Geotechnical Measurements and Explorations

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Lecture No. #19

Electrical Resistivity Method

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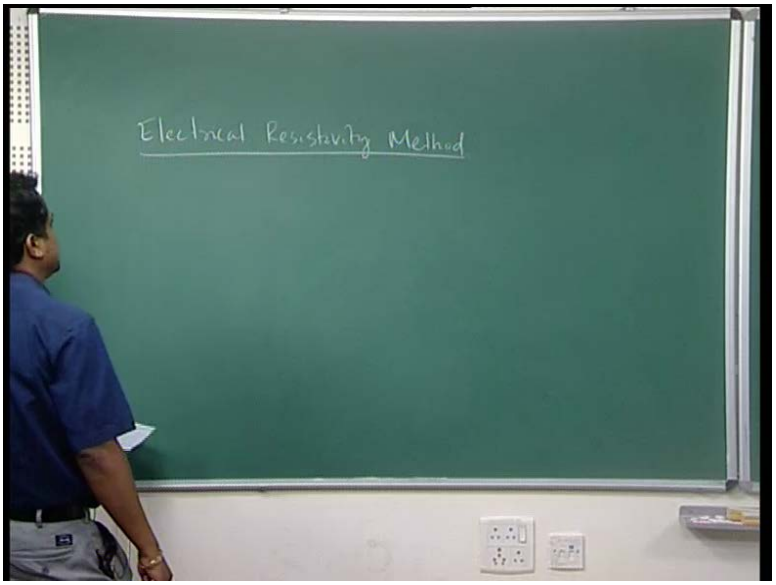

Next is your, electrical resistivity method ((no audio 00:25 to 00:36)). So, basically electrical resistivity method means, the material depends upon the particularly type of electrical current, it passed and how much is your resistance of these soil from there, you can find it out the change in strata.

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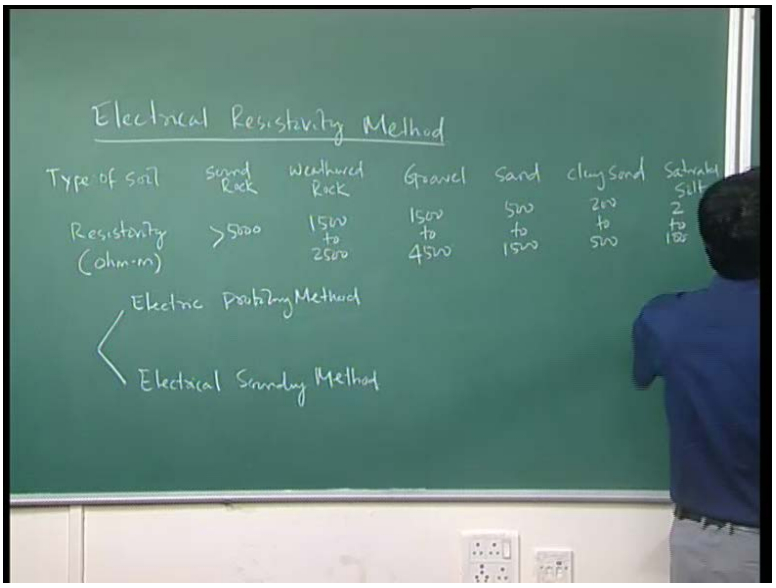

If I write type of soil, then resistivity ohm meter, then your sound rock, weathered rock, gravel, sand, clay sand, saturated silt. It is greater than for sound rock five thousand ohm meter. Weathered rock between one thousand five hundred to two thousand five hundred ohm meter. Gravel is one thousand five hundred to four thousand five hundred meter then ohm meter. Sand is five hundred to one thousand five hundred ohm meter. Clay sand is two hundred to five hundred. Saturated clay two to one hundred.

Now, there are two types of electrical resistivity method. One is your electrical profiling method, other is electrical sounding method ((no audio 02:58 to 03:08)).

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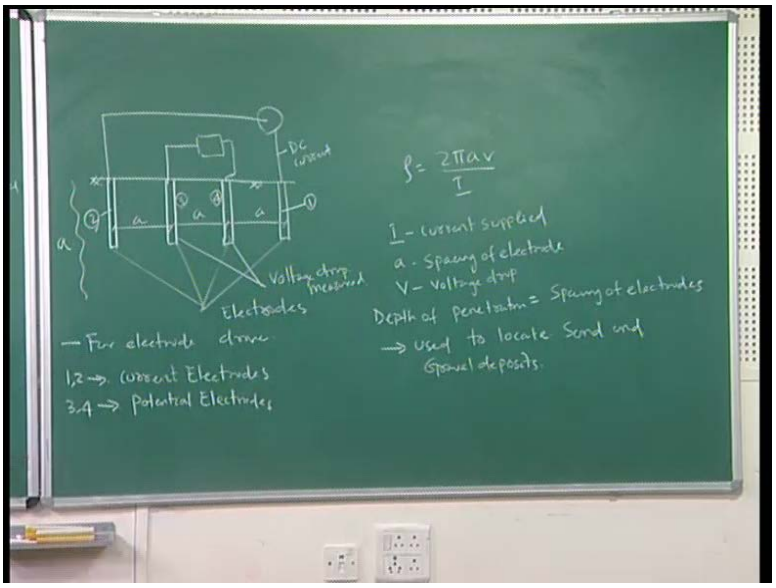

Now, in case of electrical profiling method, what happen, if this is the ground surface ((no audio 03:18 to 03:34)). Now, these are current electrodes, these are your electrodes and this is equal distance say a a and a.

Then, outer will be connected with these meters, four electrodes driven in this method, electrical profile method. Four electrodes driven inside the ground surface. Outer electrodes are known as, these two outer electrodes; this is one and this is two. One, two outer electrode, they are known as current electrodes, and inner two electrodes, this is three and four known as potential electrodes. So, mean resistance of this soil, you can get it by applying your DC current to the outer two electrodes. Then, what is the voltage drop between two electrodes, inside electrodes measured ((no audio 05:47 to 05:59)).

So, the mean resistivity rho, you can measure by means of, two phi a v by I. I is equal to current supplied, a is equal to spacing of electrode, v is equal to voltage drop. So, it can go, that means how much depth of penetration it can go, the depth of penetration is equal to your spacing of electrodes. That means, depth of penetration is equal to spacing between these electrodes. It is used to locate sand and gravel deposits.

Now, electrical resistivity method means, by drop of voltage. That means, the method one, electrical profile method. In the ground, there are four electrodes install or penetrate inside the ground. Out of four electrodes, out of two electrodes as worked as a current electrodes. That means, apply by means of DC current, current has been applied both one

and two electrodes, and how much voltage drop in three and four it has been measured, voltage drop in three and four or potential drop.

From there electrical resistivity of these soil can be measured, two phi a v by I. I is equal to current supplied, how much current supplied one and two, and a is yours spacing of electrodes, that is you are a, v is equal to voltage drop, you can measure from here voltage drop, you can measure here, how much current supplied, voltage drop in between these three and four. Based on that, you can find it out resistivity. Ones you get the resistivity, what is the value of resistivity look at, then you can say, how much is your means, what is that soil? Is it a sand, it is a rock, it is a gravel, or it may be clay, or may be saturated silt.

The limitation is, that means, this spacing of the electrodes, what is the spacing you are going to take, up to that depth. That means, suppose the spacing is a, up to that depth, that means a. These particularly, these voltage dropped you can measure. Beyond that, you cannot measure and used to locate sand and gravel deposits.

Now, come to second part, that is your electrical sounding method. The limitation for this electrical profile method is, you can go up to depth, that is equal to spacing of these electrodes. You cannot go beyond that depth, or you cannot measure electrical resistivity beyond that depth.

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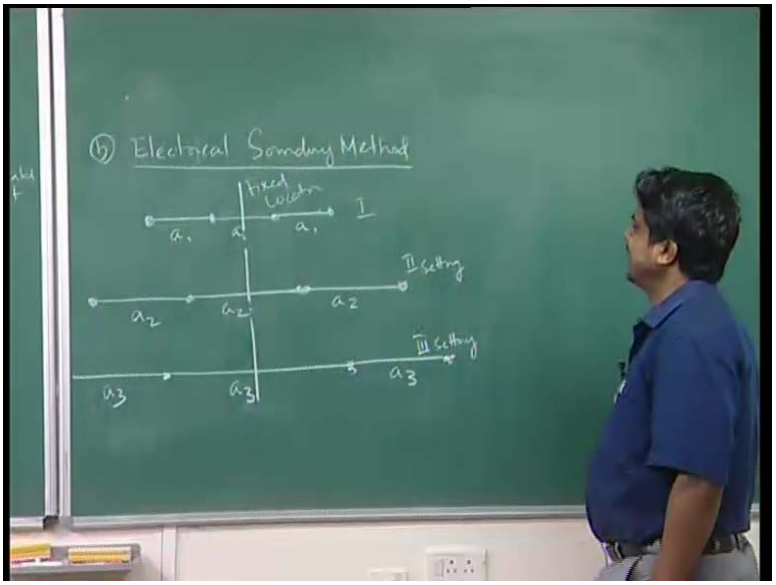

Now, part b, that is your electrical sounding method ((no audio 09:58 to 10:09)). In electrical sounding method, look second is your electrical sounding method. In this method, there is a fixed location. This location has been fixed, not like electric profile method where you can varied. These location is fixed, with respect to this location. Suppose case one, this one varying a one, a one, a one, this is varying. That means, case two you can vary, a two. Case three, you can vary, a three. With this, with respect to fixed location, you can vary the spacing of the electrodes.

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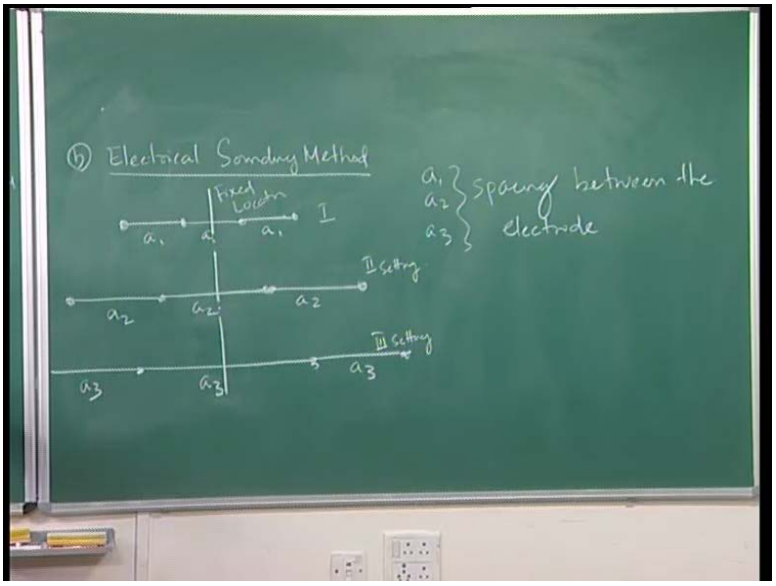

These are a one, a two, or a three. These all are spacing of electrodes. Spacing between the electrodes, you can vary the spacing between the electrodes. So that, you can reach, up to the depth of exploration.

