Foundation Engineering
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Module - 03
Lecture - 05
Field Tests

Hello viewers, welcome back to the course on Foundation Engineering. In the last class, I was discussing about the Field Test, for the geotechnical engineering.

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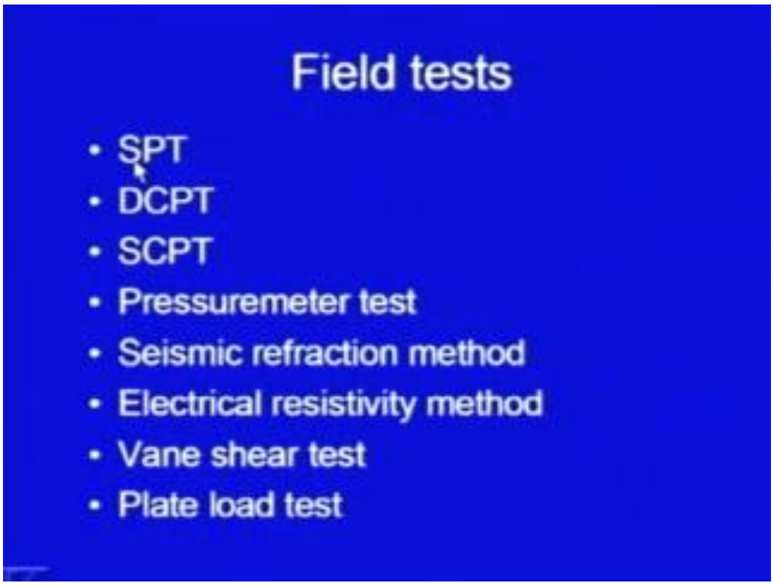

We have already discussed standard penetration test, dynamic cone penetration test, static cone penetration test, pressure meter test, seismic refraction method. And today, I will complete, I discuss these three tests, electrical resistivity method, vane shear test and finally, the plate load test.

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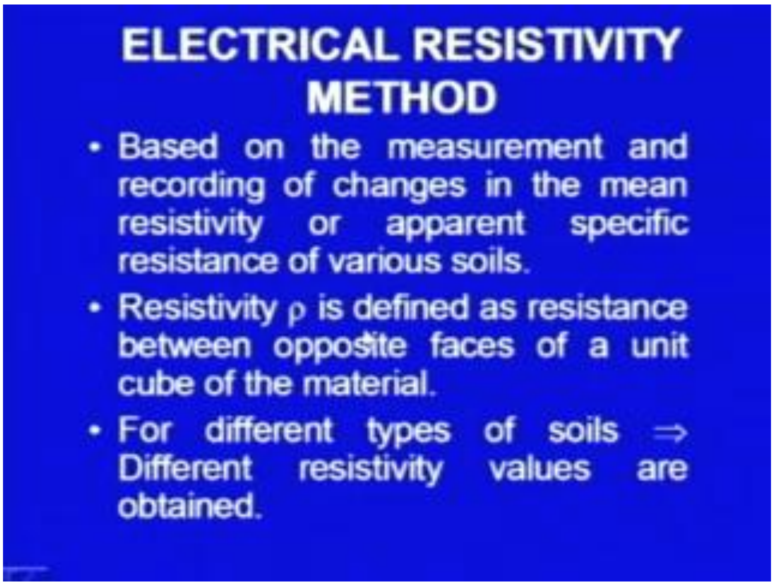

Let me start with the electrical resistivity method as is clear from it is name resistivity, the method is based on the measurement and recording of changes in the mean resistivity of various soils. The resistivity is defined as resistance between opposite faces of a unit cube of the material and the basic philosophy of the test is that, for different types of soils, different resistivity values are obtained. And these resistivity values are then correlated with the soil properties and soil types.

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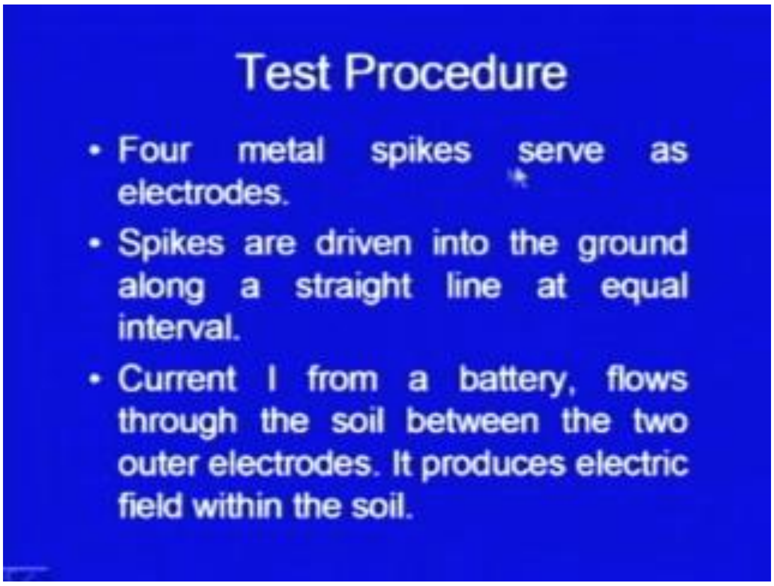

The test procedure consists of four metal spikes and these spikes will be serving as electrodes, these spikes are driven into the ground, along a straight line at equal interval and then current I; is allowed to flow through the soil between the outer electrodes.

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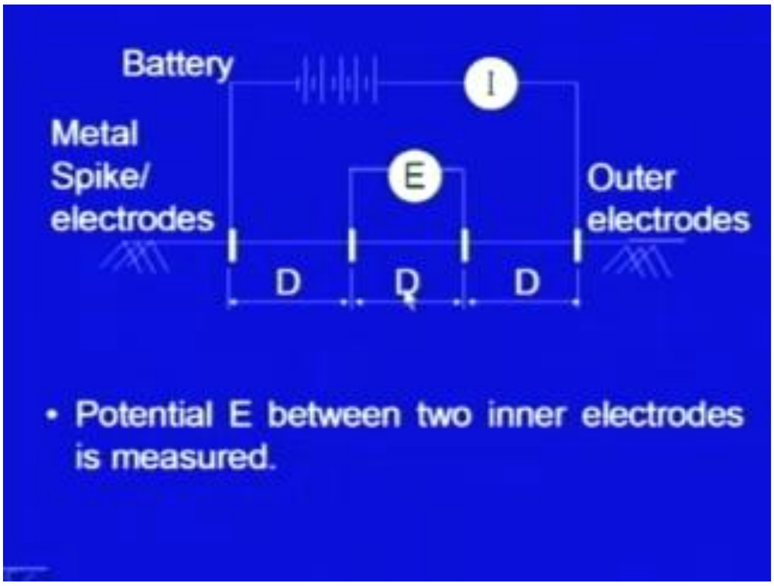

Here is the schematic diagram, this is the ground level and here are outer electrodes, this one, this one and then inner electrodes and in between these outer electrodes using a battery a current I; is allowed to flow. By doing this, there will be a potential E between the inner electrodes, this is the potential A between this these two inner electrodes and this potential E is measured.

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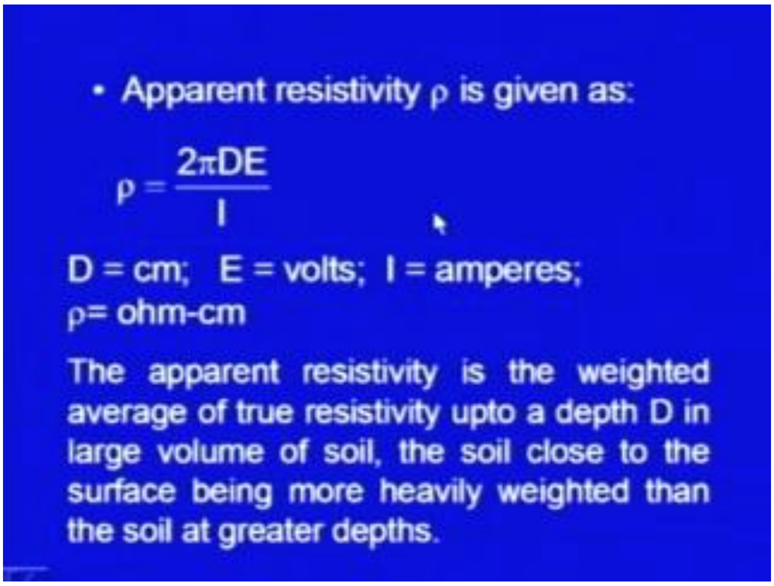

Using this measured value of E, D and I, then the apparent resistivity, it is apparent not the true resistivity, it is defined as row equal to 2 pi D E upon I, where D is in centimeters, E is in volts, I is in amperes and the apparent resistivity will be in ohms centimeter. It may be noted, that this apparent resistivity is the weighted average of true resistivity up to a depth D in the large volume of soil and the soil which is close to a surface, it is being more heavily weighted, than the soil at the greater depth.

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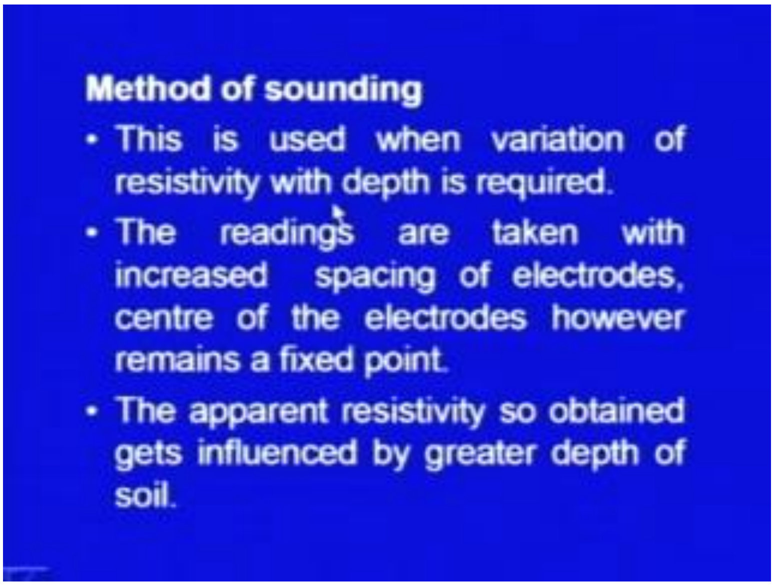

Now, this value is then, used to find out the soil types and there are two ways, first is method of sounding, this method is used when variation of resistivity with depth is required, we need the variation with the depth. In this case, the readings are taken with increased spacing of electrodes, centre of the electrodes; however, remains a fixed point. So, we keep the centre at a fixed point and we keep on taking we keep on increasing the spacing.

And then, corresponding to those spacing’s, we take the values we take the readings, the apparent resistivity, so obtained gets influenced by greater depth. In fact, so when you increase the spacing of the electrodes, the soil mass which actually affects the resistivity, it is more and more depth will be coming into picture. Now, if the resistivity increases with increasing spacing, this indicates that deeper stratum, which now comes into picture has higher resistivity.

