether the operators, I mean it is independent of any mistake that can be committed by the operator on the pressure measurements, because it cannot move beyond 1.1mm, maximum it can go 1.1mm + -0.02mm, so whatever is the pressure corresponding to that, because the buzzer sound is there it will directly give you, okay, when there is a sound you have to measure actually the pressure on the dial gauge reading.

Generally we go for two dial gauge readings we go for dial gauges, one audio buzzer that is buzzer on and off, and then electric pneumatic cables, so electric cable will be required to connect to actually, sense that complete circuit, completion of the circuit that will be corresponding to buzzer sound and the pneumatic cable in order to apply gas pressure at the

depth of the interest, so these are the components of control units which are kept at the surface, so generally we go for two pressure gauges,
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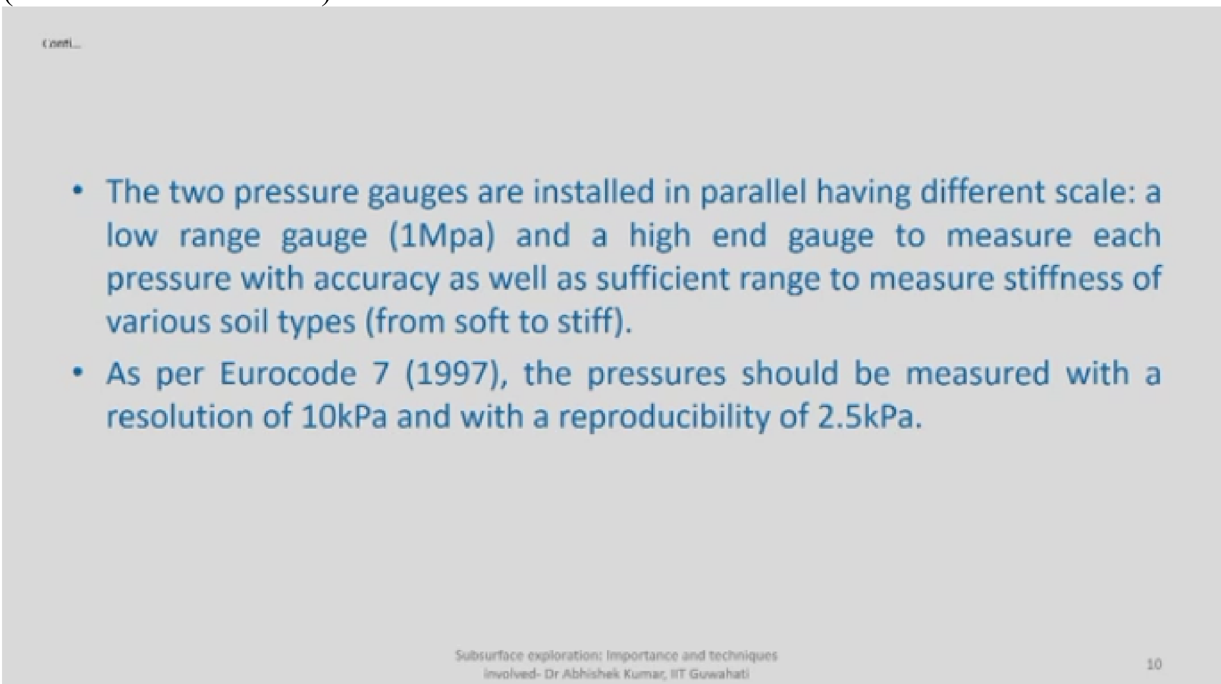

two pressure gauges in order to determine, I mean these two pressure gauges work in parallel, so one pressure gauge will measure higher fraction of the pressure applied by the gas cylinder, and second one will measure the smaller unit of the pressure applied like 350, so one will measure with like 354 is there, if the pressure, so one will measure 300, again second one will measure 54, so that way so that you can measure accurately the larger fraction of the pressure as well as the smaller fraction of the pressure, so two pressure gauges are installed in parallel, it's not like one will be used for P1, one is used for P naught, no it's not correct so you have to measure two pressure simultaneously, and each of this pressure will be corresponding to each position of the membrane, whether it is in contact with the blade or whether it is outside the, I mean 1.1mm deflated, I mean inflated into the soil.

So each pressure gauge will be working on different scale, a low pressure gauge, a low range gauge and high range gauge, so that you can measure actually the pressure required to inflate the membrane as quickly as possible, okay.

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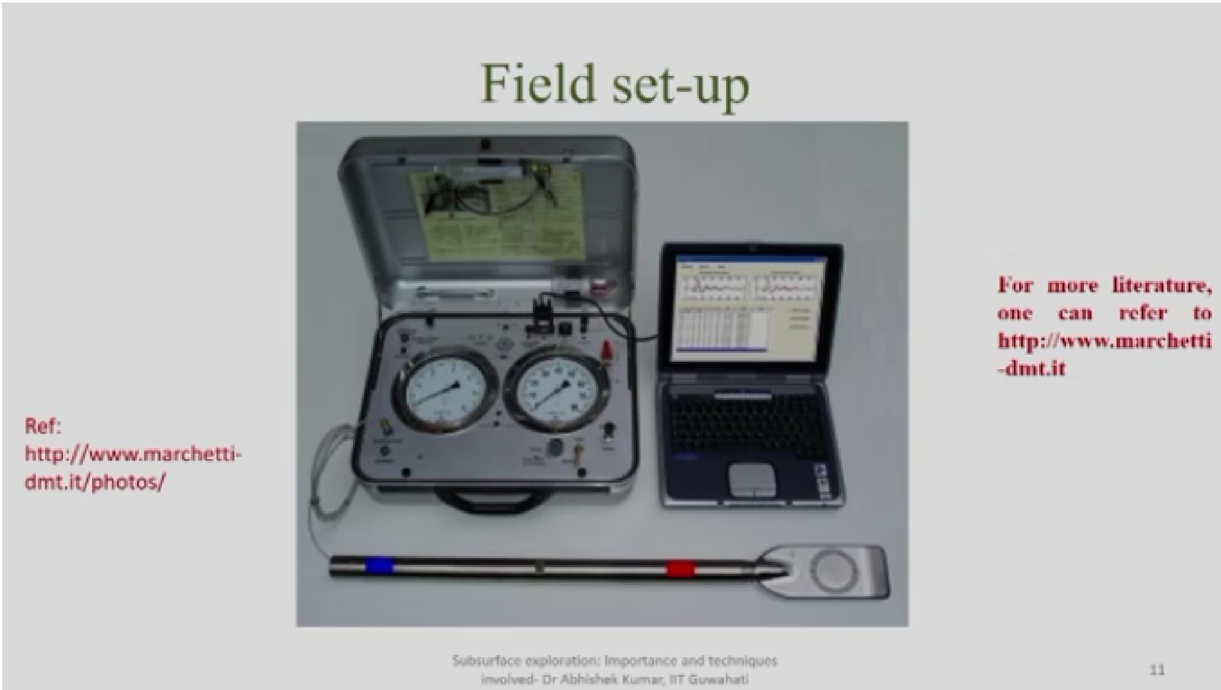

As per Eurocode 7, 1997, the pressure should be measured with a resolution of 10KPA and with a reproducibility of 2.5KPA, so this is the setup you can see here this has been taken again from marchetti.dmt.it who are interested you can further go from more literature on this particular website, so this is at field setup you can see the dilatometer then disconnect it to one kind of drill rod here, more drill rod you can use it as you go deeper and deeper, this is pneumatic cable, then there will be another cable which will be used for electric connection in order to ensure like the buzzer is complete and this is the membrane, okay.