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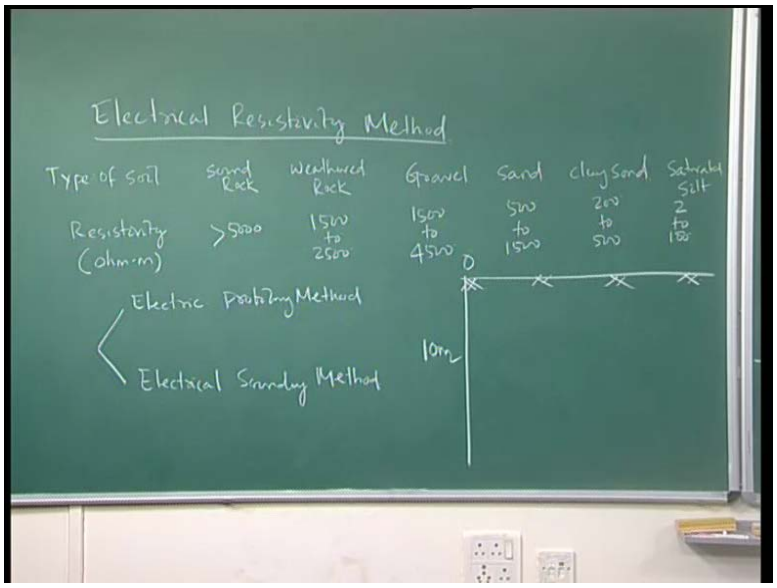

Suppose, this is the range, where the depth of exploration has to taken up to ten meter from the ground surface, zero to ten meter depth of exploration has to be carried out. Suppose, in zero meter to ten meter, you are going to carrying out, sub soil exploration.

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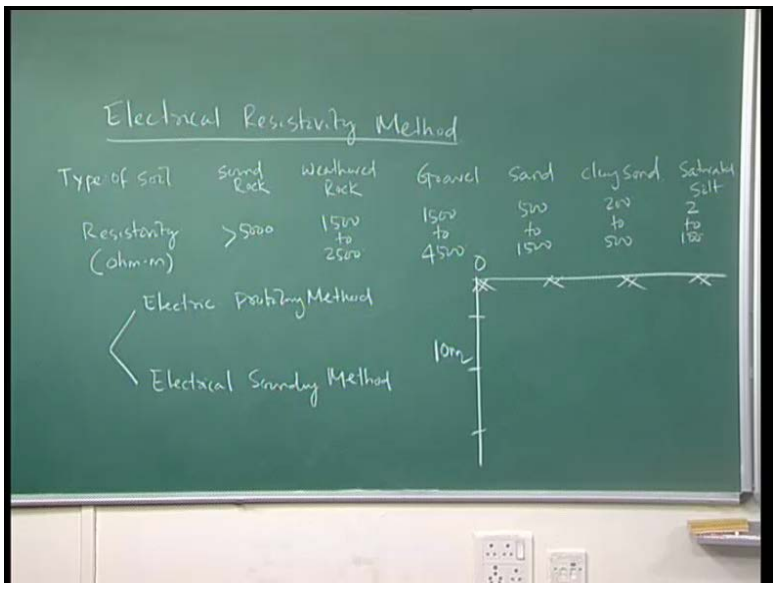

Let us say, every two meter interval. For two meter interval, then you said, from the fixed location. So, a one should be two meter. Then similarly, next four meter, a two should be four meter. Because in electrical resistivity, the resistance you can measure up to a distance, that is equal to spacing between these electrodes. So, a one is two meter.

Second case, a two is equal to four meter. Similarly, third case if you want to measure electrical resistivity or may be ground response sub soil exploration at ten meter depth, by means of electrical resistivity. In that case, this spacing should be ten meter. So that, exploration you can do it below ten meter up to the ground surface.

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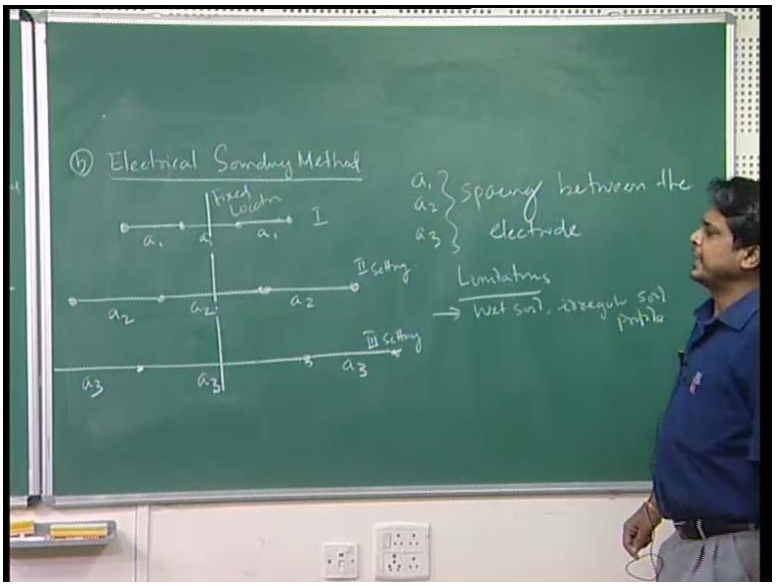

Now, there are limitations, also in this methods means, particularly if there is wet soil, or irregular soil profile, you may not get the electrical resistivity, whatever you are getting, you may not get accurate data.

So, despite of this limitation, sometimes electrical resistivity has been used many places also to find it out, resistance of the soil. Based on the resistance of the soil, you can say that, this is either sand gravel or clay sand or saturated silt.

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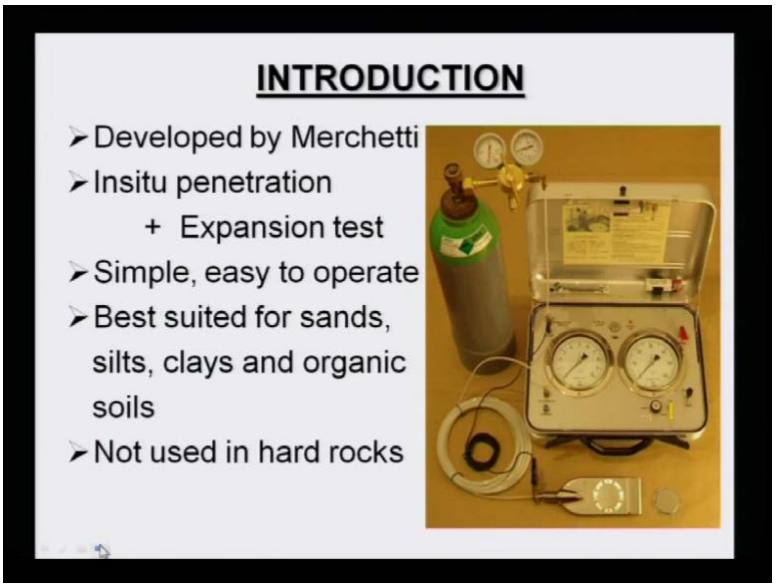

Next is your dilatometer test, means dilatometer test has been developed by merchetti. It is basically insitu penetration as well as expansion test, it is simple and easy to operate. So, best suited for sands silt clay and organics soils, it has not been used for hard rock.

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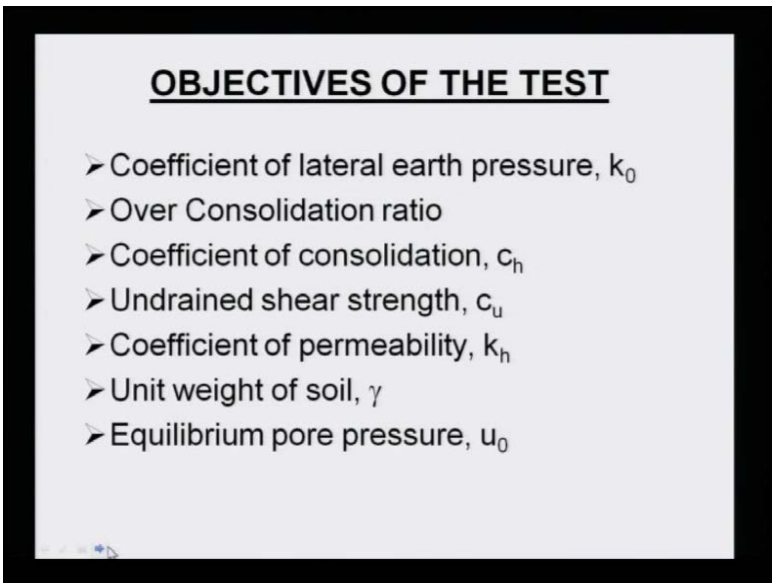

Now, what you are suppose to get from this test. Coefficient of lateral earth pressure, this coefficient of insitu conditions. I mean in insitu condition coefficient of lateral earth pressure k zero. Then over consolidation ratio, coefficient of consolidation c h, undrained

shear strength c u and coefficient of permeability k h, unit weight of soil as well as pore water pressure.

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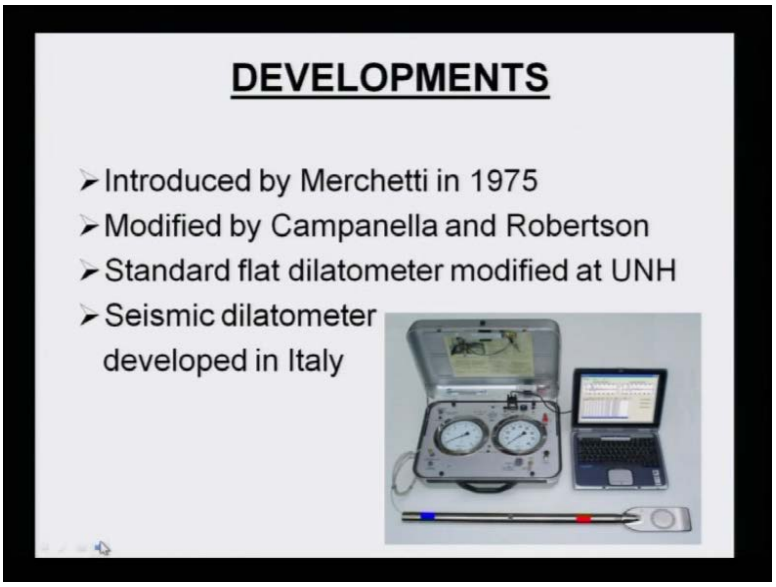

Now, it has been initially introduced by merchetti in nineteen seventy five. Then modified by Robertson, it is a standard flat dilatometer.

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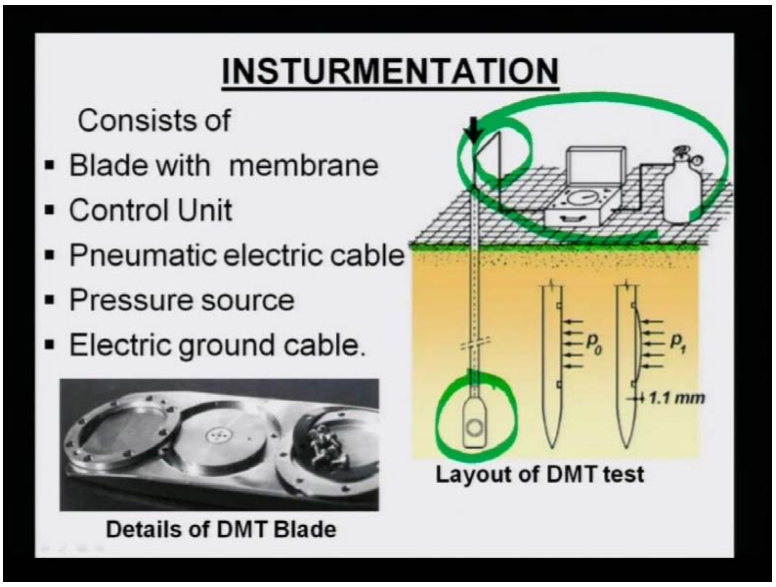

And if you look at this part, you can say, if you look at here, the layout of this D M T, it consists of a blade, this part is your blade. Now come back to this instrumentation, it consists of blade with a member, this is the blade, generally with a member. Then control

unit, this is your control unit outside, and pneumatic electric cable, this is your pneumatic electric cable. Then pressure source, electric ground cable.