As I told you, as we increase the spacing more depth will come into a picture and if the value is increasing; that means, those soils which are at greater depth, they are having higher resistivity values. Similarly, F with increase in spacing, the resistivity is found to decrease; then it will indicate that the underlined stratum, which has started now influencing the apparent resistivity, has low value.

So, we take different values, we keep on increasing the electrodes spacing and those resistivity values are plotted. This is a typical curve, which is obtained and as you can see the curve becomes asymptotic to true values R 1 and R 2 are the true values of resistivity, it may be noted that, it is plotted the graph is plotted on log-log scale. Now, the curve as I told you becomes asymptotic to the true resistivities R 1, R 2 and then approximate thickness of the layers may be obtained by comparing the plots with the set of standard curves.

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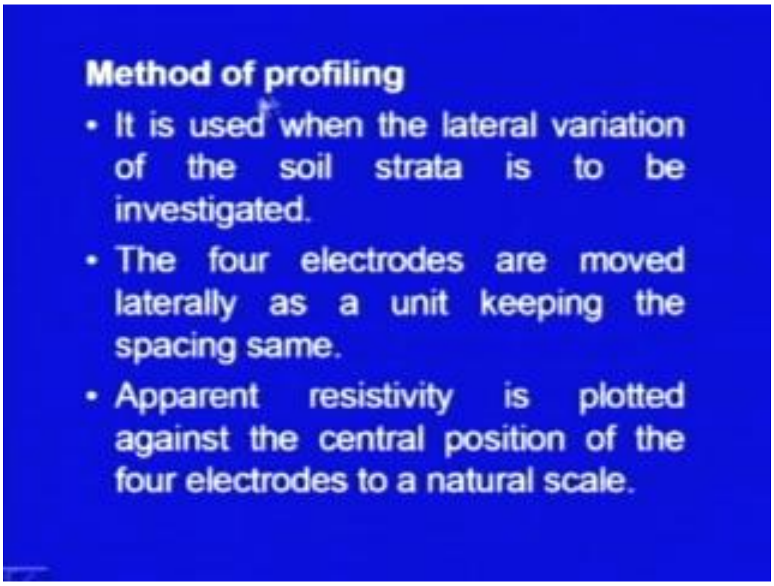

In case of the method of profiling, the method is used when the lateral variation of the soil strata is to be investigated. So, here what we do is, the four electrodes, they are moved laterally as a unit keeping the spacing same, so this time we keep the spacing same and we move all the four electrodes laterally and apparent resistivity values are recorded. Then, those apparent resistivity values are plotted against the central position of the four electrodes to a natural scale.

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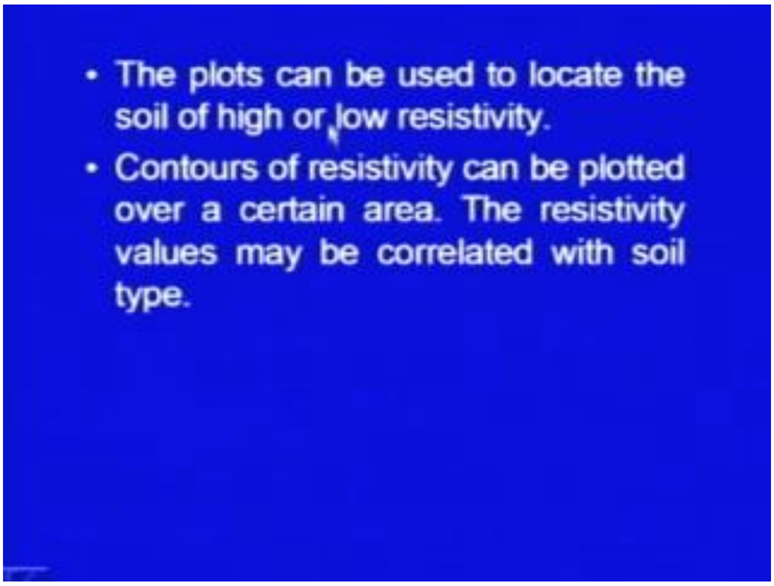

These plots; then can be used to locate the soil of high or low resistivity and then also one can plot the contours of resistivity and these resistivity values, then can be correlated with soil type.

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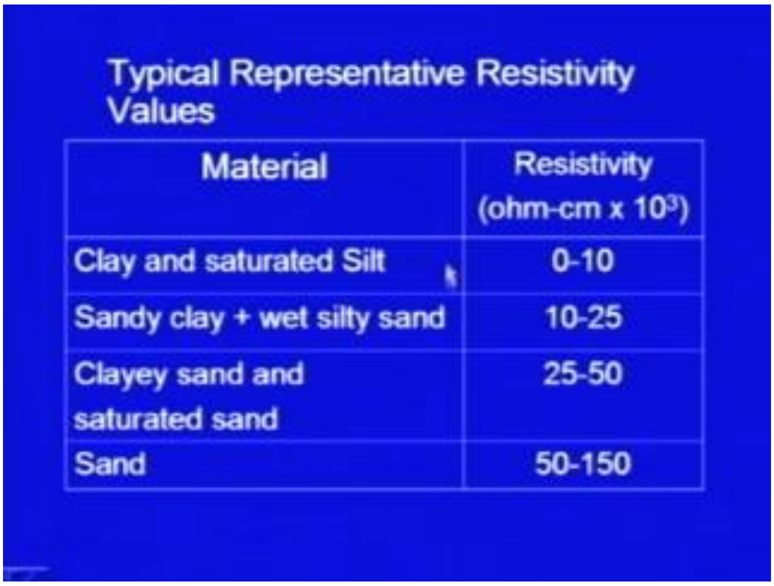

Here are some typical values, using these values, one can roughly assess the kind of the soil which is existing; for example, for clay and saturated silt the resistivity is between 0 to 10 into 10 to the power 3 ohms centimeters. For sandy clay and wet silty sand, this value is this coefficient is 10 to 15 for clay sand and saturated sand the value 25 to 50 into 10 to the power 3, for sand it is 50 to150.

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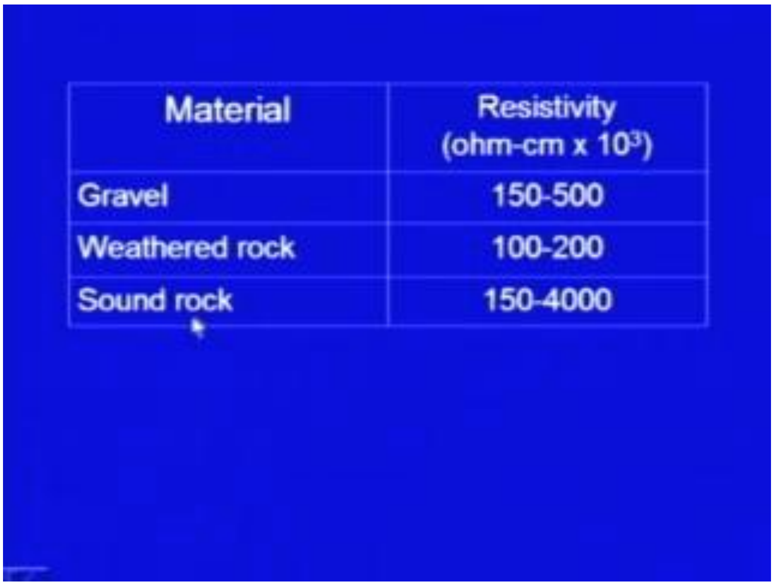

For gravels this is 150 to 500 for weathered rock it is 100 to 200 and for sound rock it is 150 to 4000 into 10 to the power 3. So, these are the values, which you can use to correlate with the observed resistivity values.

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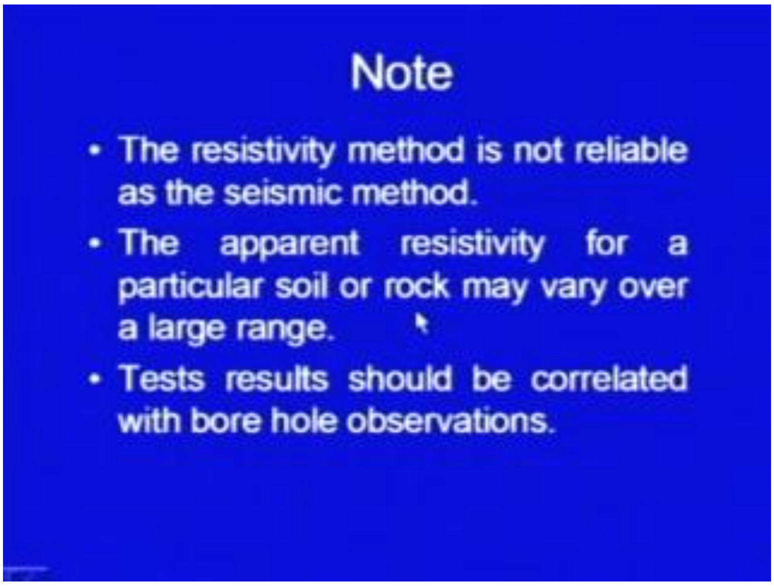

Here, I would like to put a note, that the resistivity method is not very reliable method; the apparent resistivity for a particular soil may vary over a large range. And therefore, these test the test results should be correlated with some other test for example, borehole observations, so that was the first test.

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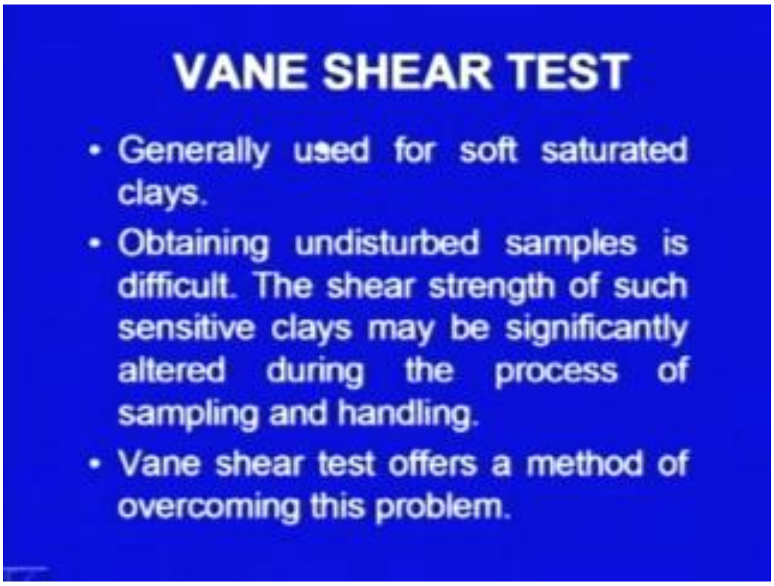

Now, let me come to the next test, it is called as vane shear test, this test is generally used for soft saturated clays, what happens in case of the soft saturated clays, if you remember we have been discussing that in case the clays, you can take undisturbed sample. But, if the soil is very soft if the clay is very soft it will get disturbed, so undisturbed sampling is very difficult.