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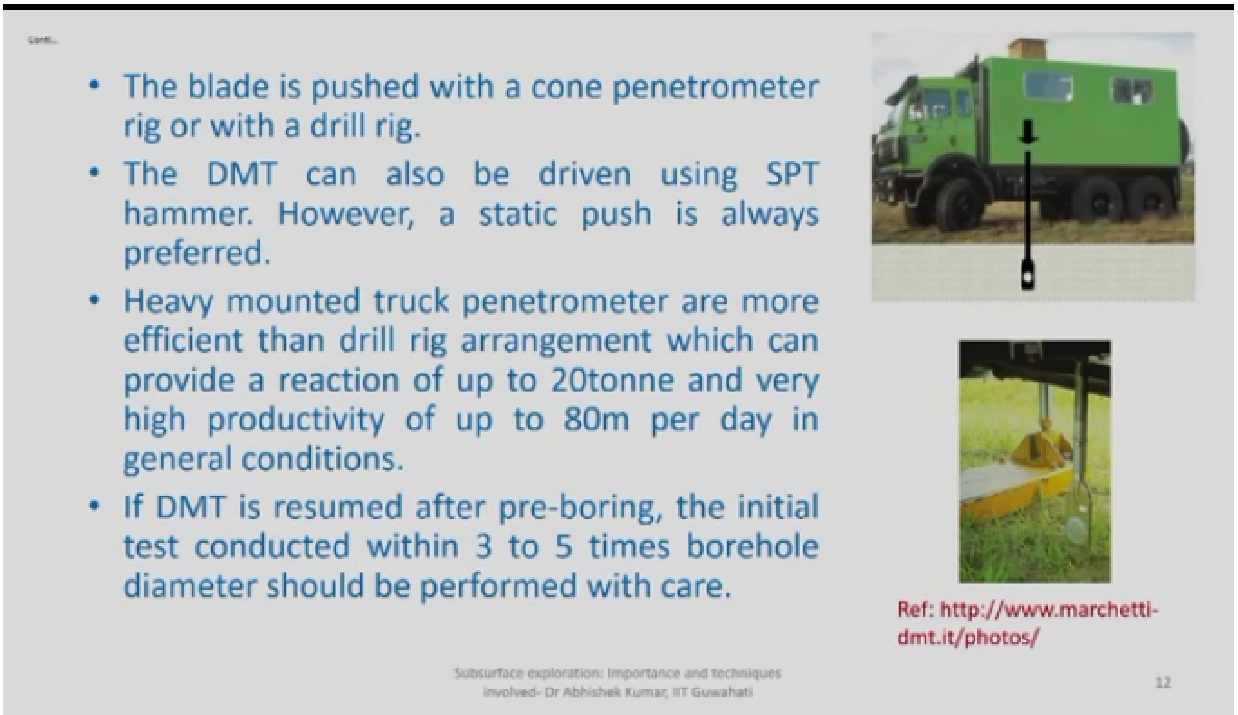

So these are field setup, again this field setup as I had mentioned here because every time you have to push to deeper depth, so the reaction frame should be sufficient so that it should be able to connect at deeper layer, the blade is pushed maybe by means of cone penetrometer rig or with a drill rig, the dilatometer can also be driven using SPT hammer, however a static push is always preferred.

Heavy mounted track penetrometer are often efficient then drill rig arrangement which can provide a reaction up to 20 tonnes and very high productivity of up to 80 meter per day, so you can go up to 80 meter so this is like that's how we mount your dilatometer on the track which acts as a reaction frame and the second one will dilute like this is in contact with the blade, and the blade is in contact with the soil, and then depending upon the reaction generated you are actually pushing it into the soil so the reaction which is required to push it into the soil and the pressure which is required to inflate or deflate the membrane will be coming from two different resources.

Again you can see here in order to ensure any kind of later movement, once it reach, once the reaction frame reaches a desired location you actually provide more stable platform, so this is like you can avoid any kind of lateral movement in the, on the truck assembly during the test.

If the DMT is resumed after pre-boring the initial test conducted within 3 to 5 times the borehole diameter should be performed with care.
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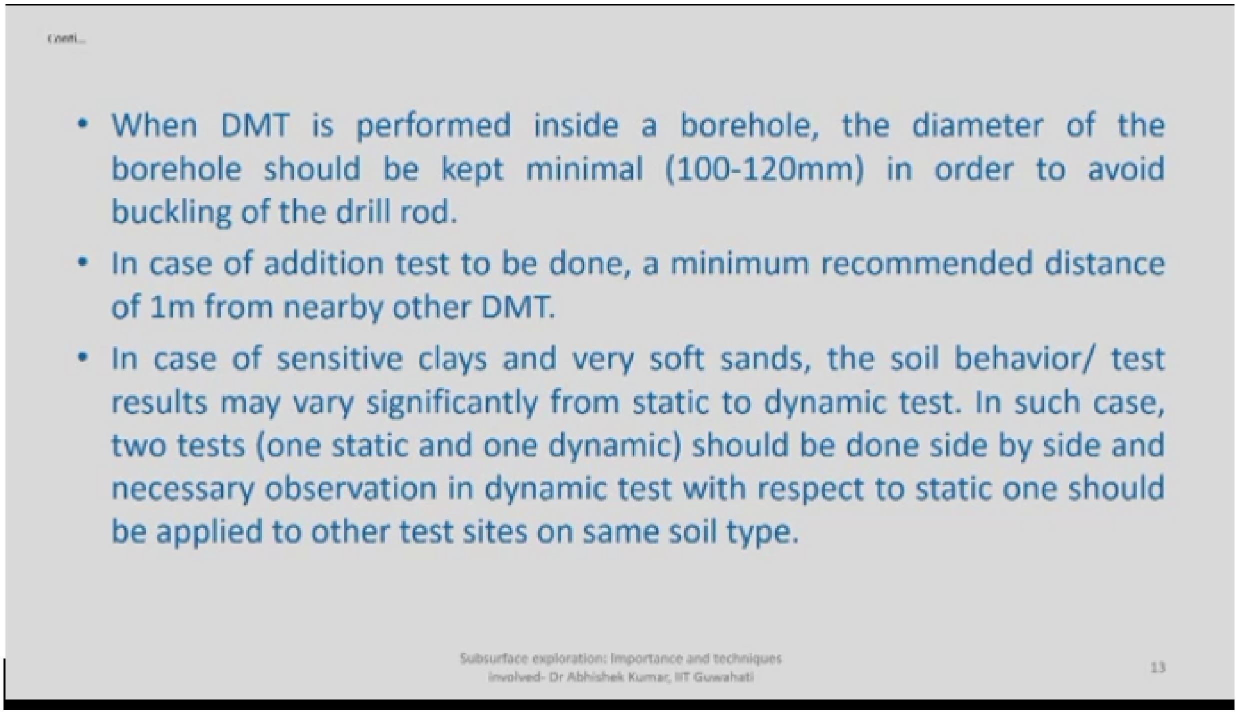

Again when the DMT is performed inside a borehole that diameter of the borehole should be kept minimal in order to avoid any kind of buckling to the drill rod.

In case additional test to be done, a minimum recommended distance of 1 meter from the nearby test, so a minimum a disturbance, distance of 1 meter should be kept from minimum distance, so if the distance is more that is fine, this is given as the guideline for minimum distance.

In case of sensitive clays very soft sands, the soil behavior results may vary significantly from static to dynamic test, so in such cases two tests, one static and dynamic should be done side by side and necessary observation in dynamic test with respect to the static test should be applied so the two other sites having same soil type, okay.

So this was about what kind of measurements you do? But we have to also take into account because it's a membrane itself has some kind of stiffness, so whenever we are measuring the minimum pressure required for bringing the membrane in contact with the blade or when the pressure required to push the membrane into the soil by 1.1mm, it will also have some component which is because of the stiffness of the membrane, so before you go for any kind of in-situ measurement you have to also go some kind of calibration, so it's like if this is a membrane, this should be like flat here, so before I mean if this is a original position of the membrane which is like this, in order to bring this membrane so you have to go for two pressure measurements even at the surface like P is the minimum pressure, section pressure required even at ground surface when there is no soil around to bring membrane in contact with blade,
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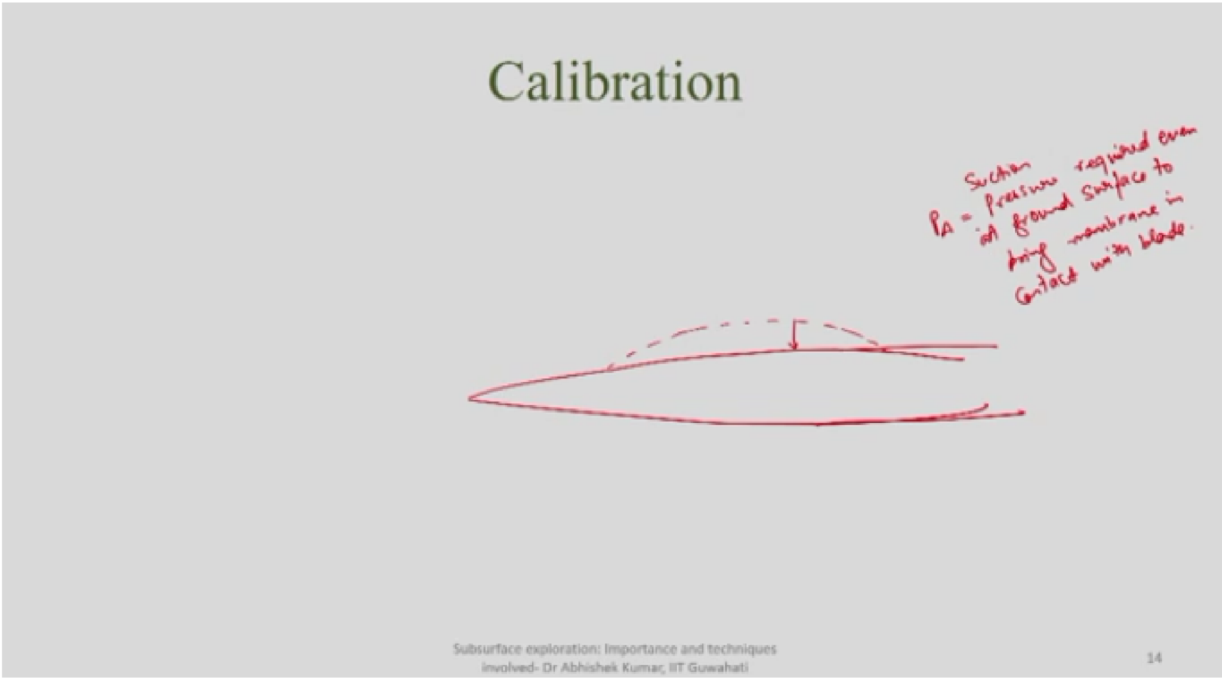