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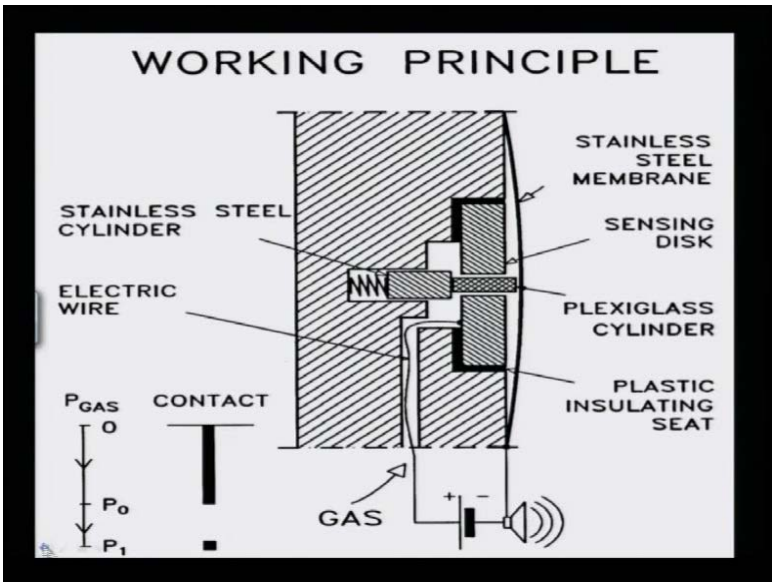

Now, how it works. Now this, if you come back to earlier p p t, how it works?

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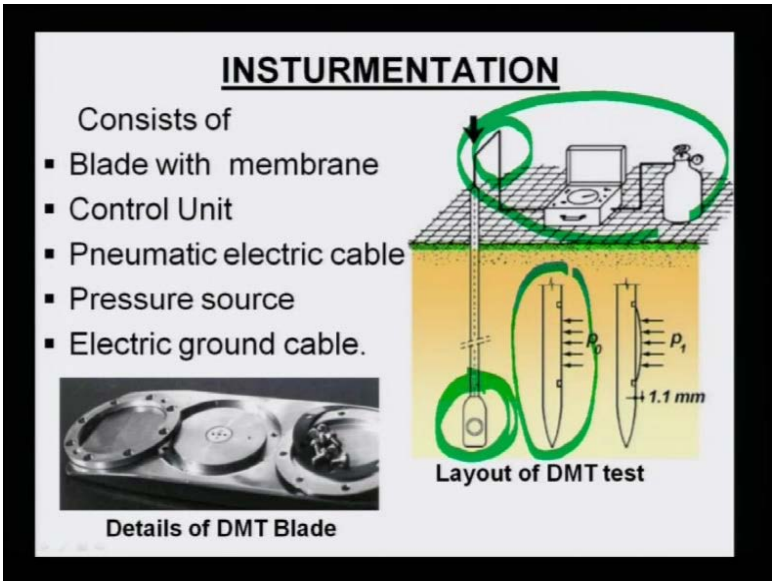

It is a blade. If you look at here, this center part is here, it is a blade. With this blade action, how it has been done in the field.

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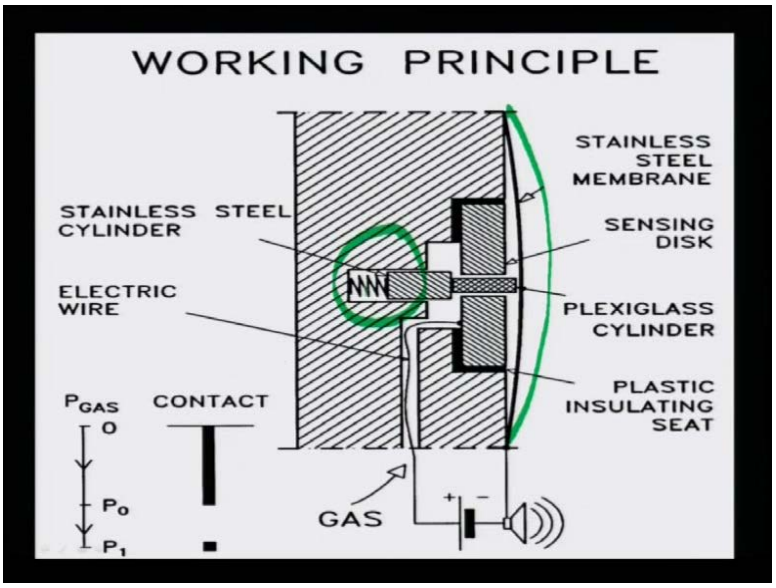

It is connected by means of a stainless steel member, inside there is a spring and plexiglass cylinder also there, and plastic insulating seeds are also there. By means of gas, ones it enters. So, it will try to expand outside. The moment it expand outside, so soil will give resistance. So, this resistance or the sigma three, you can get it, how much this spring. Spring will be compressed, from there we can get it.

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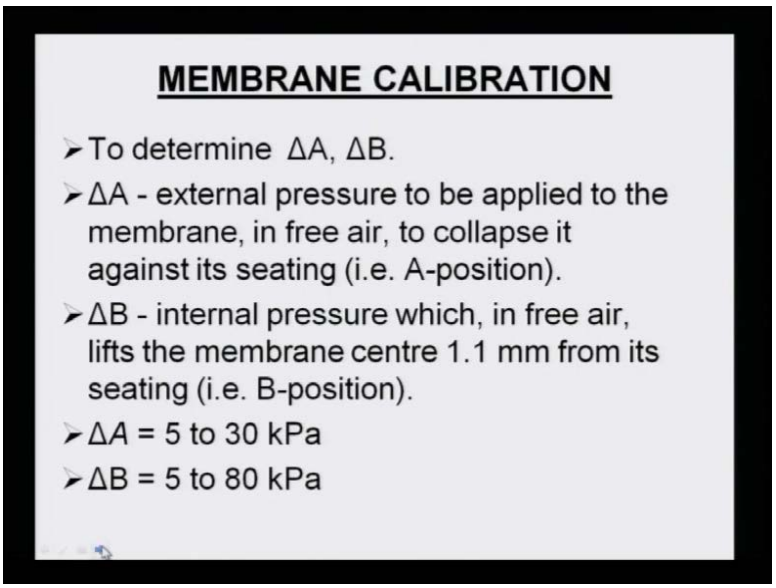

And there are two parameters required to find it out. One is your, how much external pressure applied to the membrane. Then is your internal pressure, which in free air lifts

the membrane center one point one m m from its seating position. Generally, delta A and delta B, five to thirty k P a. Delta A and delta B, five to eighty k P a has been taken.

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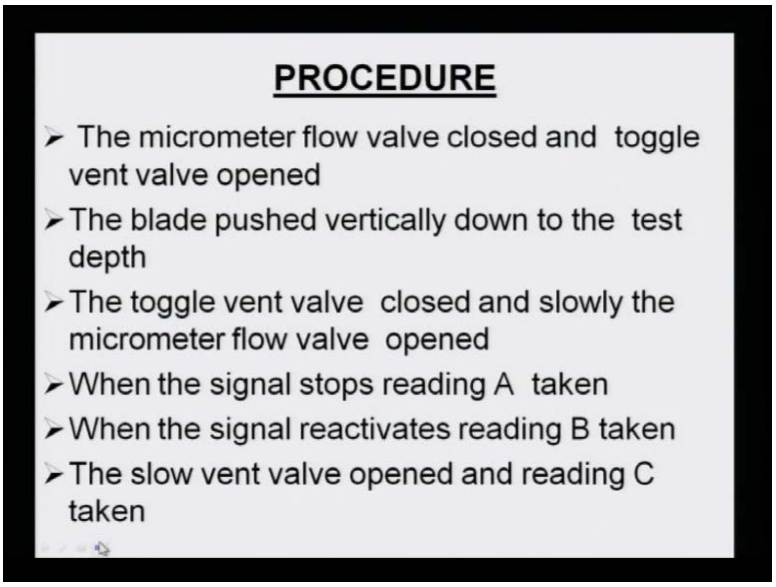

As I said earlier, the procedure is like this.

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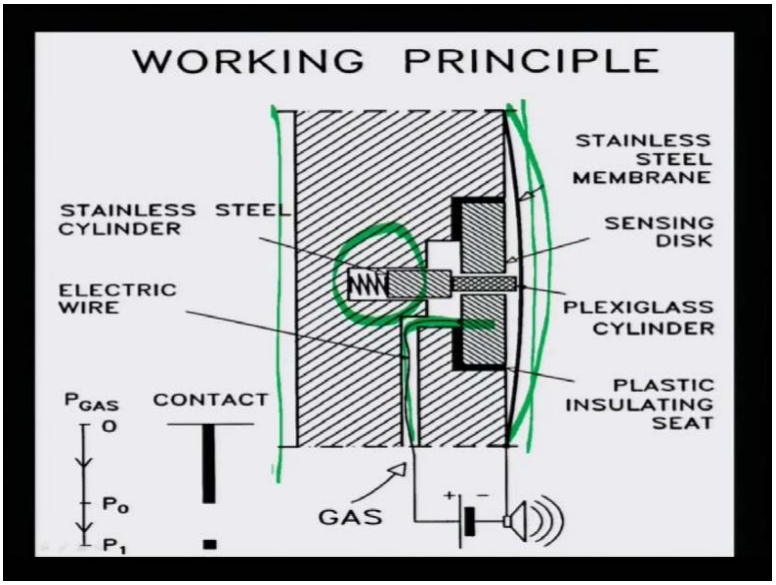

The moment by means of gas, it will try to expand. Ones it expand, what will happen, here the soil is there. With this soil resistance, then this spring will be either expand or may be contract. Based on the spring resistance, you can find it out sigma three.

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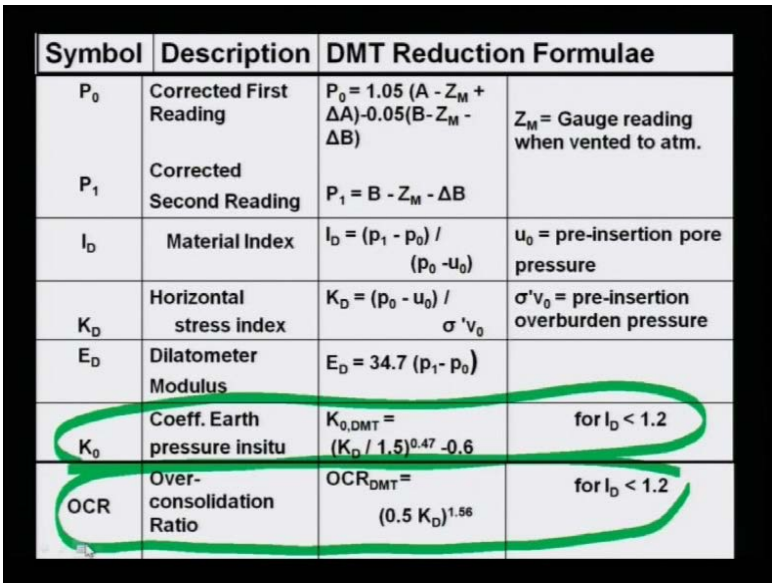

Symbol	Description	DMT Reduction Formulae	
P_0	Corrected First Reading	$P_0 = 1.05 (A - Z_M + \Delta A) - 0.05(B - Z_M - \Delta B)$	Z_M = Gauge reading when vented to atm.
P_1	Corrected Second Reading	$P_1 = B - Z_M - \Delta B$	
I_D	Material Index	$I_D = (p_1 - p_0) / (p_0 - u_0)$	u_0 = pre-insertion pore pressure
K_D	Horizontal stress index	$K_D = (p_0 - u_0) / \sigma'_{v_0}$	σ'_{v_0} = pre-insertion overburden pressure
E_D	Dilatometer Modulus	$E_D = 34.7 (p_1 - p_0)$	
K_0	Coeff. Earth pressure insitu	$K_{0,DMT} = (K_D / 1.5)^{0.47} - 0.6$	for $I_D < 1.2$
OCR	Over-consolidation Ratio	$OCR_{DMT} = (0.5 K_D)^{1.56}$	for $I_D < 1.2$

So, these are all dilatometer test reduction formula for different P zero and P one. How to find it out, K D horizontal stress index, E D dilatometer modulus, K zero coefficient of earth pressure in insitu, this is our requirement. Then over consolidation ratio also, this is also our requirement.