So, in that case, this test vane shear test is a method which can be used in the field to find out the shear strength of clay soil, here is the diagram of the vane shear test.

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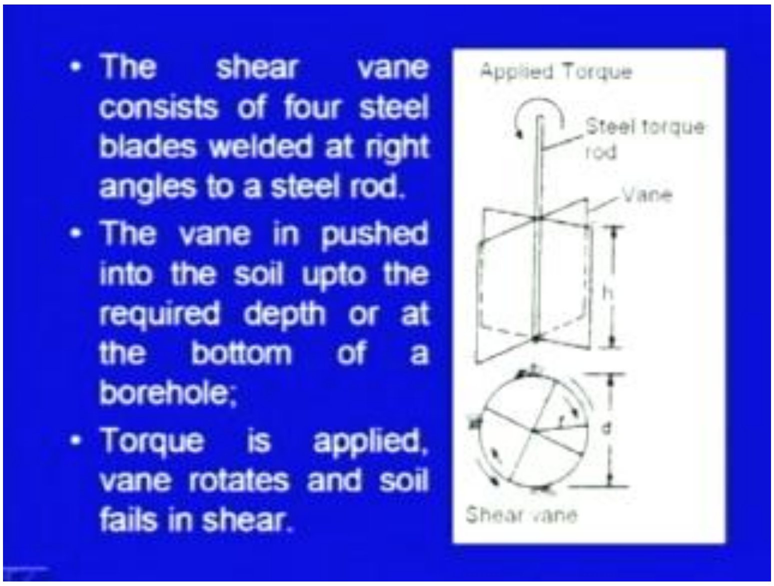

This vane shear, these are the vanes, it is it consists of four blades, first, second, third and fourth, these are the four blades and these blades are welded to a rod. And this vane is then pushed into the ground into the soil up to the required depth or at the bottom of the borehole. And then, at the top here, a torque is applied and there is an arrangement, which can measure the torque.

So, torque is applied and the vane will rotate and here at the periphery the soil will fail and this soil fails in shear and the torque can be related to the shear strength.

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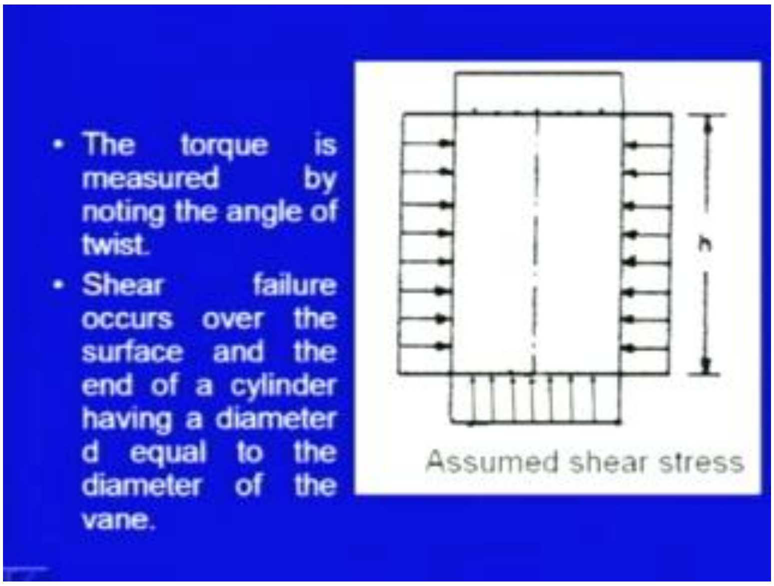

Here, it is the diagram of the assumed shear stress variation; these are the vanes here, the section of the vanes. So, it is in plan it will be a circle of diameter d, it is the elevation here the h is the height. So, torque is measured by the arrangement which is available at the top and then shear failure occurs at the end of the cylinder having a diameter d equal to the diameter of the vane. So, this is the cylinder which is shown here and one can correlate the shear strength using these expressions.

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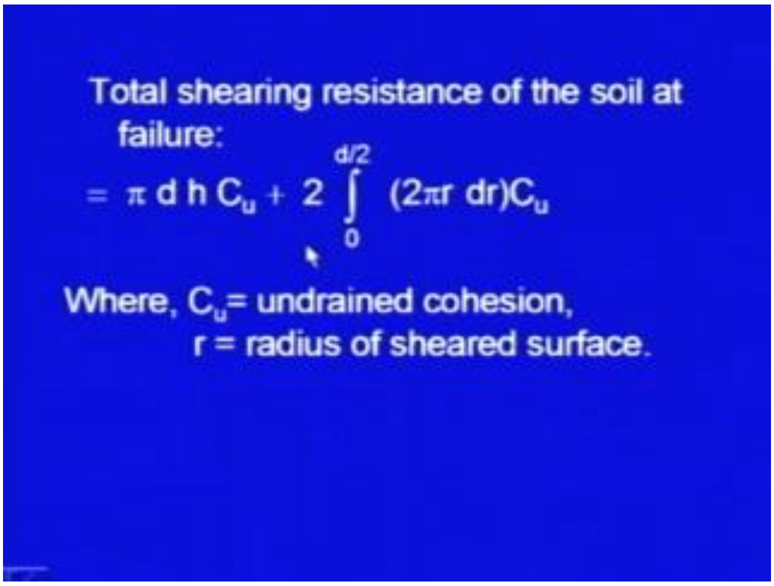

Total shearing resistance of the soil at failure will be equal to, it would take along the periphery of the cylinder phi into d; this is the perimeter into h, so this becomes the surface area into C u, C u is the undrained cohesion. So, this is the force which is acting along the periphery of the cylinder and 2 times, this is the force which is acting at the top.

So, 2 phi r d r, in fact we are taking a small stripe of radius d r and radius r and thickness d r, so 2 pi r d r will be the area of that stripe and it is multiplied by unit cohesion. That gives you the shear strength, at the top and it is done it is calculated 2 times that is for the bottom. So, C u is the undrained cohesion and r is the radius of the sheared surface and if you calculate the moment of the total shear resistance about the centre, that will be equal to the torque.

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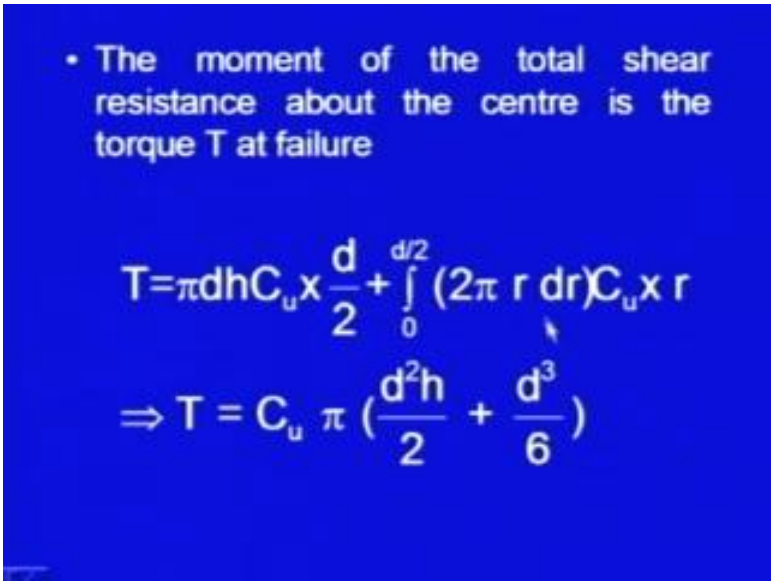

So, torque will be equal to phi d h C u, this was the force and this multiplied by radius d by 2 plus and this again this force multiply by radius and it is integrated over the radius that is 0 to d by 2. Finally, we will be getting this expression T is equal to C u into pi d square h upon 2 plus d cube upon 6, so if you know T, you know d h, you can calculate C u.

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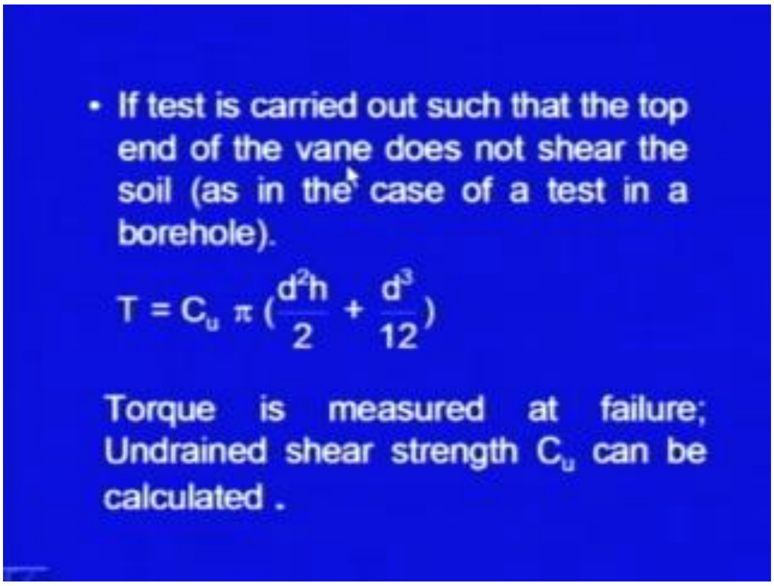

If the test is carried out in such a way, that the top end of the vane does not shear, for example, many a times will be doing it at in the borehole. So, may be at the top will not be shearing, in that case, that coefficient 2 will not be coming here, so only the bottom will be shearing. So, T will be equal to C u into pi d square h upon 2 plus d cube upon 12.

So, this is the basic equation for this case and torque is measured in the field, as I told you torque can be measured, there is an arrangement at the top using which you can measure the torque. And once that torque is available, you can calculate the C u from the dimensions and from this equation.

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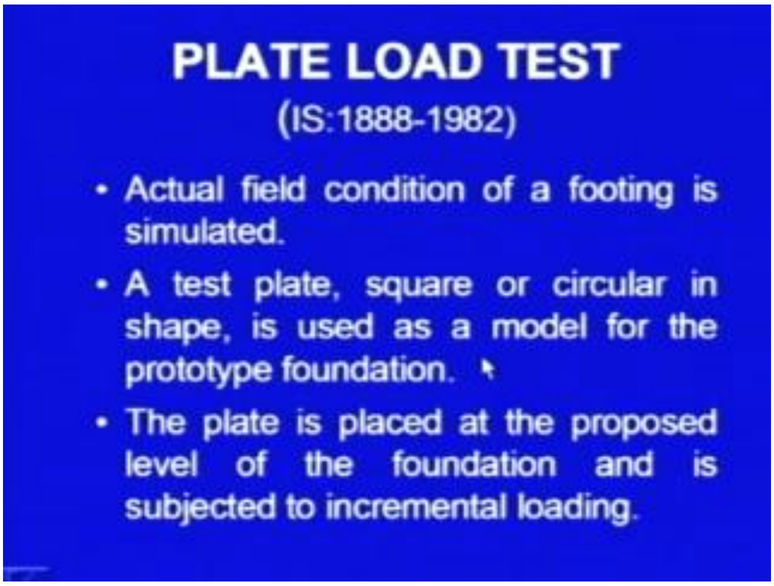

So, this was the second test and now let me come to a very, very important test, the plate load test. This is a very important test especially for the sandy soils, as I told you in the beginning, in case of the cohesion less soils, it is very difficult to get the undisturbed samples, you cannot get it; so we have to rely on the field test. So, this is a very important field test for the cohesion less soils and in this test, the actual field condition of a footing are stimulated, we try to do the same thing as actual footing does in the field.