so this pressure will be required even though there is no soil in the surrounding.

Second one will be the, so this is about position A, second I'm telling position B is ensuring an, this you can call it as position B you can maybe draw it with firm line, because after all it is indicating the measurement you are doing at the site, so this is like corresponding to 1.1mm displacement at the centre of the membrane.

So again as I told you because the membrane itself has, is made up of some material so it is having again some stiffness so you have to measure just like PA you have to measure PB like the minimum pressure required at ground surface to push the membrane by 1.1mm, so this is the pressure even required at the surface,
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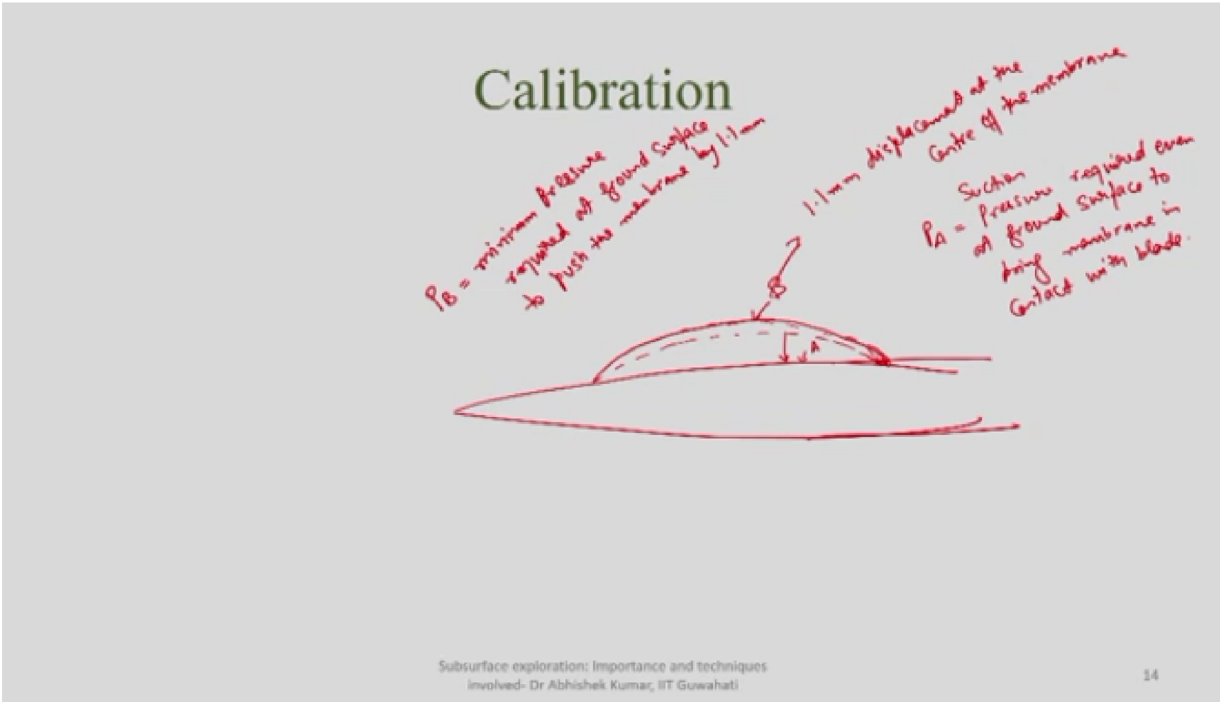

remember we were interested to find out the pressure required to push the soil by 1.1mm, but actually because of the membrane material some pressure will be required to bring, to push the membrane itself even when there is no soil, so this is some kind of additional calibration you have to do at the site of the interest.

And so based on these value of PA and PB, your earlier measured value which was, which were at the depth of the interest again at the site of the interest, those pressure values will change because in those pressure values some component will be there from PA, some component will be there from PB values, so let's see how you get those pressure values now.

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Field record and data reduction

- Record A and B corresponding to position A and B within the soil, ΔA, ΔB observed during membrane calibration and Z_M which is gauge zero offset are to be observed before proceeding for data interpretation.
- Once each of the above values are known, Po and P1 can be determined as;

$$P_o = 1.05(A - Z_M + \Delta A) - 0.05(B - Z_M - \Delta B)$$

$$P_1 = B - Z_M - \Delta B$$

So record A and B corresponding to the position A and position B within the soil, second thing delta A and delta B to be observed during membrane calibration which is generally done, I mean we do at the site of interest even at the ground surface. ZM will be the gauge zero offset are to be observed, so like delta A how much is the pressure required delta A you can go maybe calling in the previous one as this is as like delta A, this has like delta B, and ZM is like gauge zero correction kind of thing, okay.

So remember, so okay, so whatever field measurement here done at the site of the interest again to find out how much is the pressure required to bring the membrane in contact with the blade, and how much is the pressure required to push the membrane 1.1mm you have to apply some pressure, so this is like the pressure reserved at the depth of the interest corresponding to position A, this is the pressure required again to bring the membrane in position A at the ground surface, this is the zero I mean gauge zero offset, so it was like minus because it is some component which is additional from the, because of membrane stiffness and then it will be minus delta A because it is a section pressure, so that will come up minus minus +1, + delta A so that's how you get it, so this is like some component and some component you will get from while pushing it on to the ground, so again this is the pressure required at the depth of the interest to push the membrane 1.1mm this are pressure required to push the membrane by 1.1mm even at the ground surface and this is Z, so based on this first formula you can get how much is the actual pressure, whatever pressure because at the site of interest you will getting the value of A, you will be getting the value of delta A, B delta B based on this collective how you determine, how much is the pressure required to form membrane infiltration, membrane deflation, that will be again indicated by buzzer sound, buzzer on because initially if you remember the insulating disk came in contact with the membrane and that's how the circuit was complete, this is when it is corresponding to 1.1mm membrane movement, membrane centre movement.

Again the buzzer sound was on because steel cylinder come in contact with disk and then on other side with membrane as a result of which buzzer sound was on, so you get the value of P naught, you get the value P1 that correction has to be applied otherwise whatever value you are measuring that will overestimate your pressure, actual pressure values.