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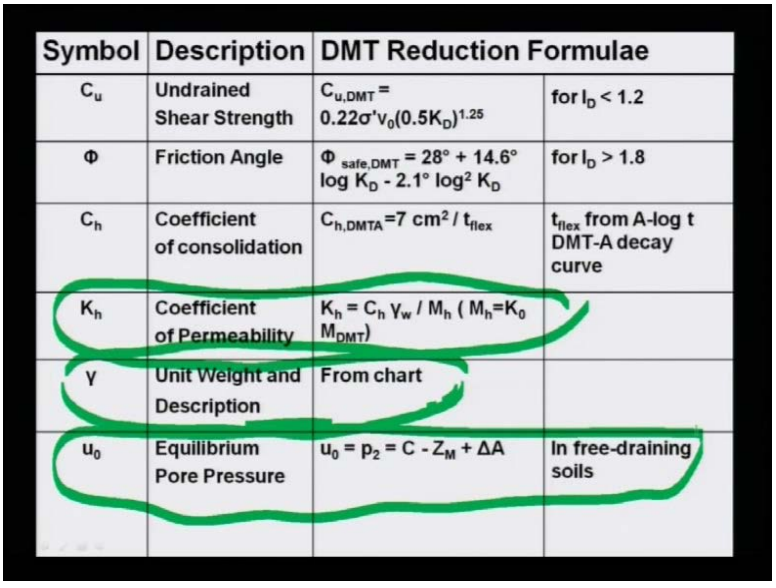

Symbol	Description	DMT Reduction Formulae	
C_u	Undrained Shear Strength	$C_{u,DMT} = 0.22\sigma'_{v_0}(0.5K_D)^{1.25}$	for $I_D < 1.2$
Φ	Friction Angle	$\Phi_{safe,DMT} = 28° + 14.6° \log K_D - 2.1° \log^2 K_D$	for $I_D > 1.8$
C_h	Coefficient of consolidation	$C_{h,DMTA} = 7\ cm^2 / t_{flex}$	t_{flex} from A-log t DMT-A decay curve
K_h	Coefficient of Permeability	$K_h = C_h \gamma_w / M_h$ ($M_h = K_0 M_{DMT}$)	
γ	Unit Weight and Description	From chart	
u_0	Equilibrium Pore Pressure	$u_0 = p_2 = C - Z_M + \Delta A$	In free-draining soils

Then, this is your coefficient of permeability, unit weight of the soil required, also in free draining soils, equilibrium pore pressure, you can measure it. It has great advantage ,many parameters you can get it.

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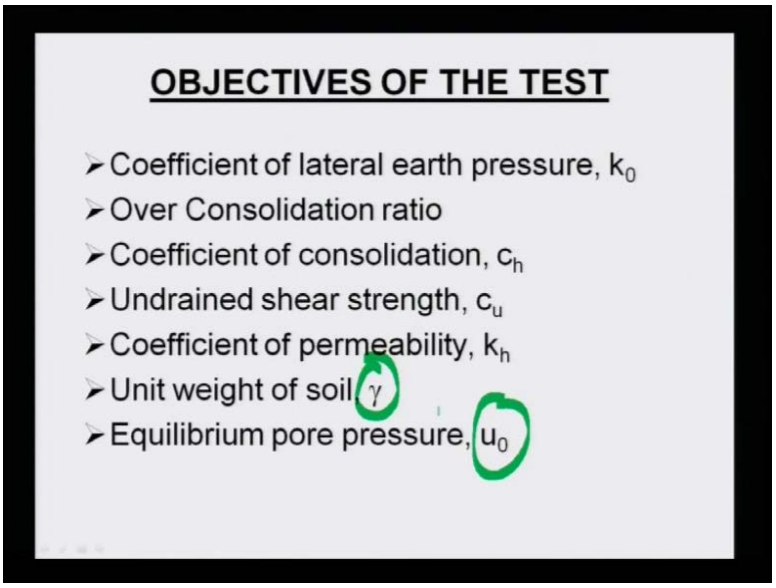

Like I say, you can find it out, k value. Then also, you can find it out, permeability, coefficient of lateral earth pressure k zero, over consolidation ratio, coefficient of consolidation, undrained shear strength, permeability, unit weight of soil gamma, equilibrium pore pressure u zero. Many things you can find it out from this test, it has advantage also, as compare to other insitu test.

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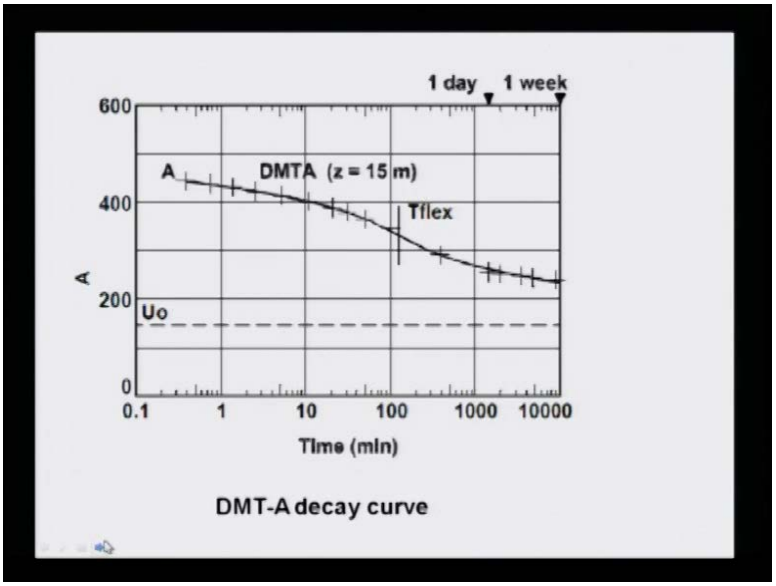

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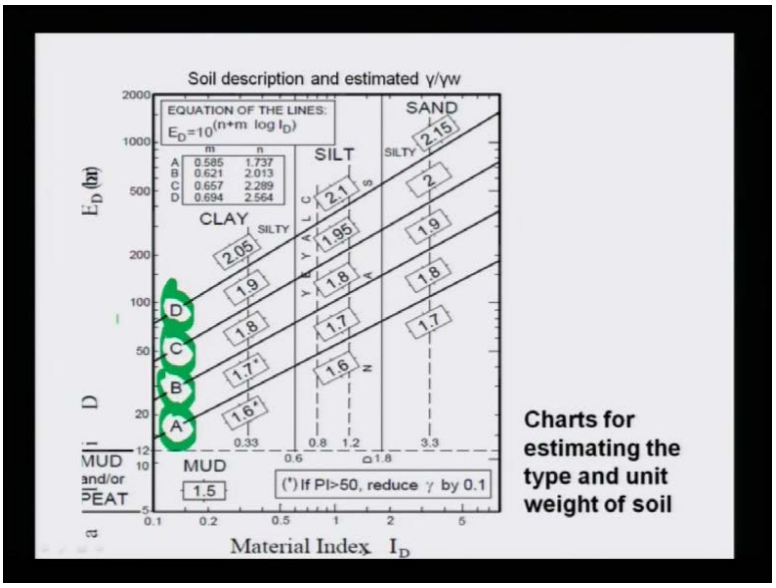

Now, that is another, it is plotted with dilatometer index E D versus the material index I D, task for estimating type and weight of soil. If you see this, there are range A, B, C and D types of soils. From this range, you can find it out, if you know E D and material index you can find it out, what kind of soil, where is the range, you can easily find it out.

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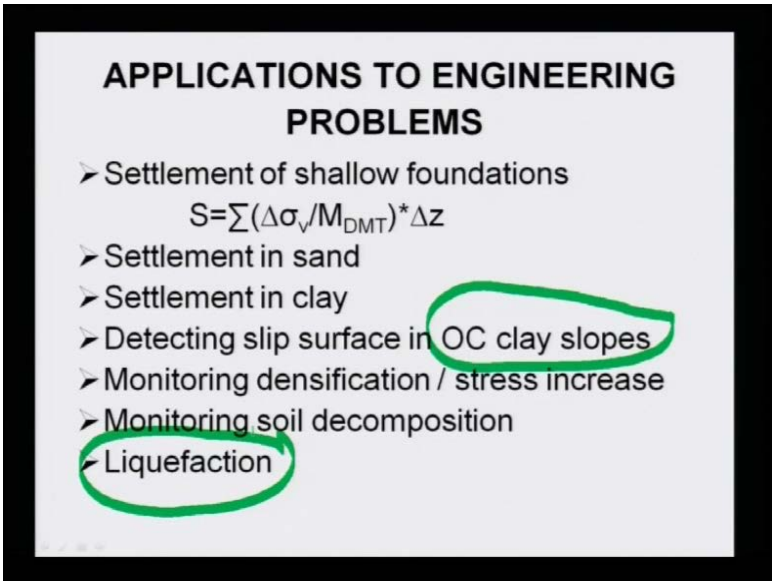

Application to engineering problem, settlement of shallow foundation, you can also get settlement in sand, settlement in clay, then detecting slip surface in slopes, and also as

well as, as you are measuring pore water pressure. You can also determine liquefaction as well.

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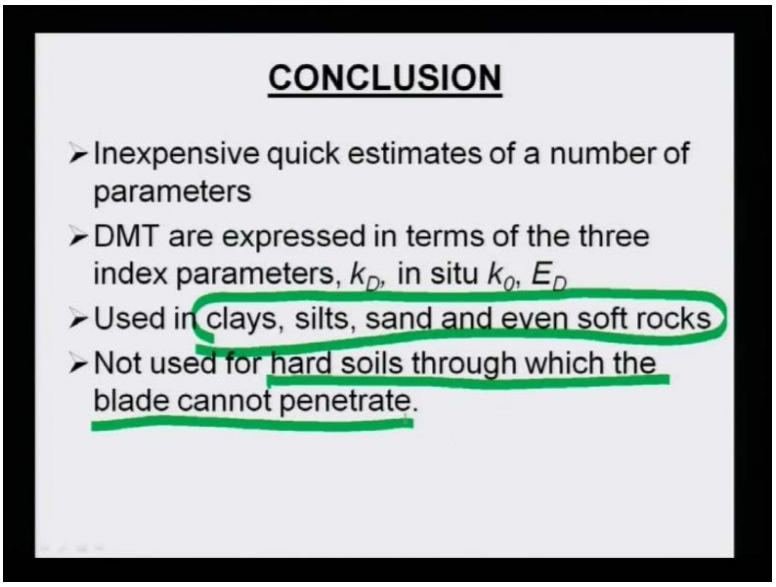

It is a quick estimate, it is a quick test, sometimes you say, it is an quick test. D M T generally, dilatometer test expressed in terms of three parameters. That is, k D, insitu k zero and E D. Used in clay, silt, sand, even also soft rock. However, it cannot be used for hard soil through which blade cannot penetrate. Because, you have to penetrate that blade for hard soil, it is very difficult to penetrate that blade.