What it does is, that it applies load on the foundation, there are settlements. So, we try to stimulate those conditions. So, here a test plate, which is square or circular in shape is used as a model for prototype foundation, so the foundations may be rectangular foundations may be square. We will be using a test place, which will be stimulating the foundation.

And the plate is placed at the proposed level of the foundation, wherever the foundation is purposed to be kept, this plate is placed at that level and then it is subjected to incremental loading. Like, it in case of actual foundations also, the foundations get incremental loading as the construction proceed; the loading increases.

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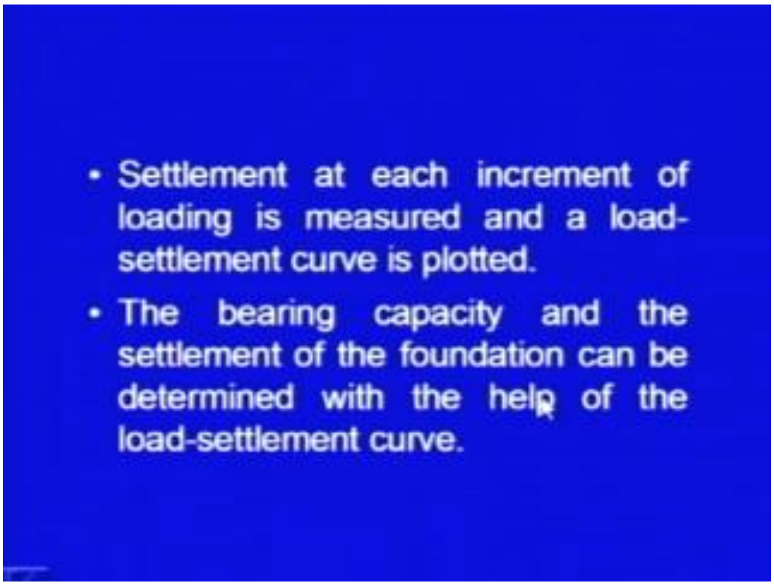

Then, settlement at each increment of loading is measured and a load-settlement curve is plotted, so this is the basic thing. We will be measuring this settlement using some dial gauges and those settlements for every incremental load we will be measuring and set and then load-settlement curve will be obtained. Then, the bearing capacity and the settlement of the foundation can be determined with the help of this load settlement curve that we shall discuss; how we do it.

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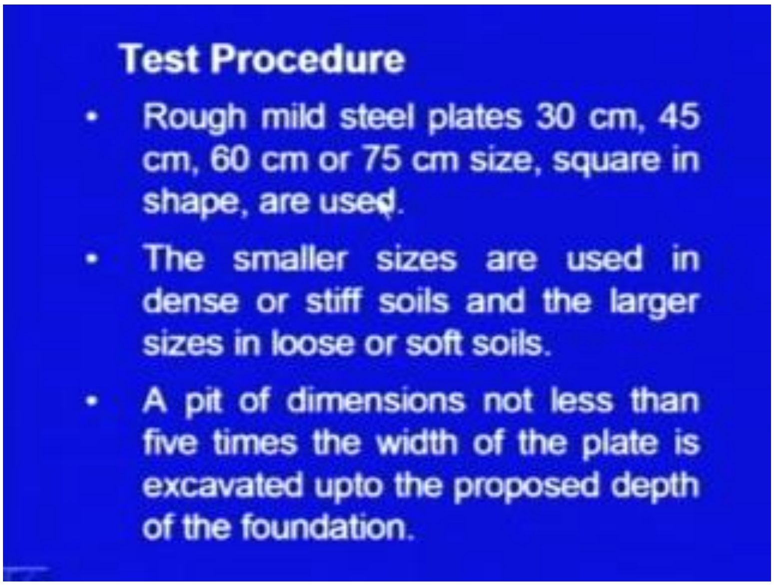

Here is the test procedure as per the specifications a rough mild steel plate and these are the sizes, standard sizes which are recommended, one can have 30 centimeter 45 centimeter 60 or 75 centimeter size, they are used. The smaller sizes are used in dense or stiff soils and in case the soil is loose or soft, it is better to use a greater size or small.

The smaller size, you can use for a stiff soil and for dense, dense means, it is the bearing capacity will be high, stiff soil means you have to apply much more load to make the soil fail. So, in those cases, you can use smaller sizes and larger sizes, when the soil is loose or soft.

Thirdly, a pit of dimension not less than 5 times the width of the plate is excavated; this is the usual procedure and specified procedure. That a pit is made and the dimensions of the pit are at least 5 times that of the plate and the depth of the pit will be the same as the proposed depth of the foundation.

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Here, I have shown a photograph taken of a pit, this is a pit here and in this vertical direction is the depth. So, this pit is excavated and here we will be doing that test at the bottom.

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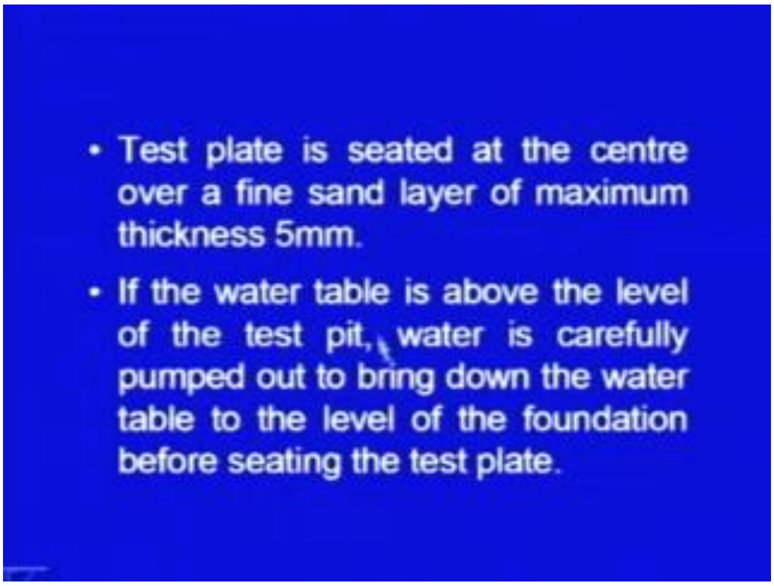

Now, the test plate is seated at the centre over a fine sand layer of maximum thickness 5 millimeter. So, let me go back to this photograph, here you will find that the layer, the surface is not even, then what we do is, we sprinkle some sand here, a layer of 5 millimeter, half a centimeter sand layer is placed there and test plate is seated on that sand layer.

Now, this is an important point, if the water table is above the level of test pit, then water is carefully pumped out to bring down the water table to the level of foundation, before seating the test plate. So, if the water table is above, you have to this arrangement has to be made and water has to be pumped out.

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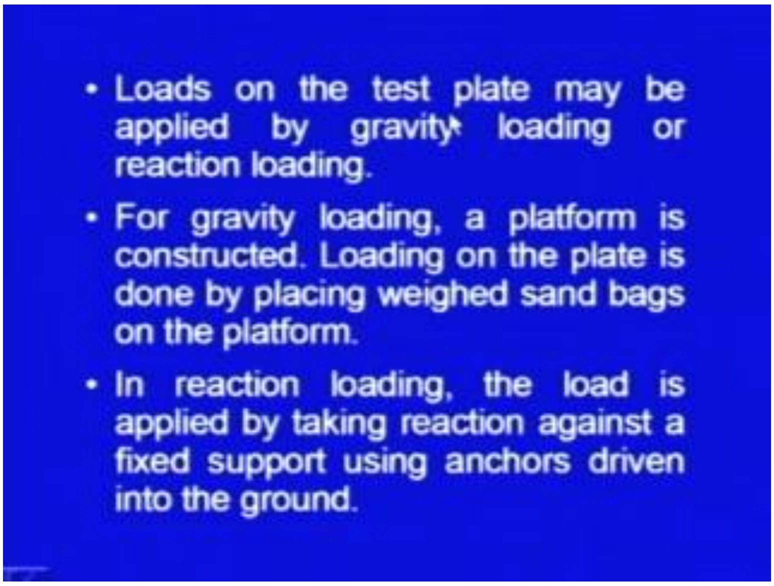

The loads on the test plate, as I told you what we are going to do is, we are going to stimulate the actual field conditions, in actual field the foundation is subjected to incremental loading. So, loads on the test plate have to be applied and we can have two types of the arrangements to apply those loads. The first kind of the arrangement is gravity loading and second kind of the arrangement is reaction loading.

Gravity loading, it is clear from, it is name means, it is deriving the force out of gravity, out of it is weight. So, what is done is a platform is constructed and on that platform generally sand bags are placed, using this sand bags, the loading there will be weight on sand bags using which the load can be applied. In the second case, in case of reaction loading there is no platform, in fact a frame is there and load is taken load is applied by taking reaction against a fixed support using anchors. So, there we use the anchors, these anchors are driven into the ground and from there those anchors and using a frame, then we take the reaction.

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Here, it is a photograph which is showing the gravity loading, somewhere here there is a pit, it is going down; up to the proposed level of foundation and these are the girders. Cross girders are there; then planks are there, a platform has been made and on that platform, then sand bags are kept and using the weight of the sand bags, then we will be applying the load on the base on the plate.

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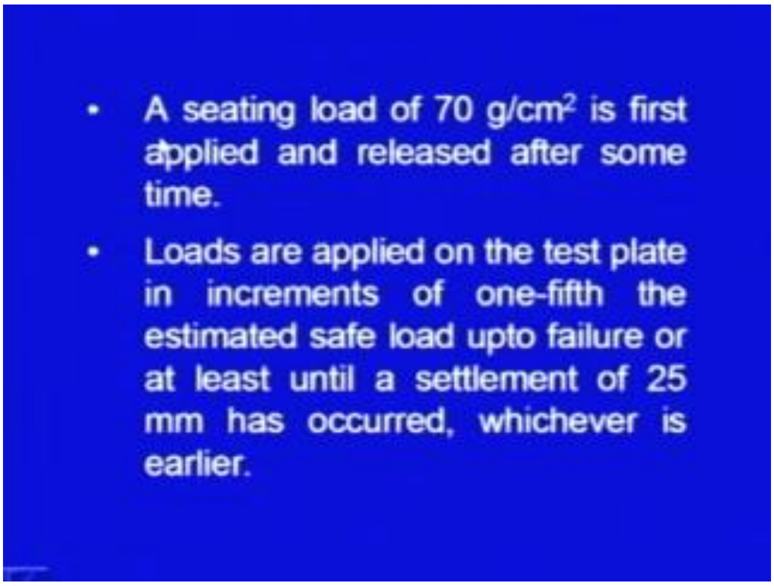

Now, next step is a seating load of, this is a specified value 70 gram per centimeter, this is the specified by the code, that before you actually start doing the experiment, some seating initial load has to be applied. So, a seating load of 70 gram per centimeter is first applied and then it is released after some time. Now, we start the actual experiments, the loads are applied on the test plate in increments of one-fifth the estimated safe load.