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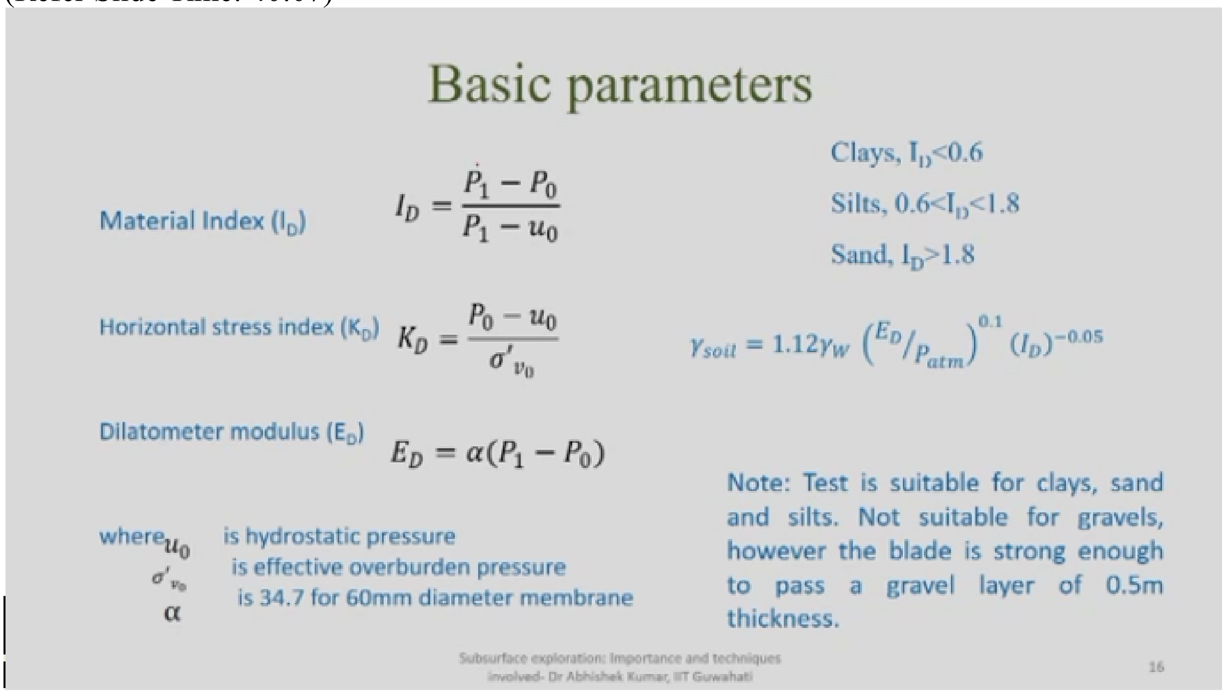

So once you know the P naught and P1 value again there will be some transducers which will be corresponding to if you are, how much is the pressure required at different, different depth condition that will indicate how much is the value of pore water pressure, we have some separate formulas what we will be discussing in probably in coming slides how you get the value of pore pressure. P naught and P1 you have already known how to determine so once you know each of this parameter like P naught, P1, U naught you can determine actually the material index depending upon the material index you can understand there are other different range is given for ID value, like ID is less than 0.6 indication of clays ID 0.6 to 1.8 indicates silt, then ID greater than 1.8 indicate sand.

Second parameter is horizontal stress index, KD, which can be calculated as P naught – U naught divided by effective overburden pressure, so the gamma of the soil you can also determine using 1.12 gamma W, ED this is the dilatometer module as which is used here and atmospheric pressure in bars at 0.1 and ID value whatever you have calculated in the previous equation.

Alpha value, once you go for dilatometer modulus these are different, I mean minimum constants you can tell like based on the field recording it determines some constants and based on these constant you try to determine what is your shear strength parameter, what is your shear value, what is your phi value, what is your over consolidation ratio, and many other things, so if you go with alpha determination you can see particularly for 60mm diameter membrane the value of alpha will be 34.7 this value, 34.7 otherwise depending upon what is the value of membrane diameter you can get the value based from the calibration, from the standard charts.

So note, the test is suitable for clay, sand and silts, however it is not suitable for gravels, because not suitable for gravels however the blade is strong enough to pass a gravel layer, it should be strong enough so that you can actually, because it is pointed you can actually able to break the gravel and then pass it and then again if it’s deeper layer you are having again sand, silt and clay you can actually perform the test rather than bring it entire assembly out, then go for any kind of boring you can proceed, so that’s why it says though you cannot do the test in gravel, but the blade should be strong enough so that it can actually pass it, it can break the gravel you can go to deeper depth.

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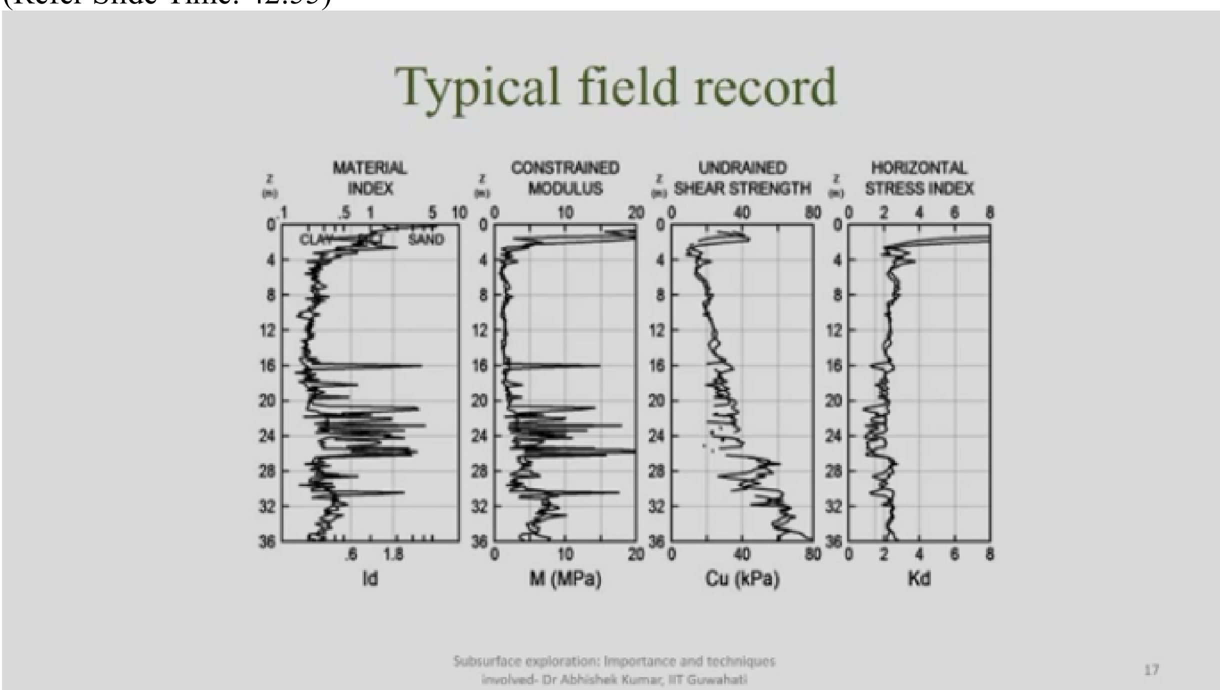

Generally of 0.5 meter thickness gravel the blade should be capable of crushing, breaking or any kind of other disturbance, okay, these are the measurements of some typical field records you can see here, so again these has been taken from Marchetti DMT site, so anybody interested you can again go for like, so this is like based on P naught and P1 value you determine the material index, ID values based on that constant modulus whatever we have just determine, and based on these using different correlation you can determine actually what is the value of un-drained shear strength, what is the horizontal stress index, how much is the value of, so this is like very basic parameter determination with respect to the depth, once you know this parameter like ID, KD, ED values as we discussed in the previous slide you will be able to determine un-drained strength, horizontal stress index and so many parameters, so this is like typical field record, that’s how you do the test.

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Typical outputs

Symbol	Description	Correlation
p_0	Corrected First Reading	$p_0 = 1.05\,(A - Z_M + \Delta A) - 0.05\,(B - Z_M - \Delta B)$
p_1	Corrected Second Reading	$p_1 = B - Z_M - \Delta B$
I_D	Material Index	$I_D = (p_1 - p_0) / (p_0 - u_0)$
K_D	Horizontal Stress Index	$K_D = (p_0 - u_0) / \sigma'_{v0}$
E_D	Dilatometer Modulus	$E_D = 34.7\,(p_1 - p_0)$
K_0	Coeff. Earth Pressure in Situ	$K_{0,DMT} = (K_D / 1.5)^{0.47} - 0.6$
OCR	Overconsolidation Ratio	$OCR_{DMT} = (0.5\,K_D)^{1.56}$
c_u	Undrained Shear Strength	$c_{u,DMT} = 0.22\,\sigma'_{v0}\,(0.5\,K_D)^{1.25}$
Φ	Friction Angle	$\Phi_{safe,DMT} = 28° + 14.6°\log K_D - 2.1°\log^2 K_D$
c_h	Coefficient of Consolidation	$c_{h,DMTA} \approx 7\ cm^2 / t_{flex}$
k_h	Coefficient of Permeability	$k_h = c_h\,\gamma_w / M_h\ \ (M_h \approx K_0\,M_{DMT})$
γ	Unit Weight and Description	(see chart in Fig. 16)
M	Vertical Drained Constrained Modulus	$M_{DMT} = R_M\,E_D$ if $I_D \le 0.6$ $\quad R_M = 0.14 + 2.36\log K_D$ if $I_D \ge 3$ $\quad R_M = 0.5 + 2\log K_D$ if $0.6 < I_D < 3$ $\quad R_M = R_{M,0} + (2.5 - R_{M,0})\log K_D$ with $R_{M,0} = 0.14 + 0.15\,(I_D - 0.6)$ if $K_D > 10$ $\quad R_M = 0.32 + 2.18\log K_D$ if $R_M < 0.85$ $\quad$ set $R_M = 0.85$
u_0	Equilibrium Pore Pressure	$u_0 = p_2 = C - Z_M + \Delta A$

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Now I told you based on P naught value, P1 value you determine the value of ID which is given like this, and similarly the KD that is horizontal stress index P naught – U naught over effective overburden pressure, ED value can be determined 34.7 P naught – P1 and so on, so many like earth pressure, coeff and detorized, over consolidation ratio and then shear strength, phi value, then even you can determine what is the density of the soil, mass density of the soil, and then so this is the overburden pressure U naught, you determine how much is the pressure required at position C which will be again corresponding to when it is at different, different depth how much will be the pressure required, or what is the pressure applied by the maybe the surrounding water.