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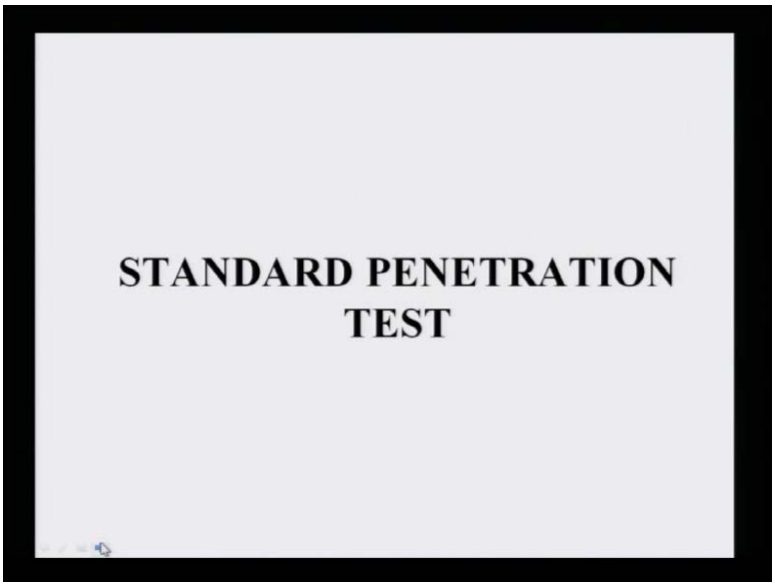

Now other test, as I said, also I have explained earlier, if you remember well. That is your, standard penetration test by black board I draw this diagram.

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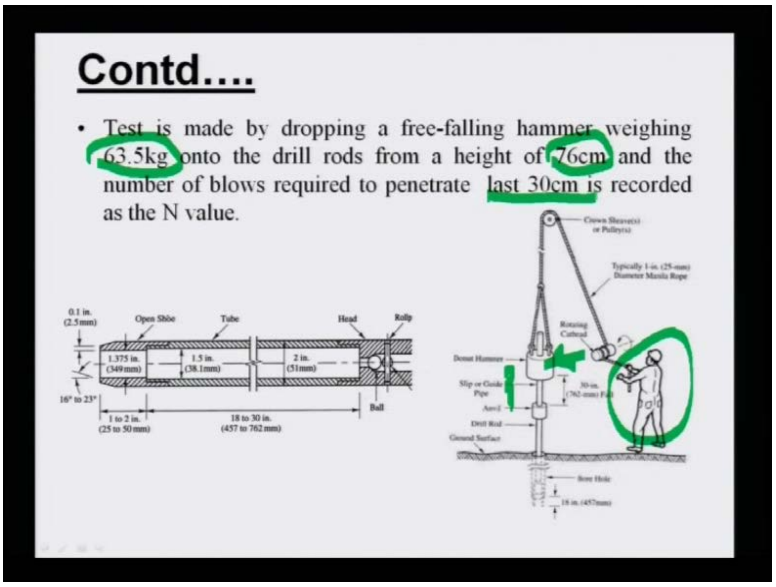

You can see this schematic diagram of the standard penetration test, if you look at here. Now, this is your hammer, then it drops height of seventy five. This is sixty five in indian condition, it is used as per a h t mit is sixty three point five, and height of fall is seventy six, but some other standard it is, sometimes seventy five, sometimes it is sixty five also.

So, this is schematically it has been shown, this is your tripod, by means of pulley, manually, you can do it, pull it. So that, you can raise certain height and it can be drop at a height of say, seventy five centimeter. So, penetration obtained for last thirty centimeter is recorded as n value.

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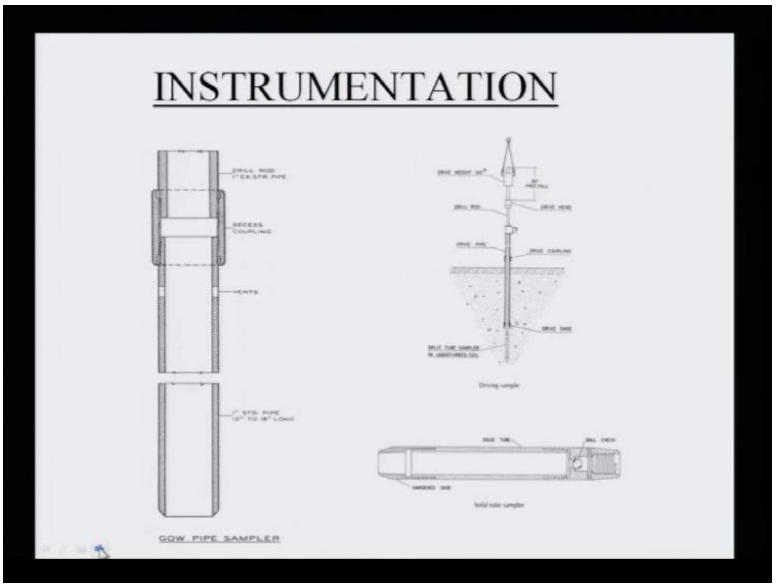

So, this is your split spoon sampler details. I have already explain.

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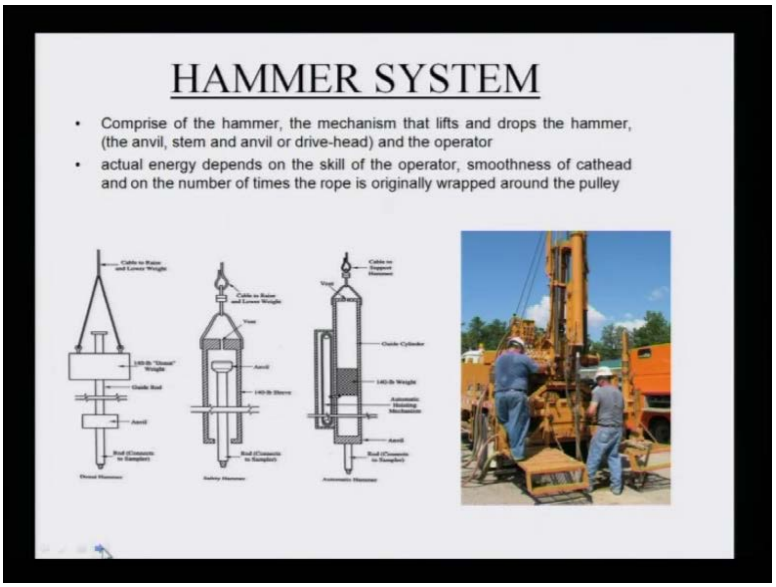

Now, if you see this, how many corrections required.

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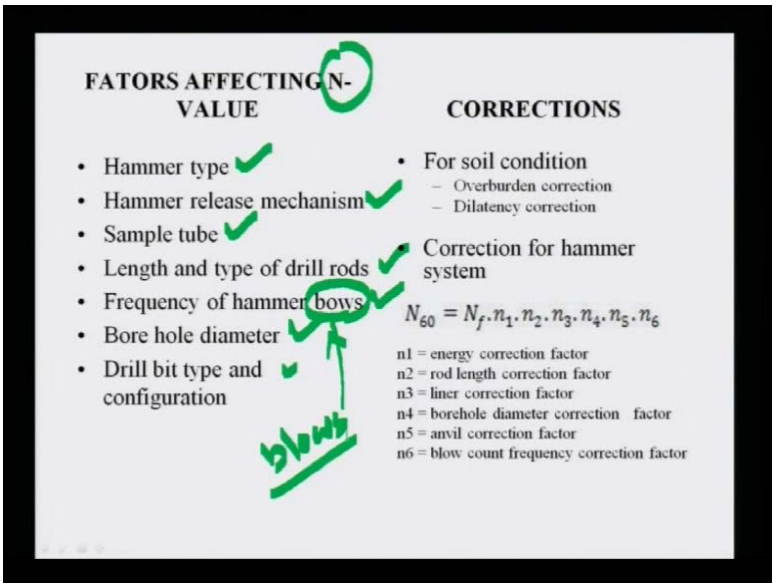

What are the factors affecting N-value in field. What type of hammer used, it depends upon the hammer type. Also, how the hammer release, it is manually or may be mechanically operated. What is the sample tube used, length and type of drill rods, frequency of hammer bows. Then, bore hole diameter, drill pit type and configurations. Then, frequency of hammer blows. Sorry, this is wrong. this will be blows.

Corrections for soil conditions- As I said earlier, there are two corrections. Overburden correction as well as dilatency correction.

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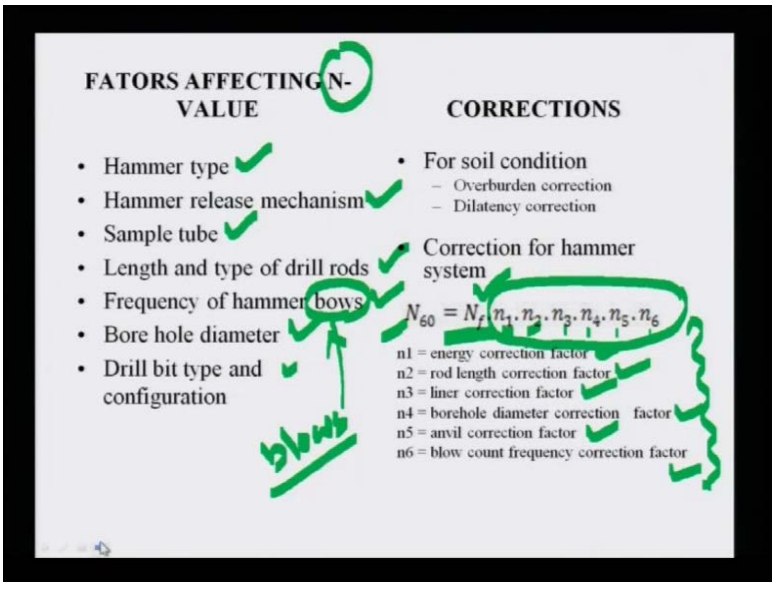

Then, correction for hammer, it is N sixty if I say, it will be N f. N f is your S P T after corrected. Then N f is your S P T in the field, not after corrected. n one, n two, n three, n four, n five and n six. n one is your energy correction factor, n two is your rod length correction factor, n three is your linear correction factor, n four is your borehole diameter correction factor, n five is your anvil correction factor and n six is your blow count frequency correction factor. These are the required corrections. You have to apply, ones you take n sixty, then it is your field value of penetration blow with these corrections, it required means, you have to apply.