Say remembers here, roughly we will be having some idea about the safe load carrying capacity of that particular foundation. So, we try to do this thing, that approximately one-fifth of the estimated load, we calculate that value and increments are applied, the idea is that within 5 to 6 increments, you should be able to reach the failure. So, one-fifth of the estimated load is the incremental load and it is applied up to failure or at least until a settlement of 25 mm has occurred, whichever is earlier.

Generally 25 millimeter has been taken as the limiting value, that is 25 millimeter settlement has occurred and soil is not failing, you can stop the test. But, is not necessary, you can go further down, you can go for more settlements, depending on the soil strata.

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Here, I have shown, how we take the measure the settlements at the top somewhere here, the platform is there, this is a cross girder and here it is the loading ring. This is the dial gauge, which reads the loading ring to give the load and this is the spacer, this is hydraulic jack, using the hydraulic jack, the load is being applied. So, load will be derived from the dead weight or from, the reaction loading and here it is a plate and these are the dial gauges, we are using here at present 1, 2, 3, 4, 4 dial gauges are there.

So, as you apply load here as you using this hydraulic jack, as you apply load, this plate will settle down and corresponding to each load the settlement of the plate will be observed.

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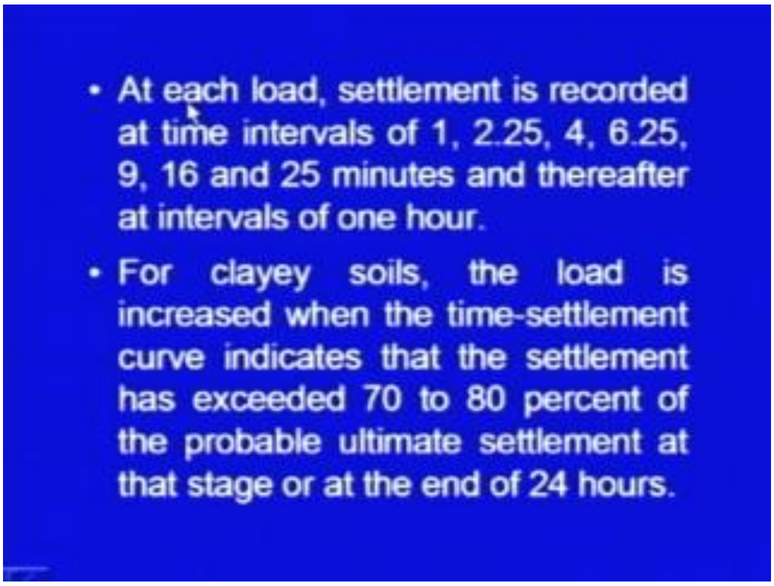

These are the specifications, that at each incremental loading, the settlement is recorded at a time interval of 1, 2.25, 4, 6.25, 9, 6 and 25 minutes. So, as soon as you apply the load, the settlement will start occurring. And you have to take the readings, generally just after 1 minute, then 2 minutes 15 seconds, 4 minutes, 6 minutes 15 second, 9 minutes, 16 minutes, 25 minutes and thereafter at an interval of 1 hour.

For clayey soils, the load is increased, when the time settlement curve indicates that the settlement has exceeded 70 to 80 percent of the probable ultimate settlement at that stage or at the end of 24 hours. If you are having a clayey soil, then we try to get, we must have some idea about the ultimate settlement and for that ultimate settlement, for that particular loading, it is a 70 to 80 percent value should have been exceeded.

So, we will be increasing the load, we will be taking the next incremental loading, when the load, when the time settlement curve indicates, we will keep on monitoring the like time settlement curve and we will increase the loading. When the settlement has exceeded, the 70 to 80 percent of the probable settlement at that stage or if it is taking too much of time more than 24 hours, then after 24 hours, we will take the next step of incremental loading.

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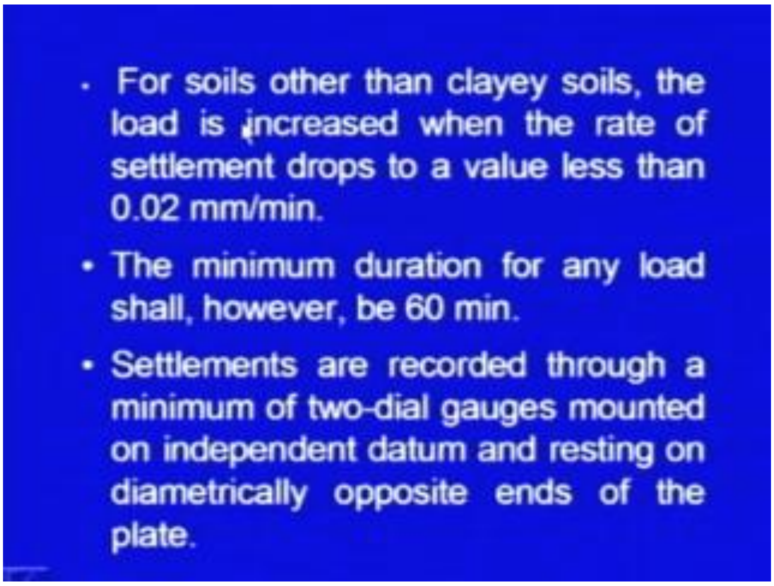

For other soils, other than clayey soils, the load is increased, when the rate of settlement drops to a value less than point 0 2 millimeters per minute. So, again we have to keep monitoring the settlement, we keep monitoring the settlement with time, how these settlements are changing with time. It will go on reducing and we have to wait, till the rate of settlement is very, very small and this is a specified value that the rate of settlement is less than point 0 2 millimeter per minute.

This means, for that particular incremental loading whatever settlement was expected that that has occurred. So, in case of the clayey soil, it may take lot of time and as we discussed earlier that around 70 to 80 percent of that probable settlement should have occurred and if, it is a sandy soil type of the things in case of the cohesion less soils it takes less time. So, we will be observing the settlement rate and when it is less than this, we take the next incremental loading.

The minimum duration for any load shall; however, be 60 minutes, this is for sandy soils, that yet one incremental loading, suppose you apply 1 ton load at least 60 minutes, you have to wait, so 60 minute is the minimum time. So, that whatever is settlement expected under this loading it occurs, the settlements are recorded through a minimum of two dial gauges mounted on independent datum and resting on diametrically opposite ends of the plate.

Now, the code specifies that at least two dial gauges should be there, but normally, we use more than two at least, we use normally four dial gauges are used and these dial gauges should be based on. It is look at here this dial gauge is based on this bar and this bar should be supported quite far away from the plate, so somewhere here, the other end is supported somewhere here.

The reason is that this particular soil mass here, when you apply the load, it is going to displace, it is going to the deformations are going to occur here, settlements are going to occur here and we need to calculate those settlements. So, the bases of this bar on which these dial gauges are mounted, it should be quite far away, so that settlements occurring here they do not affect. So, you get independent and actual settlement through the reading of the dial gauges.

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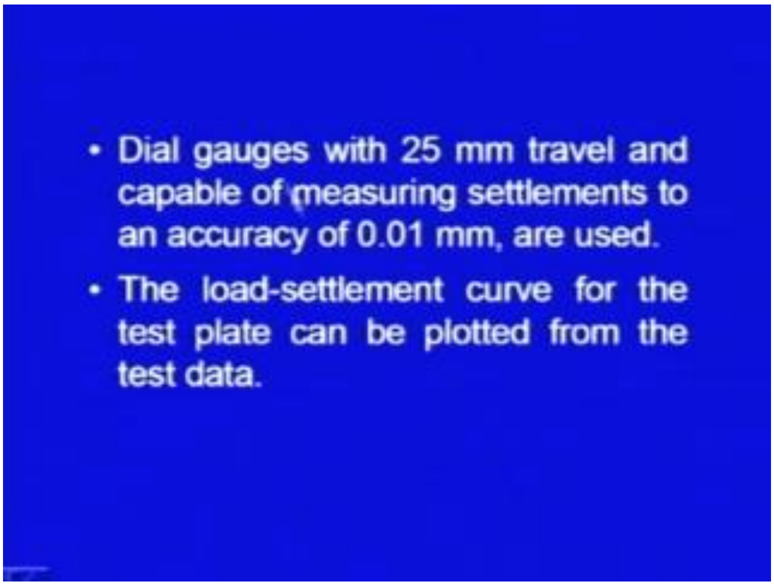

The dial gauges with 25 millimeter travel and capable of measuring settlements to an accuracy of point 0 1 mm is used. So, the important point is, we should measure the settlements to an accuracy of point 0 1 millimeter. This value can be more than 25 also and then from this test data the load settlement curve for the test plate can be plotted from this test data.

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Here is again, photograph of which is showing the arrangement here is the dead weight, these are the sand bags and through the weight of this sand bags, the loading is being applied and the test is being conducted at this place.

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load-settlement data

load	stress	D1	D-2	D-3	D4	S-1	S-2	S-3	S-4	S-av
0	0	43.75	45.52	39.15	48.3	0	0	0	0	0.00
0.25	2.778	42.3	44.95	38.45	47.75	1.45	0.57	0.7	0.55	0.82
0.5	5.556	40.58	41.19	36.55	45.8	3.17	4.33	2.6	2.5	3.15
0.75	8.333	36.8	37.35	32.55	41	6.95	8.17	6.6	7.3	7.26
1	11.11	31.35	34.7	28.85	36.58	12.4	10.82	10.3	11.7	11.31
1.25	13.89	28.85	29	23.28	31.12	14.9	16.52	15.87	17.2	16.12
1.5	16.67	23.45	24.52	18.35	26.6	20.3	21	20.8	21.7	20.96
1.75	19.44	14.35	15.3	10.6	17.5	29.4	30.22	28.55	30.8	29.74

Here is an example of load-settlement data, this is an excel sheet, here are the loads in certain unit, we took it in tons. So, 0 load, then 0.25 ton, 0.5 ton, 0.75 ton. Corresponding to this 0, load the dial gauge readings are 43.75, this is the second dial gauge reading, third dial gauge reading, fourth dial gauge reading. And then, we applied a small incremental load and then we monitored these data, those data is not shown here.

In fact, in the field, we take data at different times, as I told you at 1 minute, then 2.25 and so on. So, here the only the final readings are shown, when the settlements were complete and the system had stabilized, these are the final values for next incremental loading. So, 0.25 ton was the load and here it is the dial gauge 1 reading, dial gauge 2 reading, the reading of the dial gauge third and fourth.

So, we go on applying the incremental loadings, we wait we monitor these readings and final readings are reported here. So, it has gone from 43.75 up to 14.35, this dial gauge reading has gone from 45.5, 2 to 15.3, 39.15 to 10.6 and so on. Then, you can calculate the settlements, so corresponding to this reading, settlement of the first dial gauge is 0. The settlement of second dial gauge will be this is the initial reading, so 43.75 minus 42.3, this will be the reading here, this is the settlement of the first dial gauge.