And then ZM that is corresponding to instrument calibration then delta is how much is the minimum pressure required to bring the membrane at the surface, so that's how you will get the value of U naught, this value of U naught you will be using here, you will be using here in order to determine the value of KD, ED, and further if you go you will be understanding how much, whenever you go for even determination of over consolidation ratio you required this value, when you determine the un-drained shear strength you will require KD values and so on and so forth you can do it.

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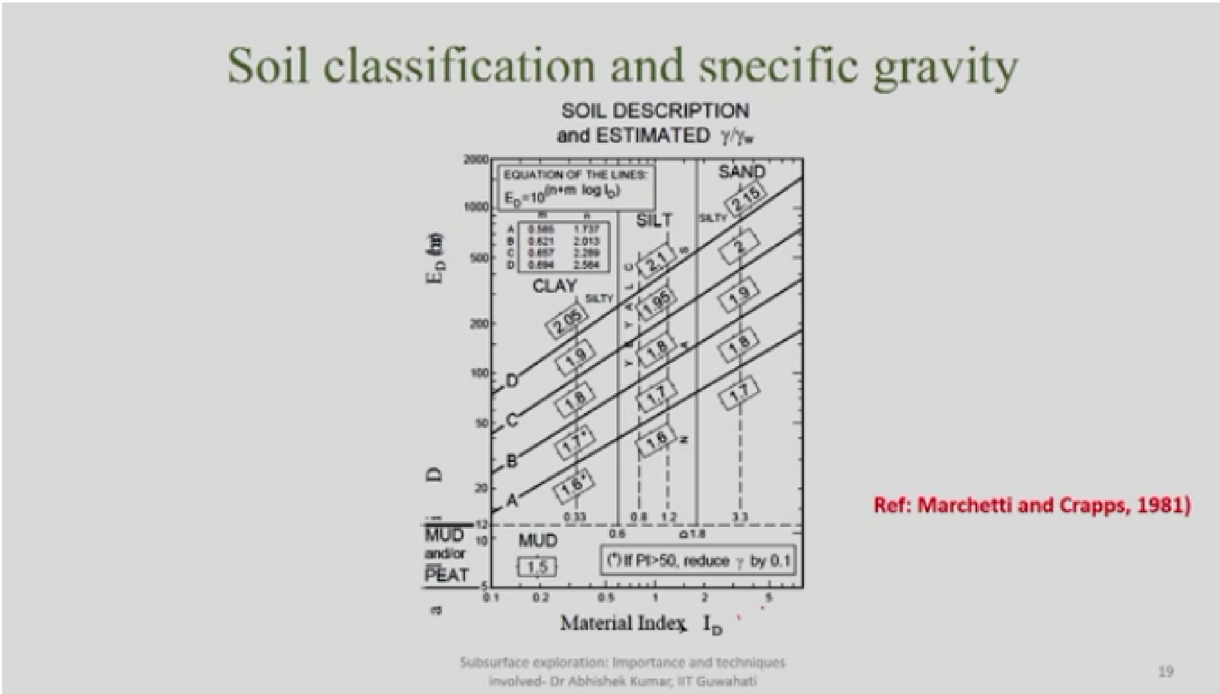

Again based on the values of ID that is material index and based on the value of ED again this is given in bar as per Marchetti and Crapps, 1981, you can see here based on this values you can actually determine whether it is silt, it is sand, you can see here, here also it is sand or clay, silt, clay and so on and then how much is the value of density of the material, so these values are given are roughly the range of the mass density of the medium.

Once you know the value of ED, once you know the value of ID based on your field recording you can actually classify your site and in addition to this you can actually get the value of density of the soil, okay.

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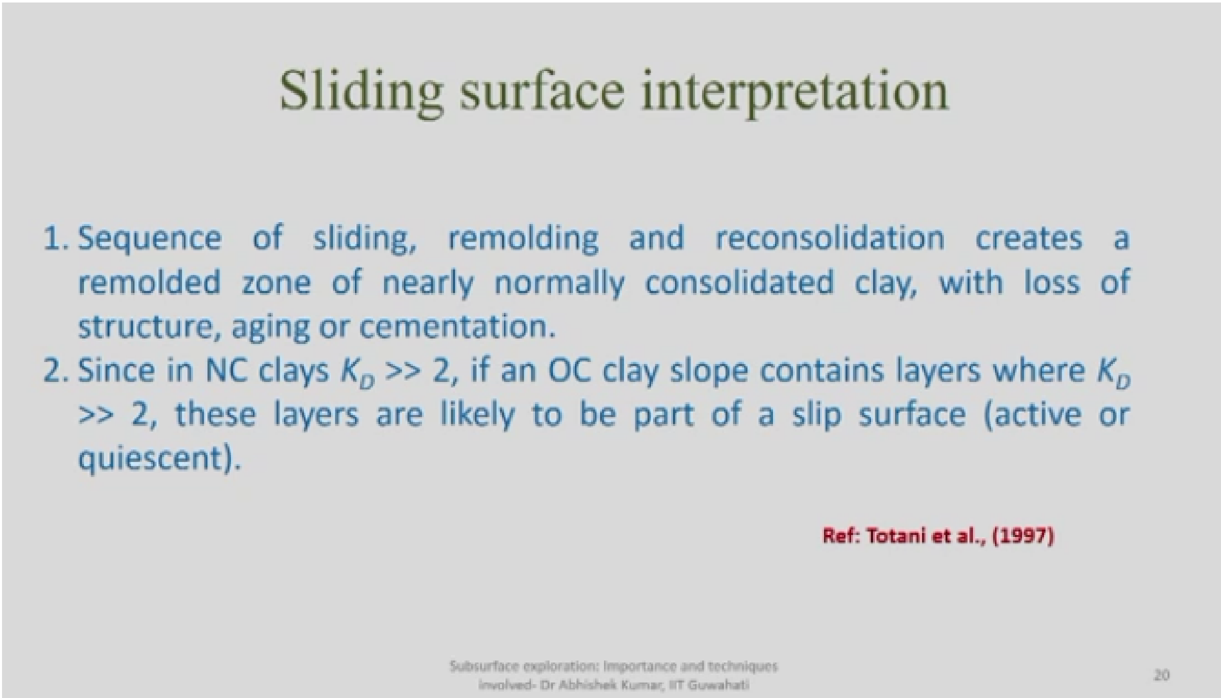

Another advantage is like DMT is very useful in identification of slip surface particularly for failure of the slopes, particularly like so it has been mentioned by Totani Et Al, 1997, like sequence of sliding, remolding and reconsolidation creates a remolded zone of nearly normally consolidated clays even within over consolidated clays due to the loss of structure, aging and cementation, so it has been found like in even in over consolidated clays if some normally consolidated clay which can be identified with the value of KD significantly higher than 2, that will indicate possible slip surface.