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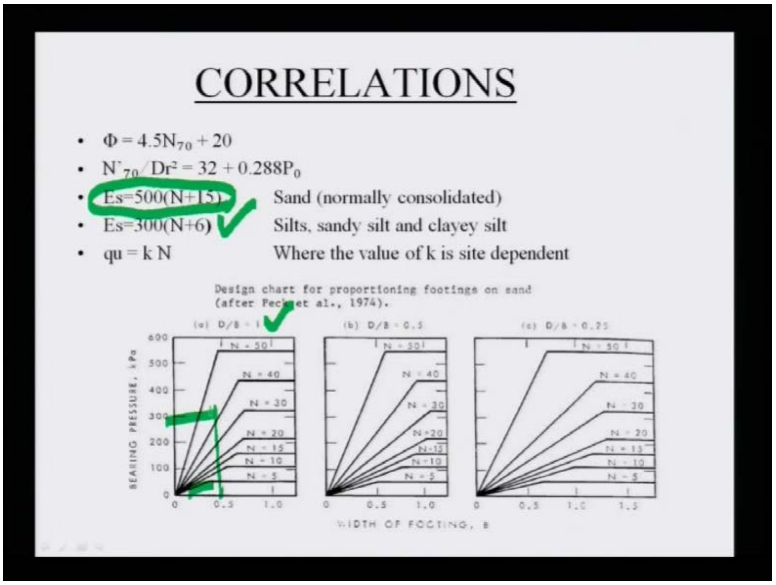

Then correlations, it has been also explained also earlier. For sand, normally consolidated sand, you can find it out E s soil, five hundred into N plus fifteen. For sand silty, silt and clay, you can find it out, E s equal to three hundred in to N plus six.

These are the designed charts, after this pit (( )) nineteen second seventy-four. With respect to N, and D by B ratio, from there you can find it out your bearing capacity. That means, suppose said D by B is equal to one. So, with this point five, depth is bearing pressure, you can find it out. Suppose N, you are getting, suppose how much is your N, based on the N, you can find it out, what is your bearing pressure. These are the chart, indirectly you can get bearing capacity of foundation, based on also N value.

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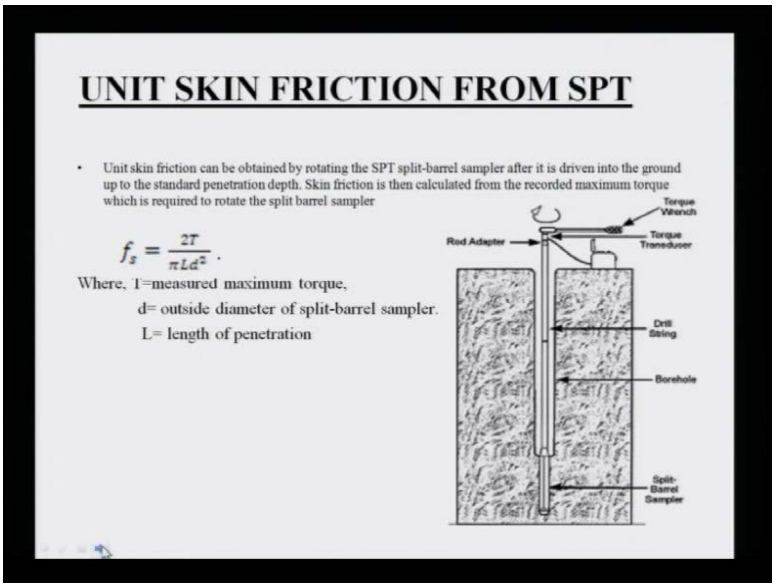

Now, another important part, I have not said. Can I measure unit skin friction from S P T? Yes.

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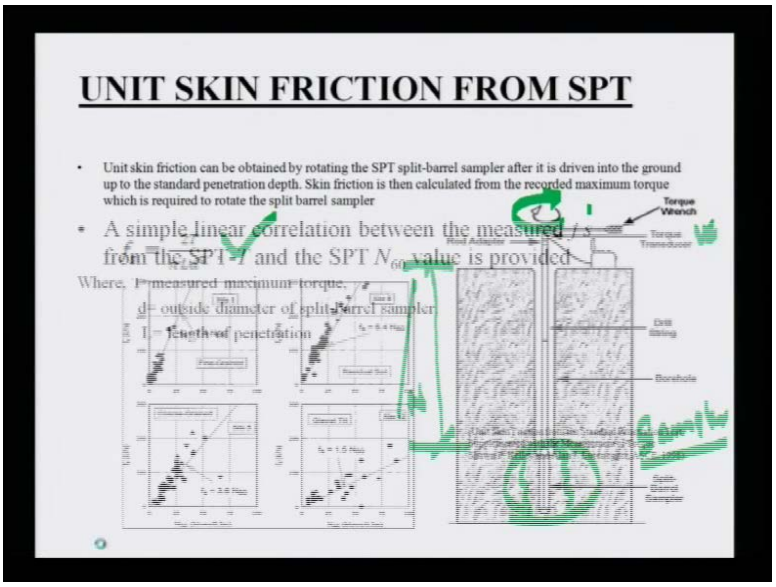

Now, it is the latest development means, unit friction can be obtained by rotating S P T, split-barrel sampler, split spoon sampler here. This is your, you can say, this is your sampler by rotating. Ones you penetrate, ones after taking the S P T. Suppose, at this height or this distance, you are measuring the value of N. After measuring the S P T, after conducting the standard penetration test.

Then, you can rotate the S P T sampler, this is your S P T sampler remain inside. So that, you can get skin friction means, how much torque it can take, by means of rotation.

Based on that, you can find it out, skin friction f s is equal to two T phi L d square. T is your measured torque, you can measure torque outside, you can find it out, how much torque it can take, d is your outside diameter of split barrel sampler, L is equal to length of penetration.

Now, whether this is possible or not unit skin friction can be carried out or not from standard penetration test.

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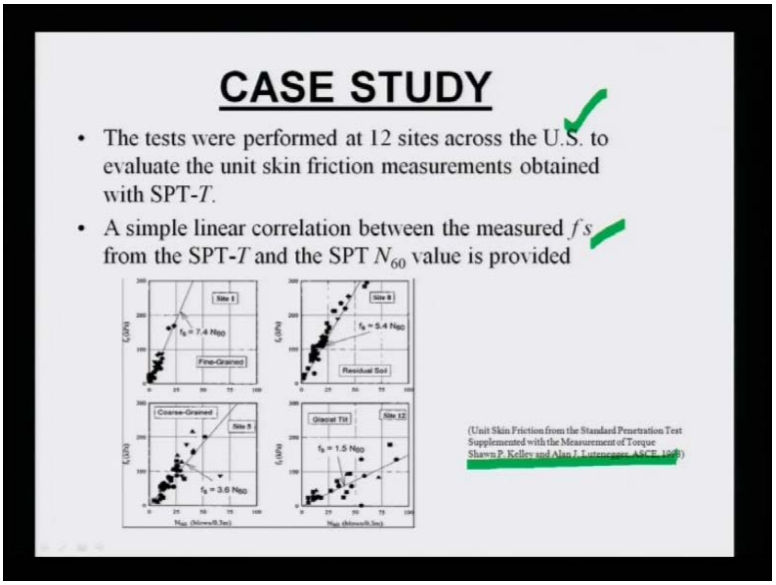

So, basically it has been, there are case studies means, test were performed at twelve sites across in U.S. united states to evaluate the skin friction measurement obtained, with S P T and T. Based on that skin friction measurement, a simple linear correlation between the measured skin friction and the S P T-T is provided. So, this has been given by shawn A T L nineteen ninety eight, they propose correlation between the measured f s from S P T-T and S P T N.

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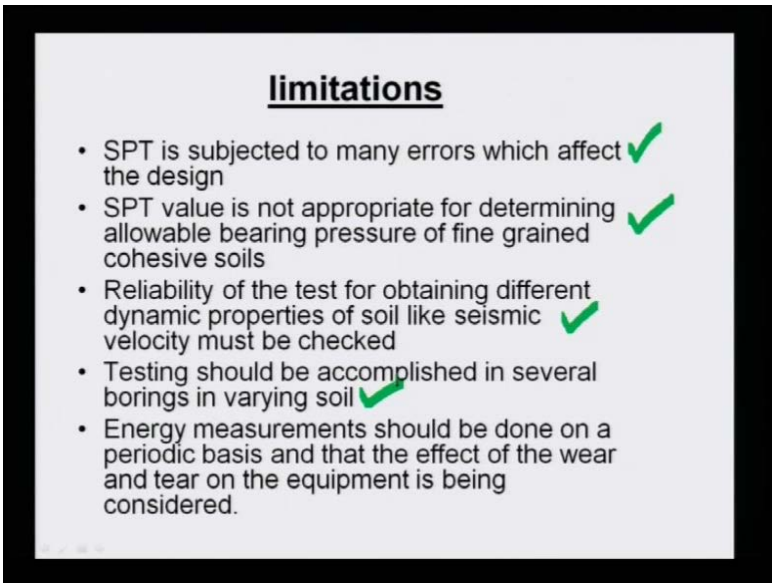

Limitations, also I said, S P T subjected to many errors, which affect the design. There are many errors, S P T value is not appropriate for determining, allowable bearing pressure of fine grain cohesive soil.

Limitation two, then reliability of the test for obtaining different dynamic properties of soil like seismic velocity must be checked. How reliable, it should checked this datas, testing should be accomplished in several boring in varying soil.

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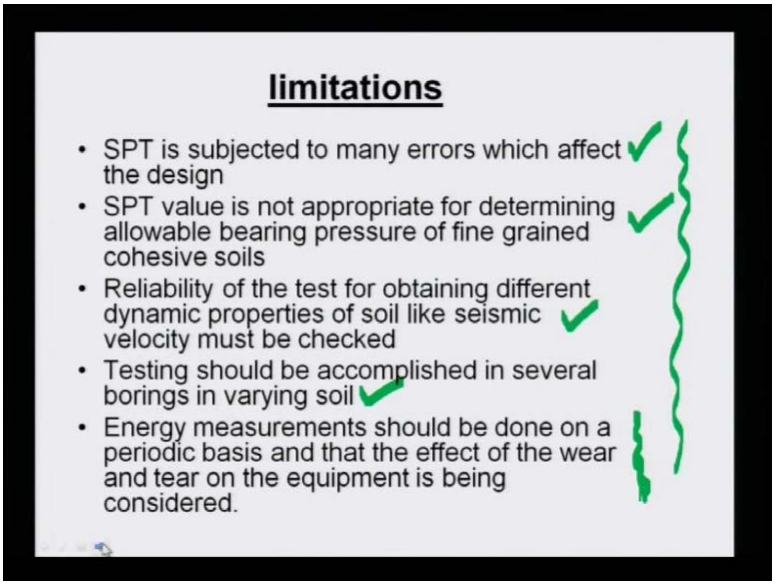

Before arriving, value of n, you have to do lot of test in several boring and energy measurement, check the energy measurement, because in this energy measurements, corrections also required. Despite, several limitations, S P T is standard penetration test is most popular to get n from there, you can get phi, from there indirectly you can get also your bearing capacity of footing.