And at the next incremental loading, the settlement will be this initial reading minus 40.58 this value, so this is here. Again at next 0.75 next incremental loading, the settlement is initial reading minus corresponding stabilized reading.

So, in nutshell, we can calculate these settlements of all the 4 or 3 or 2, whatever number of dial gauges you are having and then the settlement of the plate is taken as the average of these 4. For example this is 0, average of these four values will be this; average of these four values will be this and so on. So, here one thing you can note down, you can observe sometimes, what happens says in the field you may get some problem, some any one dial gauge may not work for sometimes. So, it is better you use more than two dial gauges and also you can all compare the values.

For example, let us see here this final values 29.4, this is 30.22, 28.55 and 30, so you can see all of them are nearly the same, if you finds some one value is extraordinarily deviating from the others then something wrong is there. So, taking using more number of dial gauges is very advantageous, so this is the final data, final settlement and here are the stress and then you can plot the curve.

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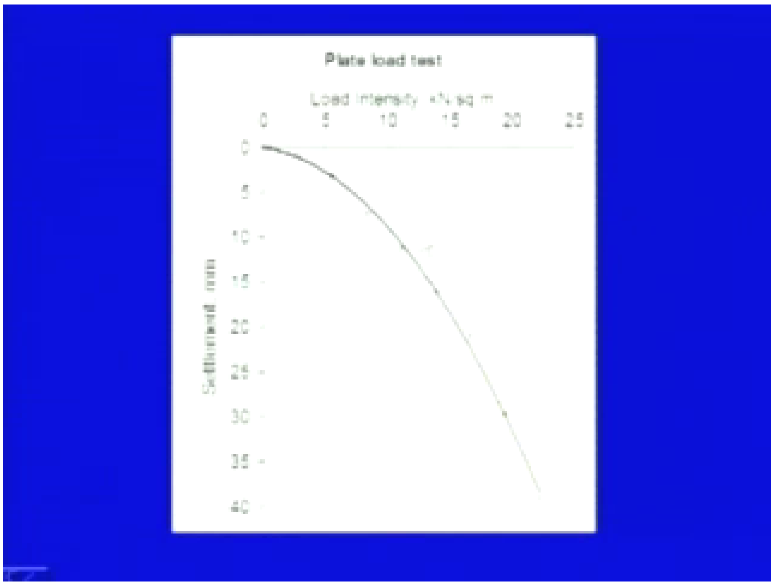

This is a typical curve on x axis, so we have kept load intensity, unit is can be for example, here it is kilo Newton per square meter or it may be in tons per square meter and so on. On y axis, we have taken the settlement, settlement is increasing in downward direction and these are the points and then you can draw a curve a smooth curve, which is showing, how the load intensity varies with the settlement for the plate.

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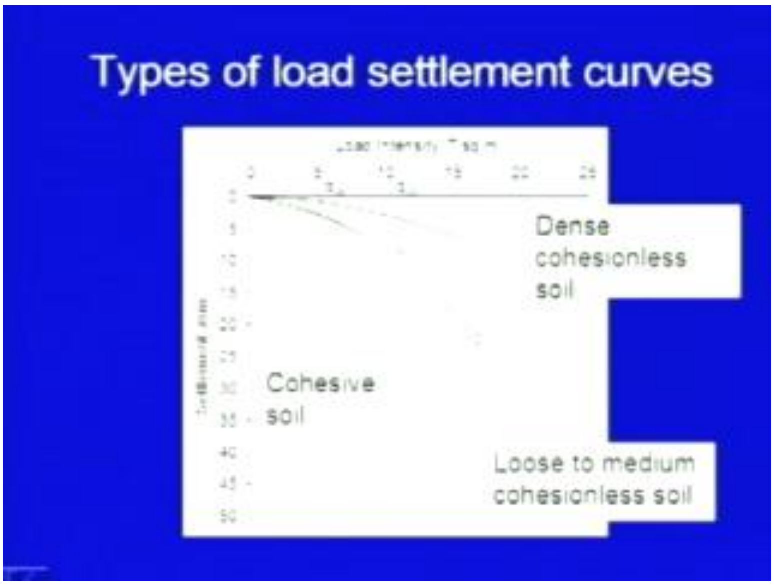

There are different types of the load settlement curves which you can get some of them I am showing here, this is the curve which is for dense; it is a dense cohesion less soil. So, dense means, it will be behaving almost elastically, so from here to here you can see it is almost a straight line. And then, there is a sudden change in the curvature of the curve, it shows that this soil has failed at this particular point.

So, there is a clear cut failure point here and this particular point, if you read, you can see here somewhere near little bit less than 20, this value gives you the ultimate bearing capacity of the plate. Here, it is a cohesive soil, in case of the cohesive soil, the settlement increases very fast and also there is no well defined failure point. Here, I have taken another example loose from medium cohesion less soil.

It is a loose soil, so again there is no clear cut, here you can see, in case of the dense cohesion less soil; it was kind of a brittle failure. So, similar kind of the failure point is not available here, the curve is gradually varying from one value to the other, this is a straight line portion and this is another straight line portion.

In such cases, we can estimate the bearing capacity of the plate, the failure point roughly by extending, this curve or you can draw a tangent on the straight-line portion here. Where, they intersect, we can assume this value to be the failure point, this method is called as double tangent method.

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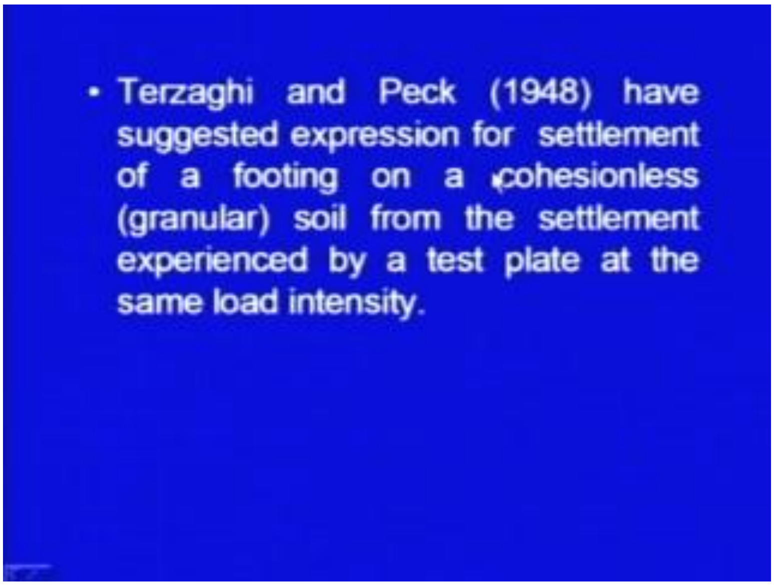

Let us now go to the method, how we can use these curves, which we have plotted. Terzaghi and Peck, they have suggested the expression for settlement of a footing on a cohesion less soil, from the settlement experienced by a test plate at the same load intensity.

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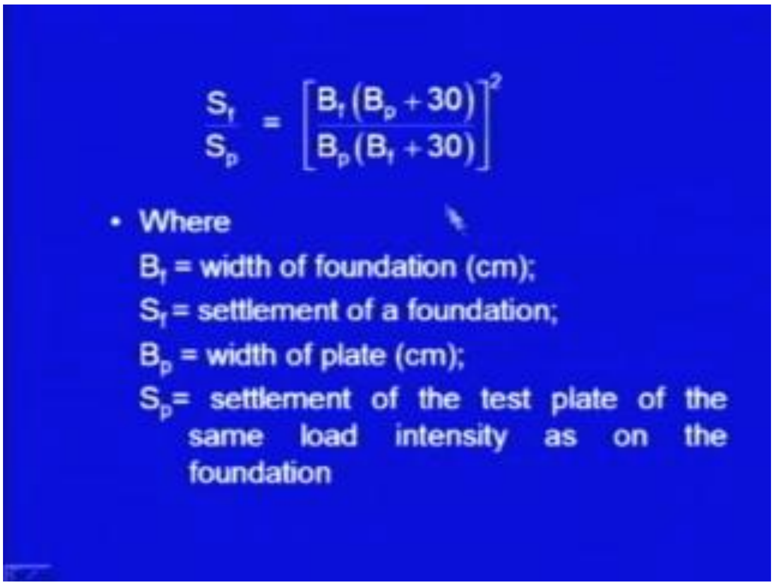

This is the expression; S f upon S p is equal to B f, B p into B p plus 30, B f plus 30 whole squares, this is the expression, which is suggested by them and very useful expression. The point which you have to remember is that the loading intensity should be same on the plate as well as on the foundations. Here, B f is the width of foundation, S f is settlement of foundation, B p is width of plate and S p is the settlement of the test plate, on the same load intensity as on the foundation.

So, using this expression, we can correlate the settlement of footing with the settlement of foundation, with the plate.

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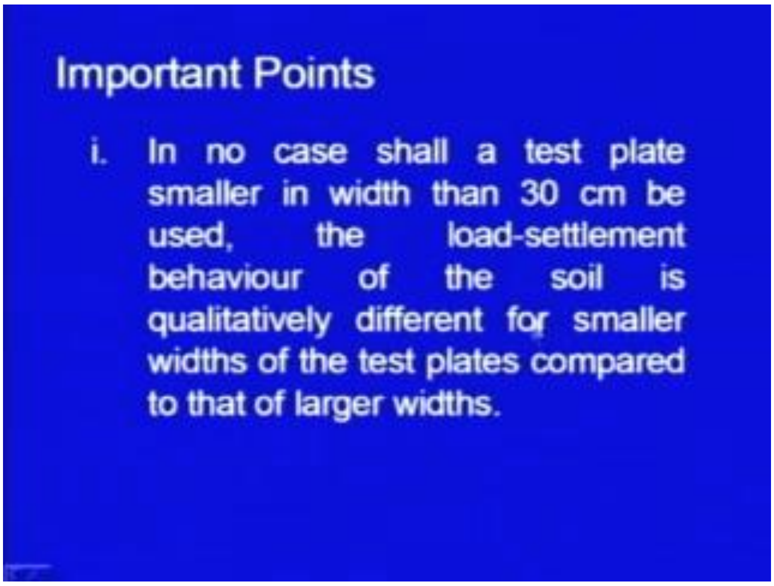

There are some important points which I should discuss before we take up some to explain this curve, in no case, shall a test plate smaller in width than 30 centimeter be used. So, it is an important specification, that the test plate should not have dimensions smaller than 30 centimeter.