So even in over consolidated clays if the value of KD at particularly depth is found as greater than 2 that is indicating like it is normally consolidated and it has become normally consolidated because of loss of structure aging and cementation and that will possibly indicate slip surface when you go for failure of the slope assessment, for more detail one can refer to this paper by Totani and you can get more understanding about that, okay.
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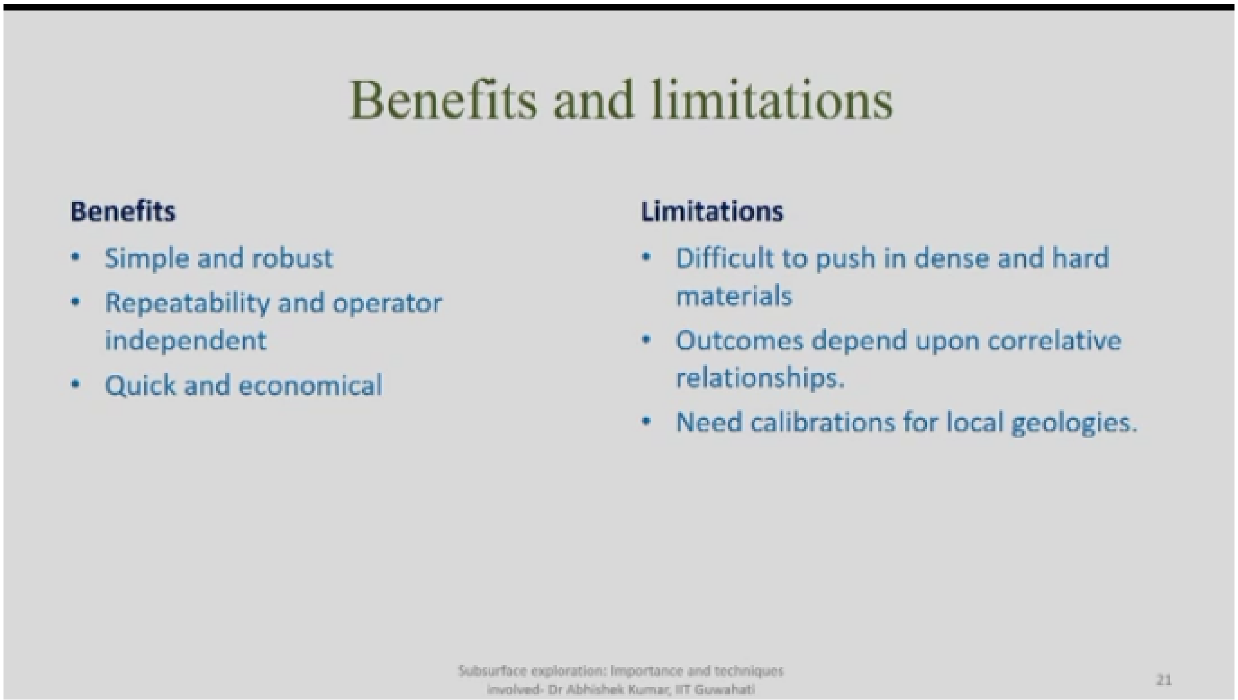

There are some methods, so there are some benefits and limitation of this method, one is like the method is simple we have to simply lower and measure the values of, values from pressure gauges at first weather sound which is inflation, other one deflation, and the other one is inflation, robust you do more and more repeatability it will get test, I mean similar values of the test, repeatability and operator independent, quick and economical but benefits and limitations are difficult to push in dense and hard material, outcome depends upon correlative relationship, so whatever correlated relationship I had showed you, these are like general sometime at the site space, region space you have similar other correlation these may not be applicable, then unless those correlations are known to you, you will not be able to interpret the data or every time you have to have correlation otherwise you will not be able to find out different parameter.

I need calibration for local geologies that will also indicate what is the tentative range of pressures you will be dealing once you push your dilatometer at the site of the interest, okay.

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Problem:

While performing in-situ DMT, following observations are made. Using the available information, it was asked to validate soil type with the one obtained from borehole in nearby location. In addition, determine its shear strength parameters and OCR When;

- Pressure required to inflate the membrane by 1.1mm while testing at the surface=48kPa
- Suction pressure required to bring the membrane in contrast with the blade while testing at the surface=-28kPa.
- Consider pressure gauge correction as 5Kpa.

Depth (m)	Pressure at position A (bar)	Pressure at position B (bar)	Pressure at position C (bar)	Soil type based on borehole
1.	2.28	3.19	0.56	Sand
1.5	2.39	3.28	0.80	Silt
2.0	2.18	3.45	0.96	Silt
2.2	2.45	3.54	1.10	Clay
2.5	2.14	3.89	1.12	Silt
2.8	2.66	3.47	1.20	Clay
3.2	2.59	3.89	1.28	Sand

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So we discussed about like how you do the test, what are the different field measurements, now we'll solve a numerical problem also here, so the problem is like while performing in-situ dilatometer test or DMT following observations are made using the available information it was asked to validate soil type with the one obtained so in the last column you can see some soil type is given based on the borehole location, based on the borehole drilled in the nearby location to the test where you have done the DMT, so you have been asked to validate.

Second thing you have to determine what is the shear strength and what is the over consolidation ratio based on these parameter.

In addition what else is given the pressure required to inflate the membrane at the ground surface will be 48KPA, so it's like delta B the pressure required of section pressure required, it is given as minus, so this is actually like this value is like minus delta A, so that delta A equals to, as I mentioned earlier delta A will always be in minus because it is actually section pressure, and because it is minus and when you go for correction you have to take, you have to deduct this value from the field measurement, so minus minus it becomes plus, so be careful once you are using the value of delta A, if it is given as minus that means the minus which is required while reducing the formula have already been accounted, so you can use the delta A value directly.

And then the pressure, consider pressure gauge correction as 5KPA, so this is the value of ZM and then the value of pressure required at the depth, at different, different depths you can see a what is the pressure required to bring the membrane to position A, position B and position C this will be particularly when you are doing the test at different, different depths in underground water table, so one thing we can assume here that depth of ground water table as zero meter that is at surface, water table at surface, so this is like information available to you from the site of interest based on borehole and these are the soil type given at different, different depth based on your borehole.

Let's see how you proceed to solve this numerical, so solution is like what is given here, you have been given the value of delta A equals to 28KPA, you can call it as in bar because other values are given bars so you can call it as 0.28 bar and the value of delta B you can call it as 48KPA or 0.48 bar.

And ZM value which is given as 5KPA so it will be like 0.05 bar, now you have the value of depth here, okay these values are there, so I'm just removing these values because we've already calculated that is given here, then we have given the value A, we've been given the value B, we've been given the value of delta A, delta B, so based on that you will be determine the value of P naught, P1, U naught, ID, sigma V prime, soil type, CU, and then OCR, so CU again it will be in bar, this will also be in KPA, this will be in bar, bar, everywhere here we are using it in bar,

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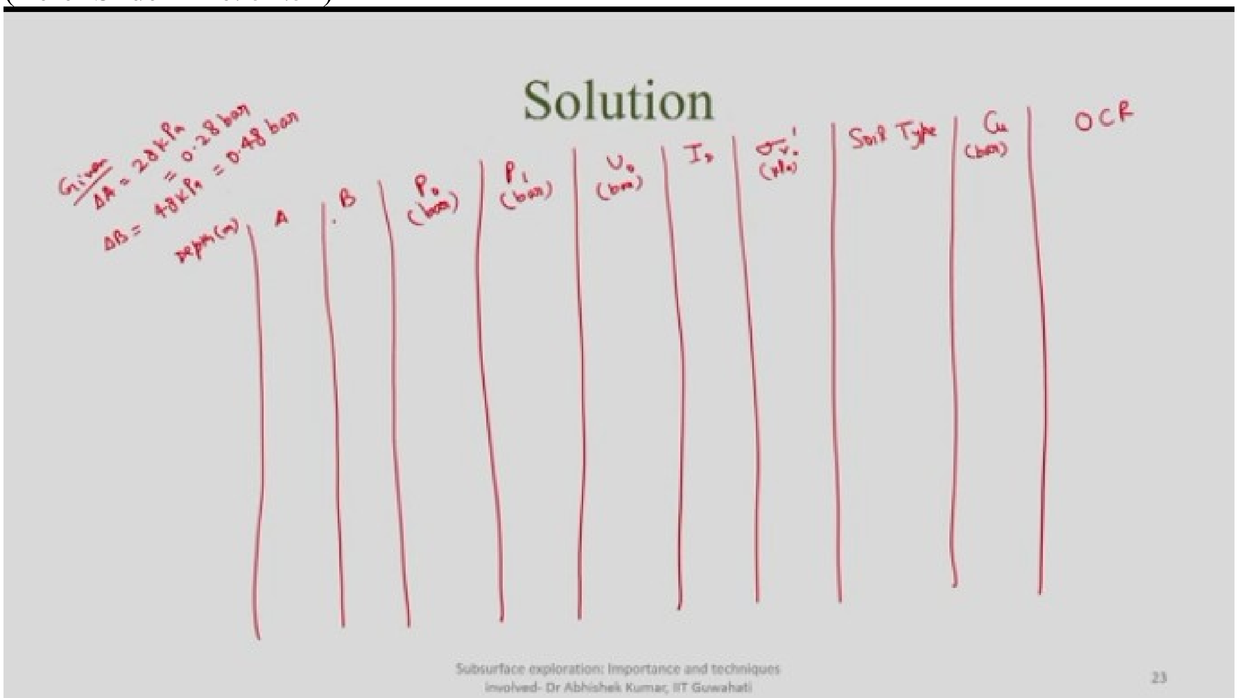

this is also given in bar, this is also given in bar, so I'm just giving you the final values here 1.0, 1.5, 2.0, 2.2, 2.5, 2.8, and 3.2, these are the different depth at which values are given, so I'm writing here directly the values of P naught, which will be called as 2.5 bar, so you can determine the value P naught and P1 as given in the previous equation you can determine the value, so it will be like 2.50, 2.61, 2.38, then 2.66, 2.32, 2.88 and then 2.79, so remember delta A is given, ZM is also given as 0.05 bar, so based on that you are actually determining the value of, actually I'm determining the value this is like P naught, this is P1 which has to be here, so I can, I'm just simply copying this values here 2.61, 2.38, 2.66, 2.32, 2.88, 2.79, these are the values, then P1 value will be equals to 2.66, 2.75, 2.92, 3.01, 3.36, 2.94, 3.36.