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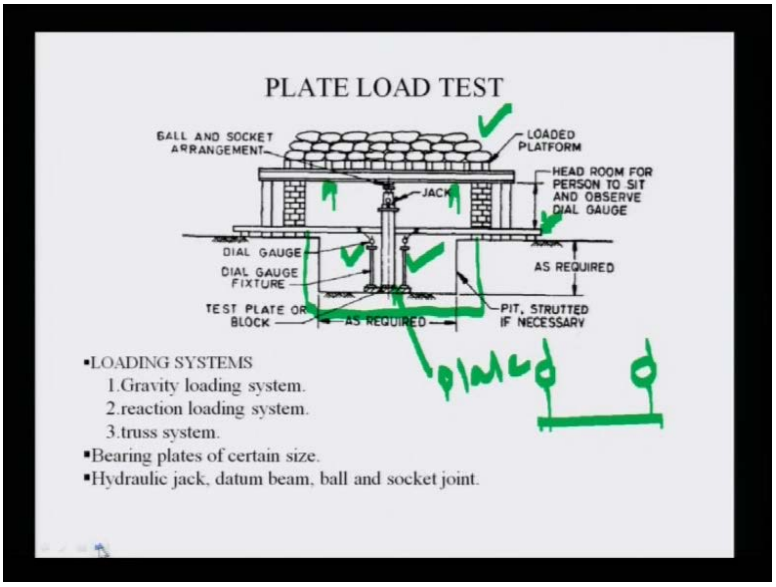

Now, if you look at the next part, as I said earlier, plate load test. The figure, now I am showing this figure, if you look at here, I have already explain in this lecture classes also. Look at the pit, here it is the pit has been made.

Then, once the pit has been made, plate is placed here, this is your plate. Then, with this plate, a reaction frame. You see, is your reaction beam, reaction frame has been placed. Over the reaction beam, a load platform has been made and also load apply.

What will happen, by means of hydraulic jack, whatever I applied the pressure to the hydraulics jack, it will try to uplift the reaction beam. If proper loading platform has been made with loading systems, so it will not allow to push this reaction frame from outside, rather each action has equal and opposite reaction from there, what will happen, ones it applied these reaction here, it will take it, then it will plate will settle with your opposite action.

Then, at this particularly in this plate, as I say, two dial gauges has been provided or placed, at the opposite of this plate. Here dial gauge one, here dial gauge two. So, this is just, I want to show it, how diagramically, how in figure it is clear. So, that you can visualize, what is this plate load test mean.

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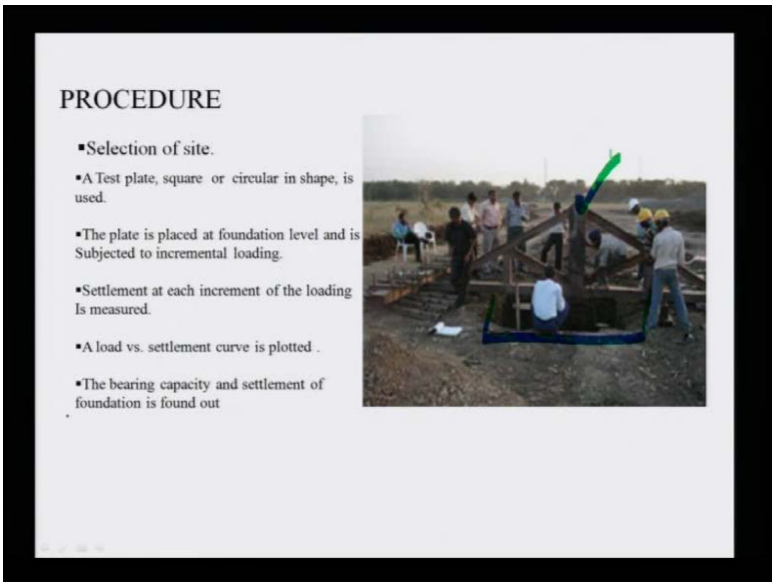

Now, look at this figure, in real field, there is loading platform, a pit has been made from here to here, pit has been made, and this is the loading platform, and this plate load test has been carried out the photograph, I put it directly.

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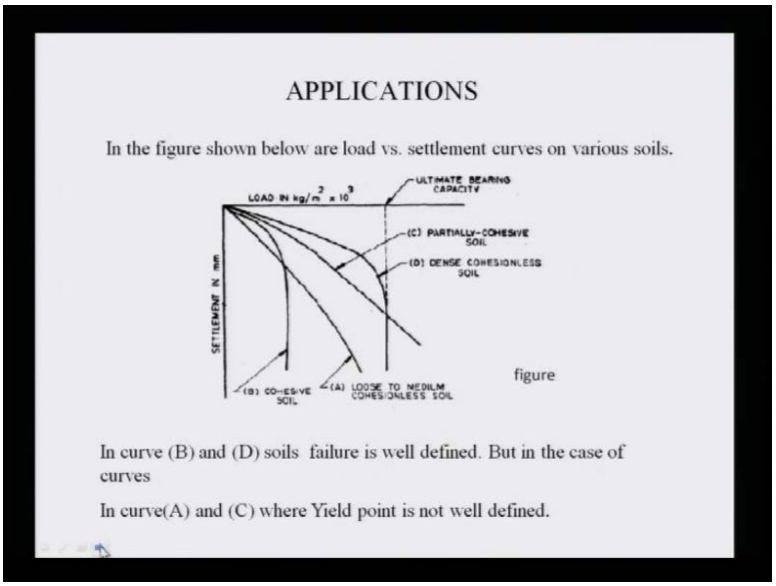

Then, this has been also discussed, what type of curve you are going to get, for cohesive soil, for medium soil figure, for this tense soil, what type of, you are going to get.

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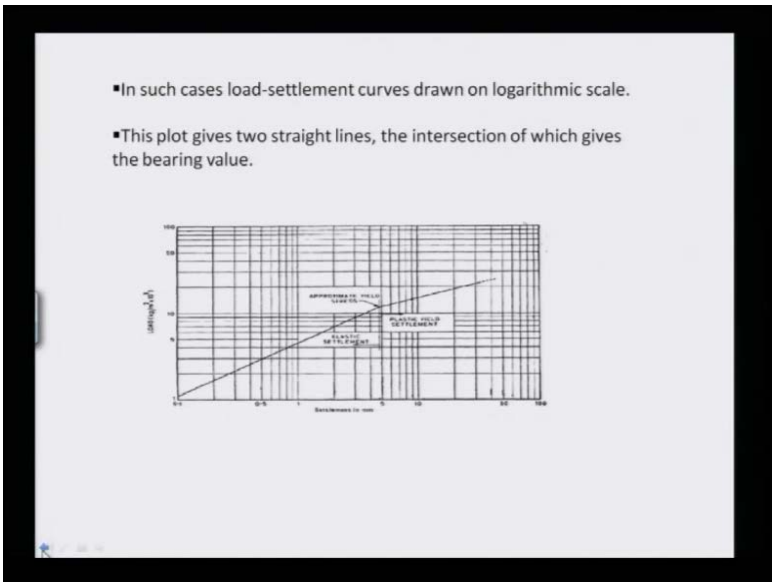

If I plot, now come back to here.

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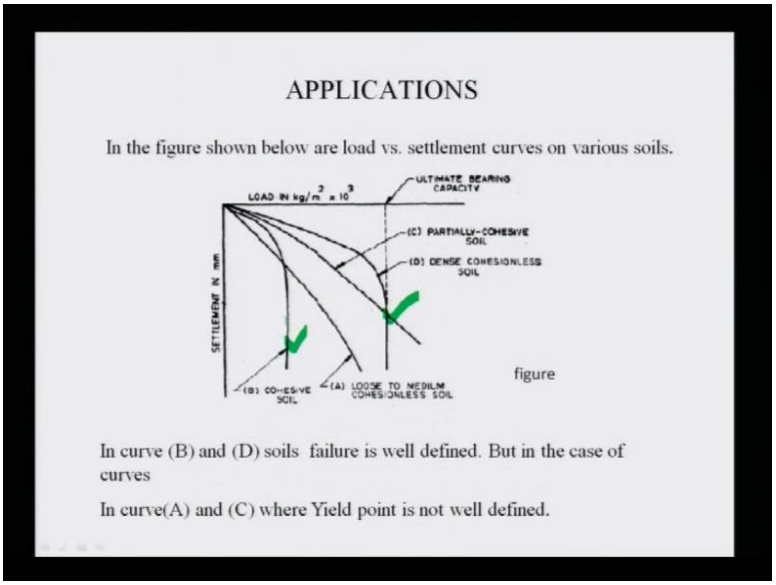

If you look the load versus settlement diagram or this, if this kind of curves are there, where you can get failure load easily.

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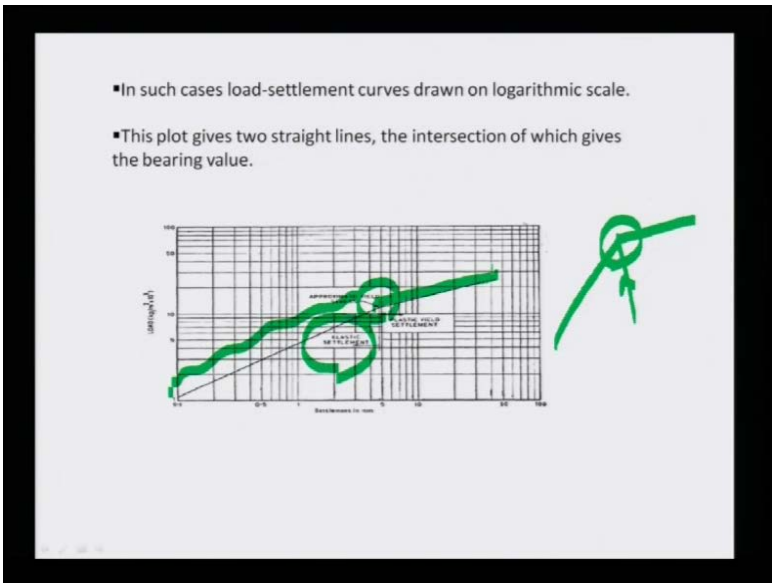

In that case, if I draw in log log plot, definitely there will be a illustrate, you get it directly. The curve in log log plot, it will go in this way, you will get one yield point or may be a point, where the failure load is observed, you can get directly. So sometimes, it is said, in this approximate yield stress, beyond this it is called elastic settlement, from here to here, it is called elastic settlement. Beyond means, before this yield stress, it is elastic settlement. Beyond yield stress, this is called plastic yield settlement.

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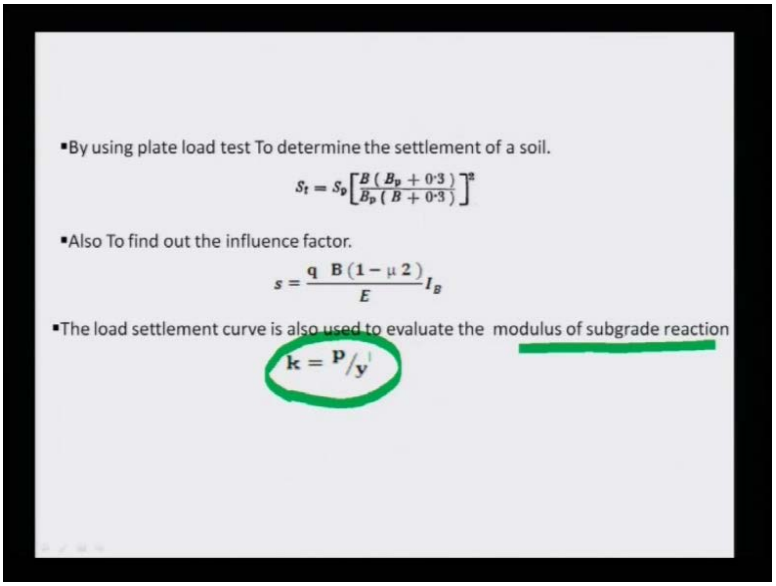

Now, as I said, using plate load test, you can find it out, settlement of soil, or also you can get influence factor. Another one is your, load settlement curve used to evaluate modulus of sub grade reaction means, k value you can find it out, p by y. From this, you can find it out, modulus of sub grade reaction.