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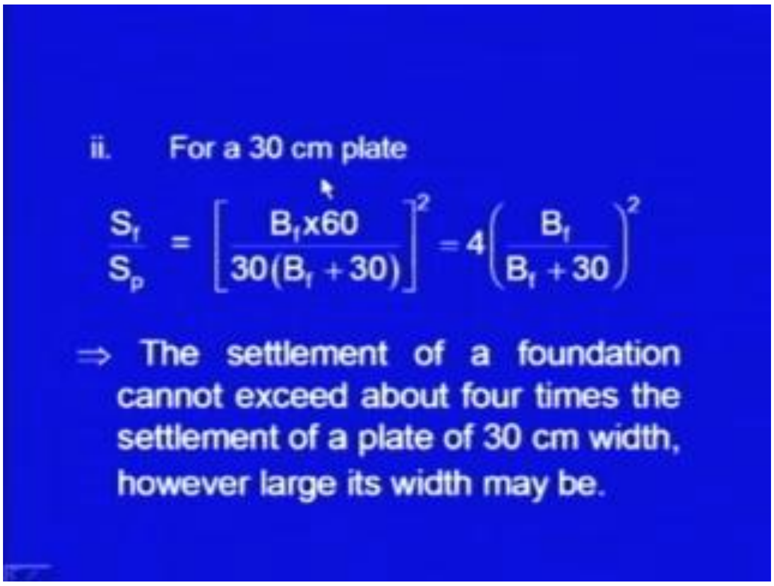

For a 30 centimeter plate, if I calculate S f upon S p, then putting B p equal to 30, you will be getting this expression. So, if you take a large B f value, so Bf is in centimeter Bf plus 30 this is the foundation width. So, this value will be approaching towards 1. So, what happens is this formula indicates that, if a very large value of footing is there, for that S f upon S p will approach towards 4, so S f will be equal to 4 times S p.

So, the settlement of a foundation cannot exceed about 4 times the settlement of a plate of 30 centimeter width; however, large it is width may width may be.

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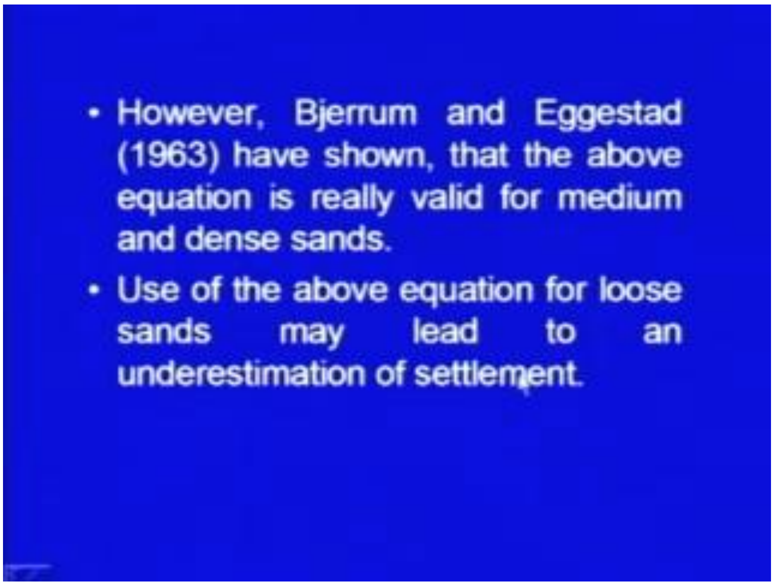

So, this is what this expression gives, but it has been observed, that the above equation is really valid for medium and dense sand. The use of the above equation for loose sands may lead to an under underestimation of settlement, so the important point is you have to be careful, when you use this equation for loose sands you are likely to get low values of the settlements.

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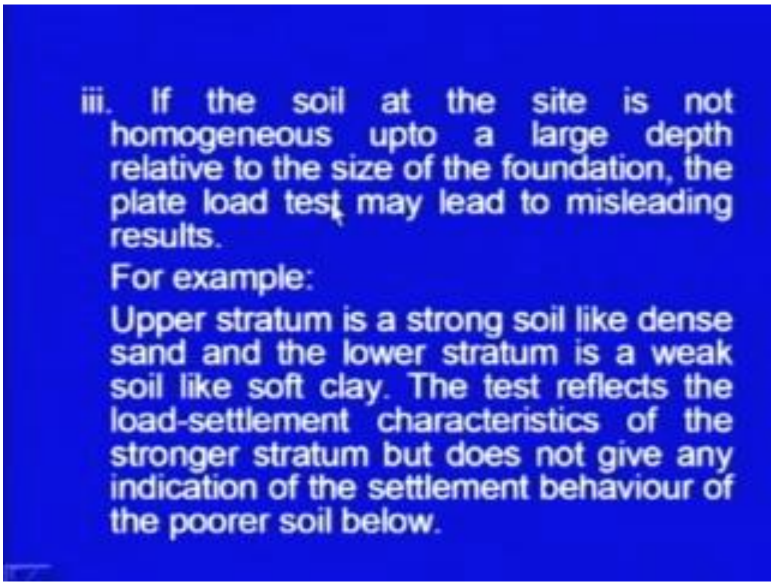

The third important point is, if the soil at the site is not homogeneous up to a large depth, relative to the size of foundation, the plate load test may lead to misleading results. What it means is that see, it is the plate size is around 30 centimeter or may be 45 centimeters and the footing size is let us say 1 meter or 1.5 meter. Then, the effective area which is governing the load settlement curve, the effective depth below the footing will be much larger as compared to that, which is there under the plate.

So, if it is the soil not homogeneous, if the characters are different, then you are getting the characteristics of this soil; which is only the depth is very small. For that depth, you are getting the characteristics, whereas in case of the actual foundations, the effect of the foundation the pressure of the foundation will go much deeper. So, it is, it may give you misleading results.

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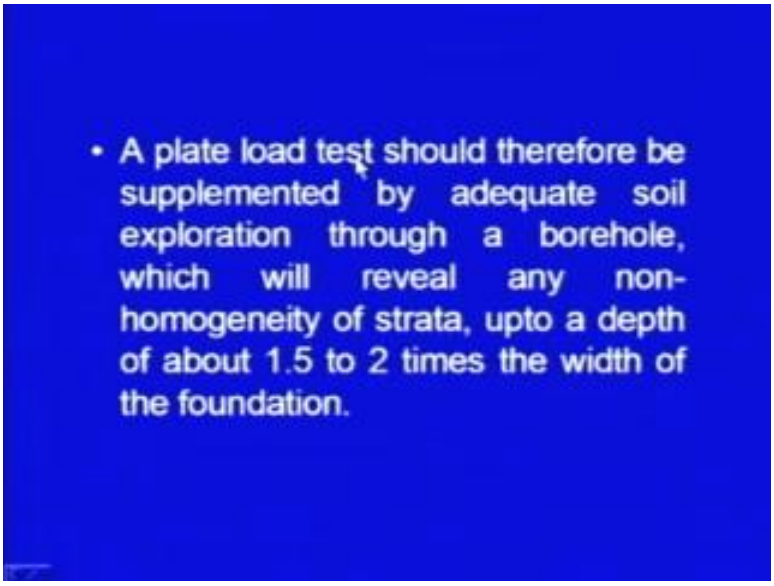

A plate load test should therefore, be supplemented by adequate soil exploration through a borehole, this is in fact, true for any field test, what we recommend is, you should not rely on one particular test, but there should be confirmation by different test. So, the plate load test should therefore, be supplemented by adequate soil exploration through a borehole, which will reveal any non-homogeneity.

So, if it is not non-homogeneous soil if it is a homogeneous soil up to a depth of about 1.5 to 2 times the width of the foundation, this is the effective depths, this is the depth, which will be contributing towards the settlement. It is around 1.5 to 2 times the width of the foundation, in case of the sandy soils. So, if that much depth is homogeneous, you can rely on these results, if it is not homogeneous then we have to do some other test.

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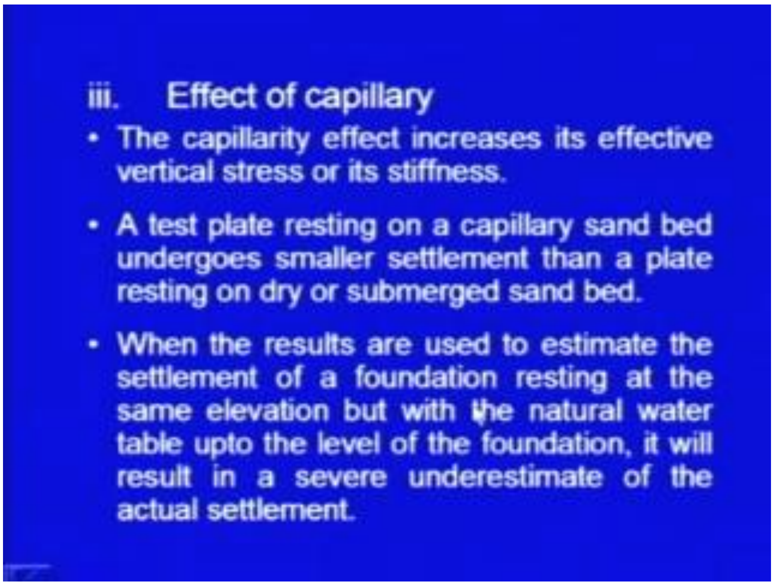

The next point is the effect of capillary, as you know the capillary effect increases, it is effective vertical stress. Due to capillary, there is negative pore pressure, which develops in the soil mass, so that results in increase in effective stress, increase in effective stress means, more strength and less settlement. So, if a test plate resting on a capillary sand bed undergoes, if you do the test on sand bed, which is having this capillary, then you are going to experience smaller settlements, than a plate resting on dry or submerged sand.

So, this is going to happen there, because of the capillary, the soil becomes more stiffness increases, the settlement decreases. So, what you are getting from the experiment is less settlement and if you use these results now and when these results are used to estimate the settlement of a foundation resting at same elevation. But, with the natural water table up to the level of the foundation, it will result in severe under estimation of the actual settlement.

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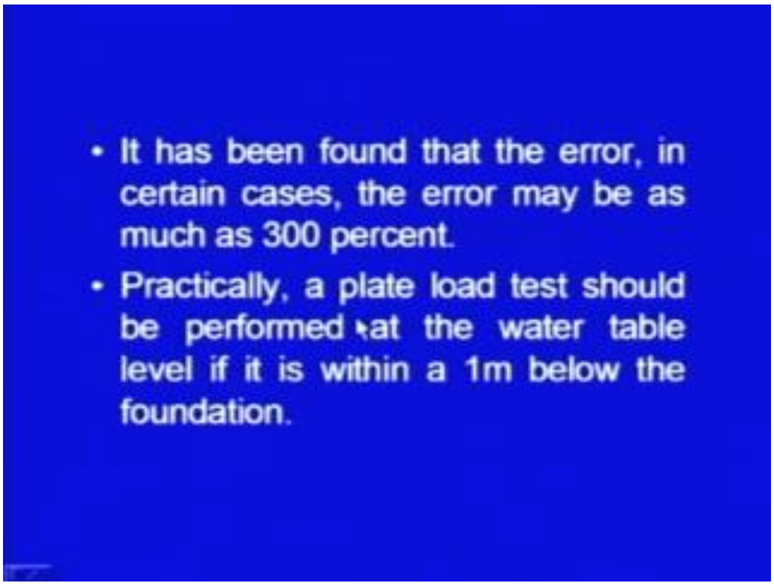

So, your results will again be misleading and it has been found that in certain cases, the error may be as large as 300 percent. So, practically a plate load test should be performed at the water table level, if it is within 1 meter below the foundation. So, you should not conduct the test on the soil, which is having capillary effect.