The value of U naught we have already discussed the formula, so put those values here so that will be equals to C-ZM + delta A that will become 0.79, 1.03, 1.19, 1.33, 1.35, 1.43, 1.51, now based on this, this is given like P1 – P naught over P naught – U naught, so based on that you can determine the value of ID that will be like 0.093, 0.090 I have calculated the value so in order to validate you are doing correct calculation you can repeat this calculation and do it yourself, 0.45, 0.26, 1.07, 0.041, 0.44 so these are values of ID.

Then sigma V naught we will discuss here, you have to also determine the value of, I'm writing here the value of ED, because ED's also required in order to classify the soil,
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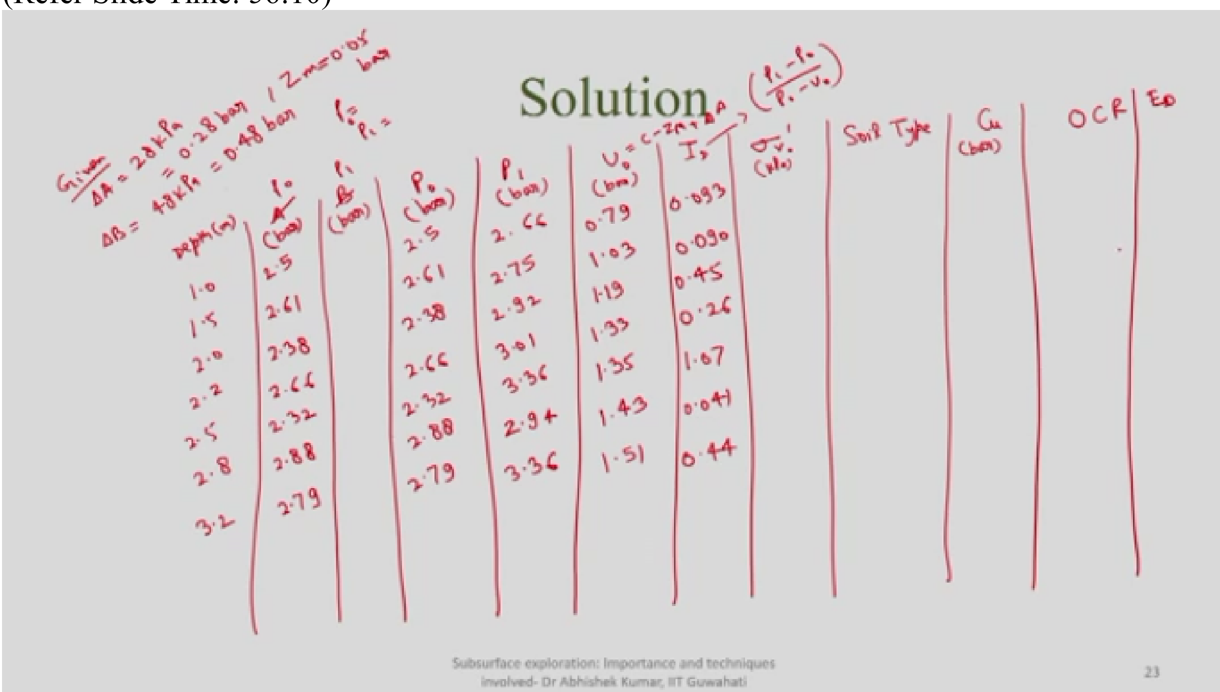

so I'm calculating the value of ED which is given as 34.7 P1 – P naught, again this value is in bar, I'm directly writing the values here 5.52, 4.85, 18.74, 12.14, 36.09, 2.08, 19.77, these are value of ED, now if you remember few slides earlier we had discussed once we know the values of ED, so based on the value of ID, based on the value of ED you can actually determine like the first one ID value is 0.093, so it will be somewhere here, and ED value is 5.5, so it will be corresponding to somewhere here, so you can determine based on this mud, and how much is the density here 1.15, 1.5 values, so you can write here soil type as mud, density also I can write here, though value as 1.5.

Then second one again you can classify at as mud, density of 1.5, third one as silt with density as 1.60, then you will have clay, density as 1.60, sand this will be sand and then mud, and then silt, again the values will be 1.60, 1.50, 1.60, so these are the density, again so you know now the soil type, you know how much is the mass density,
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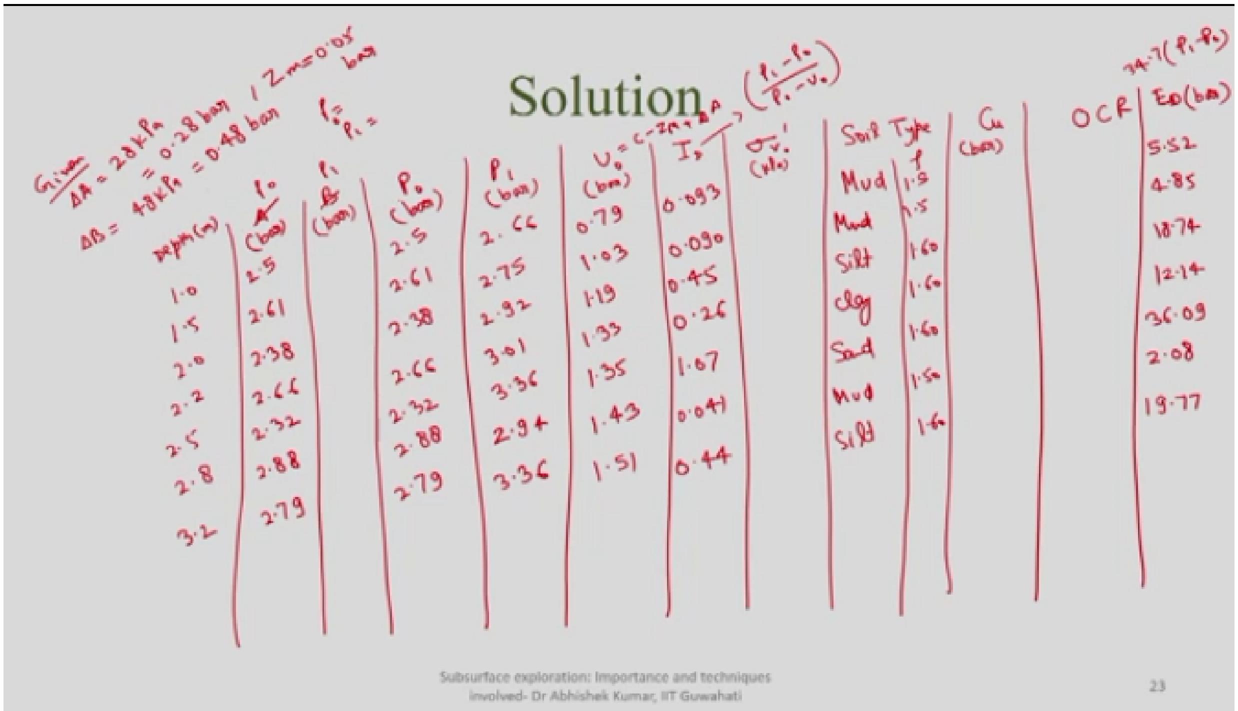

based on this you can actually determine how much will be the value of overburden pressure considering here ground water table equals to 0 meter depth.

So based on that first object is you've achieved now soil type and density, you have achieved because soil type is required as part of first question like identify the soil and validate it, so wherever it is matching with borehole you can see you are getting the same soil type, otherwise you can report different soil type.