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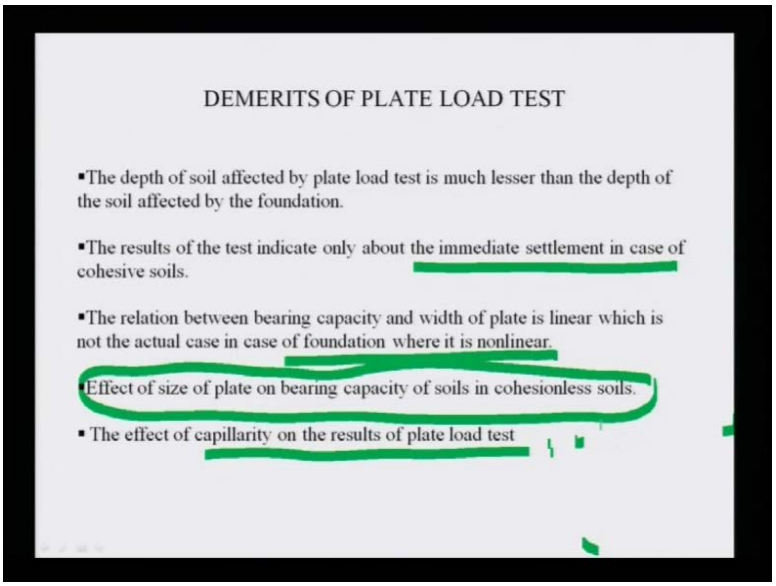

What are the limitations, this part I am not discussed. What are the limitations in plate load test, the limitation is depth of soil affected by plate load, much lesser than depth of soil affected by foundation. If I say, this is my plate. So, depth only affected by very small area, and this is my footing. That means, it is affected by much larger area.

Then results of the test indicate only about immediate settlement, relation between bearing capacity and with a plate is linear, which is not the actual case, in case of foundation, where it is nonlinear.

Effect of size of plate on bearing capacity of soil in cohesionless soil, this is called scale effect. Then effect of capillarity on the result of plate load test. These are all limitations.

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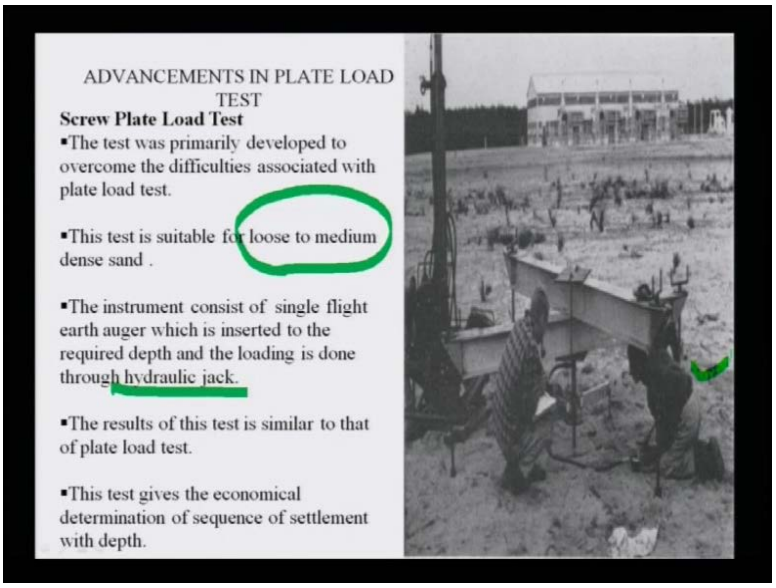

That is, another test it is called screw plate load test. This test was primarily developed to overcome the difficulties, associated with this plate load test. The test is suitable for loose to medium dense sand. The instrument consist of single flight earth auger which is inserted to the required depth, and the loading is done through hydraulic jack, you can see it here.

The results of this test is similar to that of plate load test. The test gives economical determination of settlement with depth.

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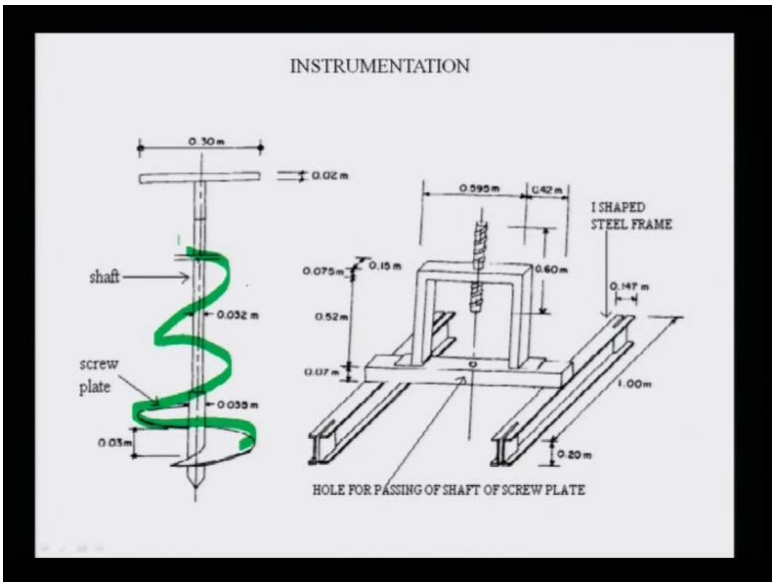

Look at here, screw plate, a plate it is screwed, it is put in a shaft, so it has been posed. Then the plate load test has been done, by means of the procedure, earlier procedure for regular plate load test, same procedure has been applied. Here the settlement observed is more accurate.

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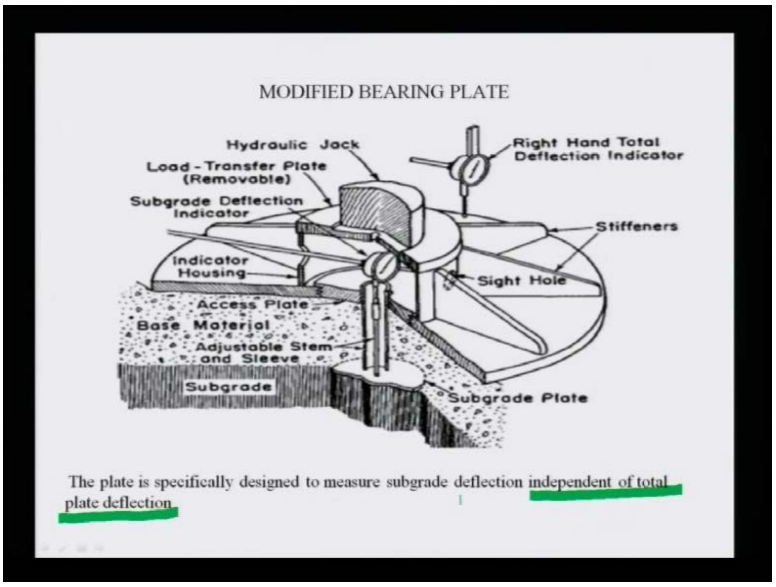

This plate is specifically designed to measure sub grade deflection independent of total plate deflection. Look the difference, it is specially designed to measure the sub grade deflection which is independent of total plate deflection.

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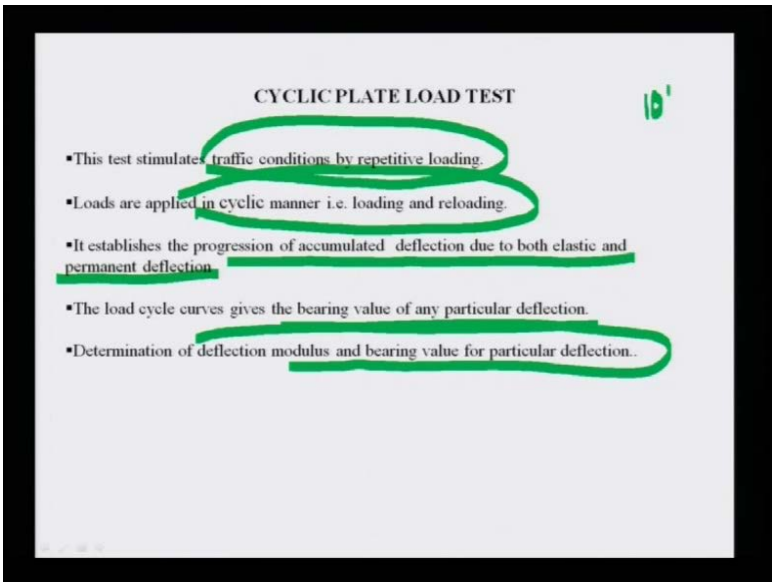

Then, next question is, with this plate load test, will it be possible to conduct a cyclic plate load test? Yes. Generally, cyclic plate load test is required to simulate traffic condition by repetitive loading. Load are applied in cyclic manner, loading and reloading. That means, first set of load whatever you applied in plate load test.

In next step, instead of applying, second increment of load, you can reloadimg. Then again you apply your, after reloading, you apply your second increment of load, it establishes the progression of accumulated deflection due to both elastic and permanent deflection. The load cycle curves gives the bearing value of any particular deflection, and determination of deflection of modulus and bearing value for particular deflection, you can find it out.

Why this cyclic plate load test is required, if somebody will ask? It basically to simulate the traffic condition by repetitive loading.

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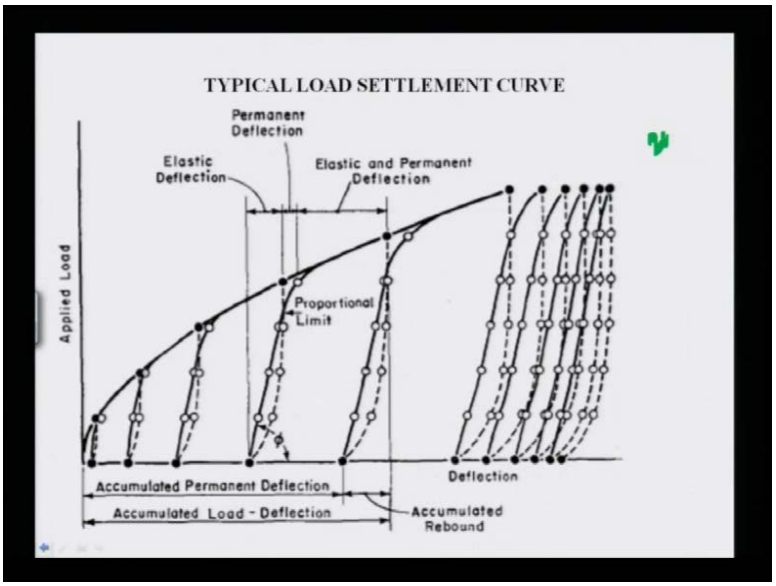

So, second step is, loads are applied in cyclic manner. That means, suppose in plate load test initially you applied, first load is ten kg per c m square, second is your twenty, third is your thirty, then forty. If you apply like this, ten, twenty, thirty, forty kilo newton per centimeter square or k g per c m square.

If you apply, what generally happen in general plate load test. First we apply ten, then we wait, the rate of settlement. Then again, we increase the second increment twenty, then

we wait, till the settlement become is equal to zero point zero one m m per hour. Then apply third, fourth increment like this, but in cyclic plate load test you first apply ten. Wait, till your settlement two become constant or less settlement occur. Then after that, you immediately unload. Unload means ten kilo newton, you immediately take out. Ones you take it out, the next step you apply, twenty kilo newton, again unloading. Then you proceed in this way.