This is again once we know the value of mass density you can determine how much will be the effective stress at different, different depth, so I'm directly writing the values here of effective stress, again in bar these values I'm writing here, so that will be 0.049, then 0.73, 0.103, 0.115, 0.132, 0.147, and 0.170, so now you have the value of sigma V naught also.

CU as given by Marchetti, 1980, it can be CU = 0.22 sigma V naught prime 0.5 KD is to the power 1.25, KD also you can determine as V naught – U naught over sigma V prime, so based on that you can determine the value of KD, and then which can determine the value of CU, so I'm directly writing here the value of CU as 0.38, 0.31, 0.203, this will not be applicable for sand, so 0.38, 0.31, 0.203, 0.227, sand it will not be applicable this formula, it is given for normally consolidated clays, so and then for mud also, and then 0.196, these are the value of CU you can determine, once you know the value of CU you can actually determine the value of OCR, OCR is given as 0.5 KD raised to the power 1.56,

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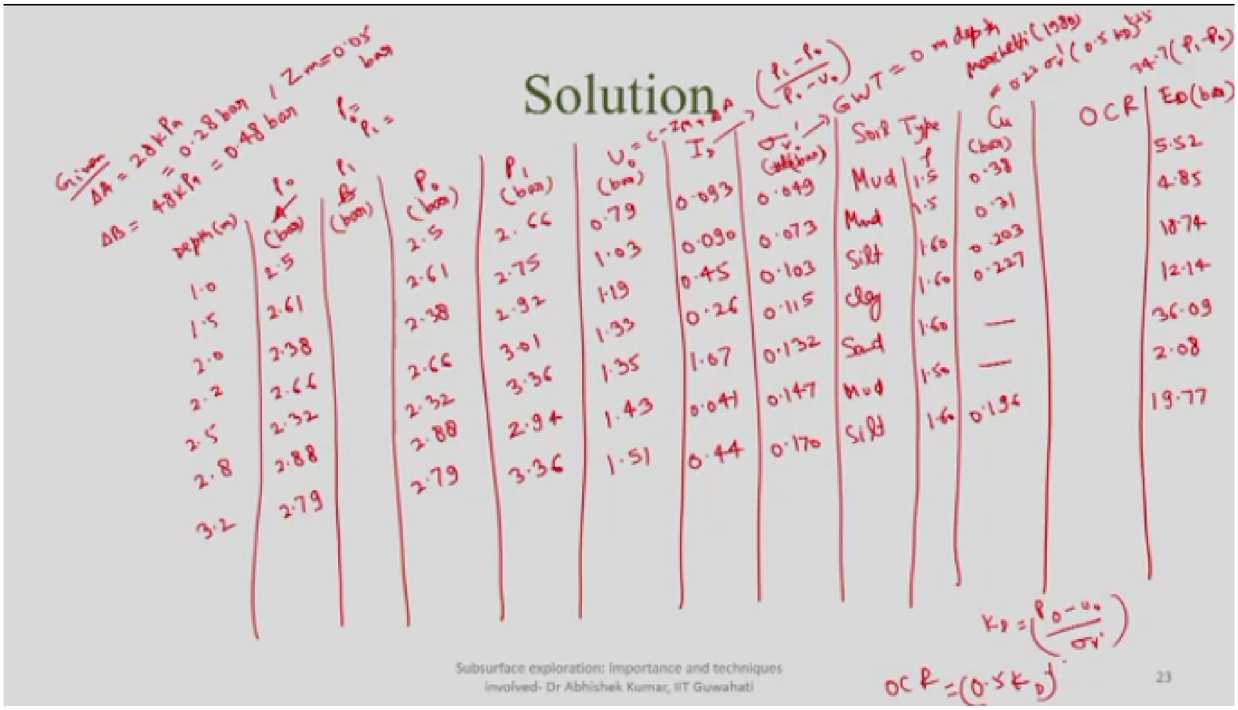

so based on this you put the value of KD, you can determine the value of OCR here, I'm directly writing here as 86.49, 41.06, 15.41, 15.44, this two will not be there and then 7.89.

So interested you can actually, I'm writing here the value of KD also, so you can validate with your calculation KD = 34.89, then 21.64, then 11.55, then 7.35, 9.86, and then 7.52, 1, 2, 3, 4 5, 6, 7 yeah,

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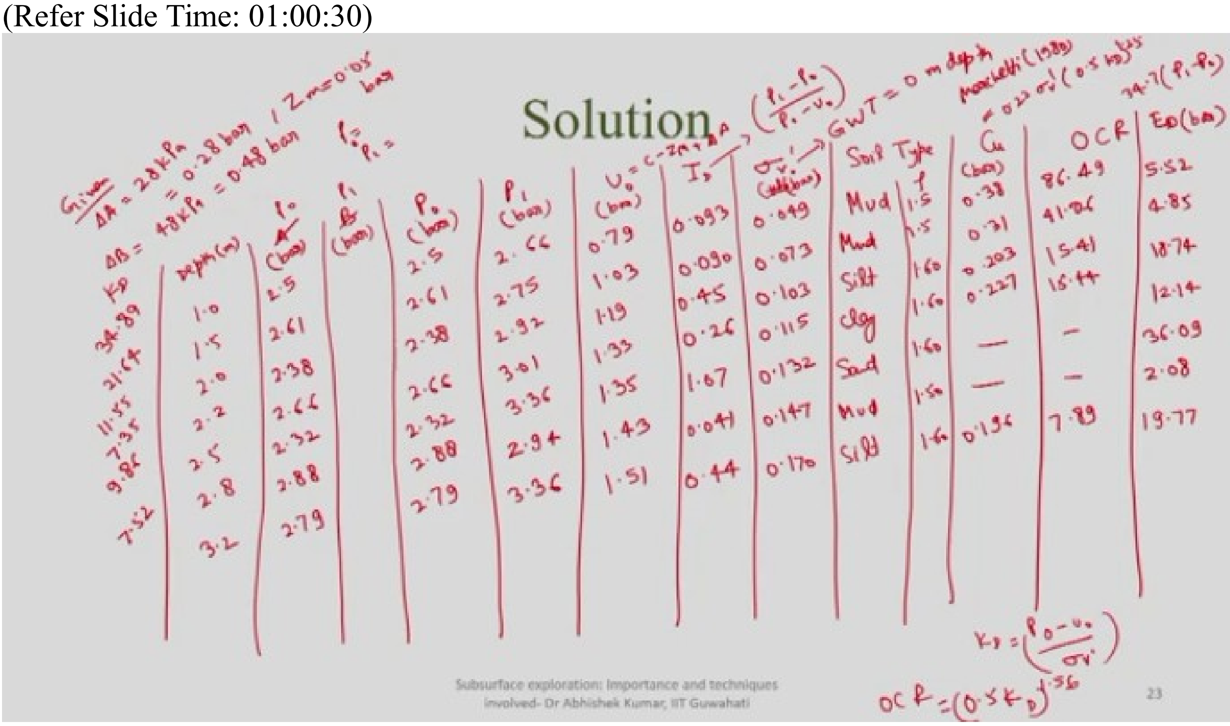

so these are the values of KD which has been obtained using this formula, you now put the values here then you will be able to remain the value of over consolidation ratio, so that's how that is simple measurements of two parameters like pressure required for inflation, pressure required for movement wise 1.1mm, you are able to determine what is the soil type, how much is the density, how much is the, based on the ID value and density value you have determined the value of overburden pressure, once you know the value of overburden pressure you can determine the value of KD, based on KD value you can determine what is the un-drained shear strength of course you have to also take into account what kind of soil is there, so whether for that particular soil the value of KD and OCR you can determine using the correlations or not that is mentioned and then over consolidation ratio.

And ED is also required if again if you are interested in finding out more parameters which are function of ED. So with this I'll stop here, this is, you can practice it yourself so that you get more and more idea about different parameters and be careful with the units whatever has been reporting, whatever are required, our prescribed were different charts, so I'll stop it here. Thank you.

CENTRE FOR EDUCATIONAL TECHNOLOGY
IIT GUWAHATI
PRODUCTION

HEAD CET
Prof. Sunil k. Khijwania

Officer-in-Charge, CET
Dr. Subhajit Choudhary

CET Production Team
Alphul Gogoi
Bikash Jyoti Nath
CS Bhaskar Bora
Dibyajyoti Lahkar
Kallal Barua
Kaushik Kr. Sarma
Mriganka Borah
Queen Barman
Rekha Hazarika
Rajib Mahapatra
Sanjib Phukan

CET Administrative staff

Arabinda Dewry
Swapan Debnath