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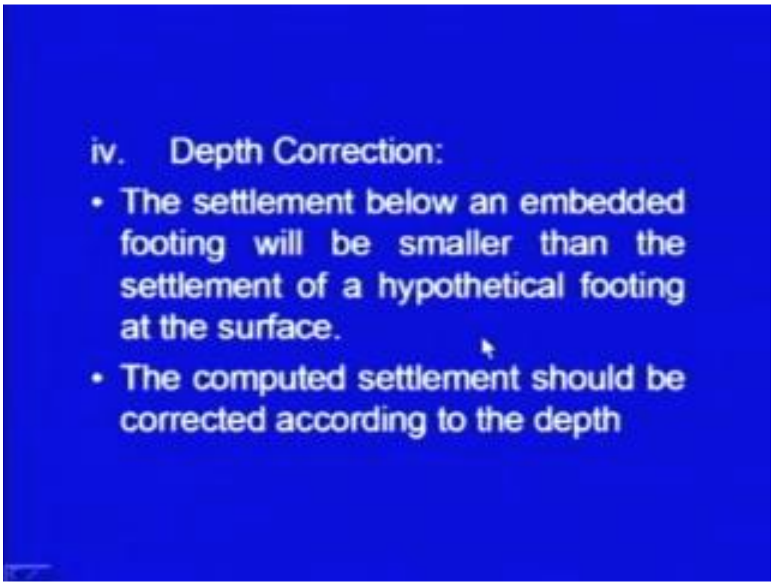

The next point is, suppose you have done a test on one depth and you are interested in finding out the settlements, you are interested in finding out to apply the results for other depth. Then, you have to apply depth correction; it is called as embedded depth correction, the settlement below an embedded footing will be smaller than the settlement of a hypothetical footing at the surface.

So, there is effect of the embedment, when the embedment is there, it is going to affect the settlements. So, the computed settlement should be corrected according to the depth.

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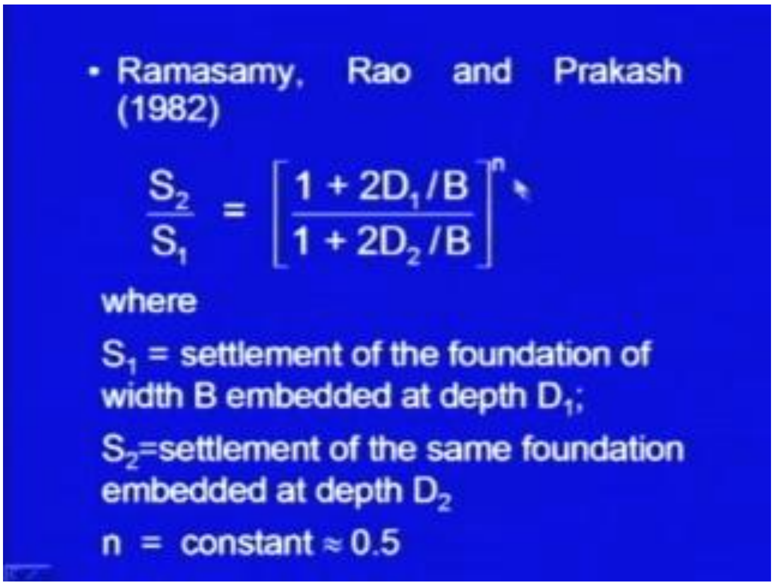

This is one of the expression which is available, S 2 upon S 1 is equal to 1 plus 2 D 1 upon B 1 plus 2 D 2 upon B to the power n. S 1 is settlement of foundation of width B embedded at depth D 1, S 2 is settlement of same foundation embedded at depth D 2 and n is the constant roughly equal to 0.5.

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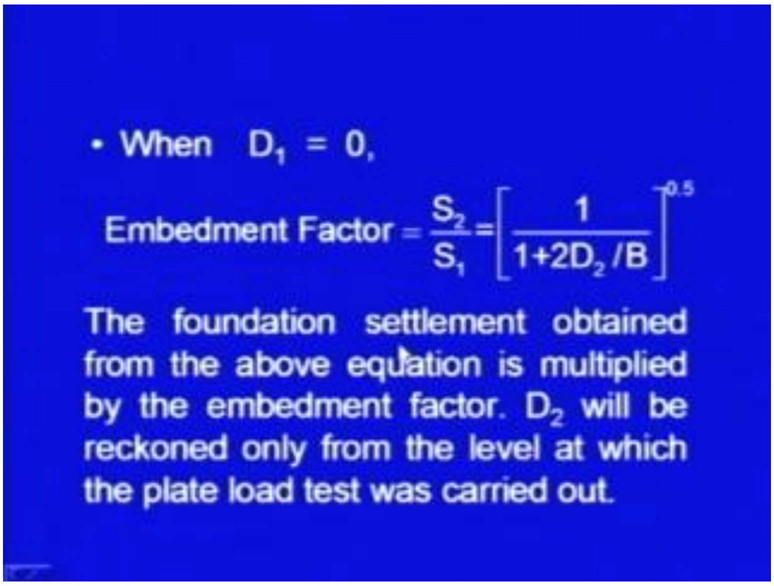

So, when we do the plate load test D 1 depth of the plate load, with respect to that level is 0, so embedment factor becomes 1 upon 1 plus 2 D 2 upon B raised to the power 0.5. So, the foundation settlement obtained from the above equation is multiplied by this embedment factor and this you have to remember that, D 2 has to be taken from the level at which the plate load test was carried out.

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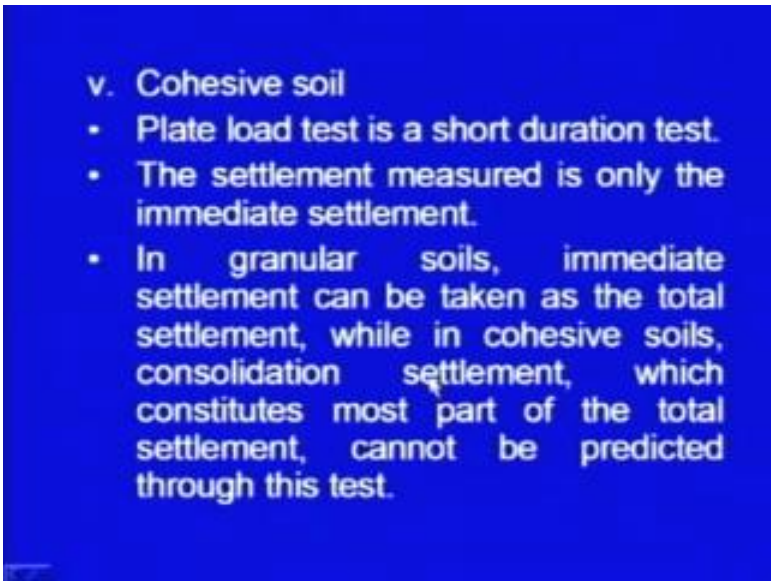

Now, in case of the cohesive soils, this is next important point, plate load test as you know it is a short duration test and incase of the cohesive soils, these are the time dependent phenomena. The time dependent settlements are very important and this particular result of this test strictly are not applicable.

So, because in granular soils immediate settlement can be taken as the total settlement, whereas in case of the cohesive soils consolidation settlements, which constitute most part of the settlement, it cannot be predicted through this test.

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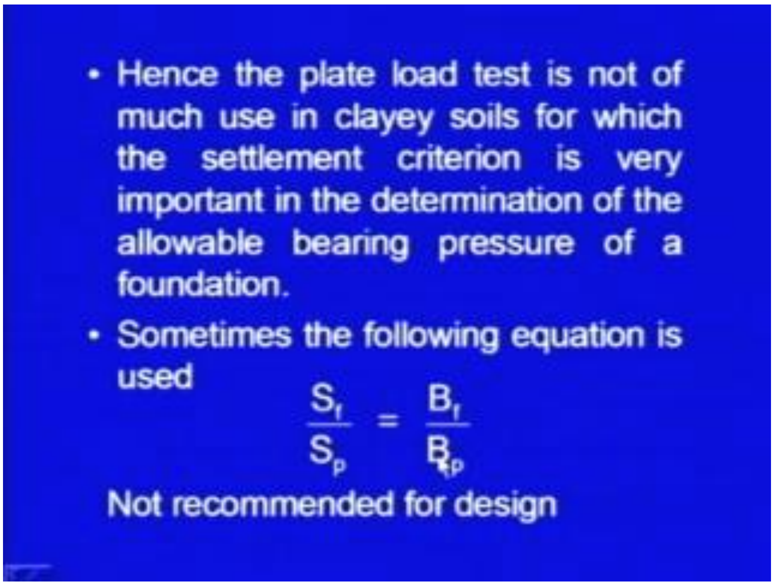

So, sometimes people use one correlation, S f upon S p is equal to B f upon B p, this particular correlation which is sometimes used, it is not recommended for design. So, as far as plate load test is concerned, it is not of that use for the cohesive soils.

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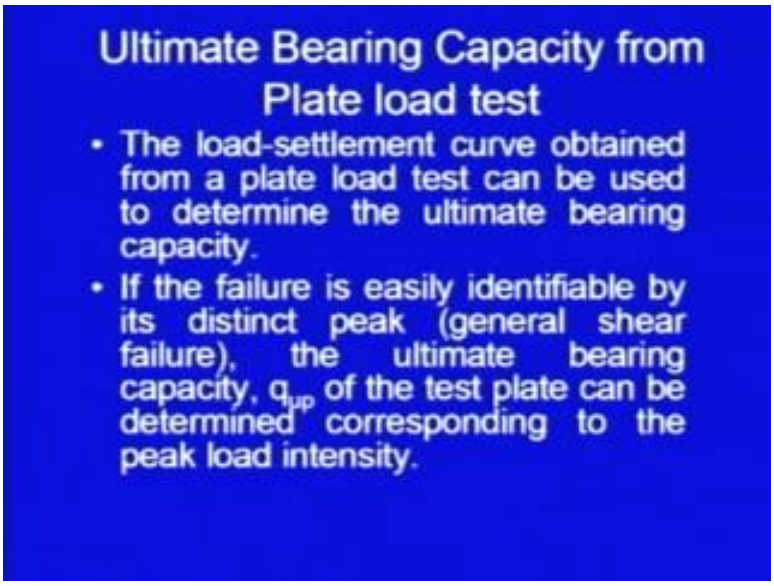

Now, let me go to the point, how you can calculate ultimate bearing capacity from plate load test. The steps will be, the load settlement curve obtained from a plate load test can be used to determine the ultimate bearing capacity; you have to get this load settlement curve. If the failure is easily identifiable by it is distinct peak; that means, a general shear failure is there, then the ultimate bearing capacity q u p of the test plate can be obtained.

So, you have to obtain this q u p, the ultimate bearing capacity of the plate, which I have already discussed.

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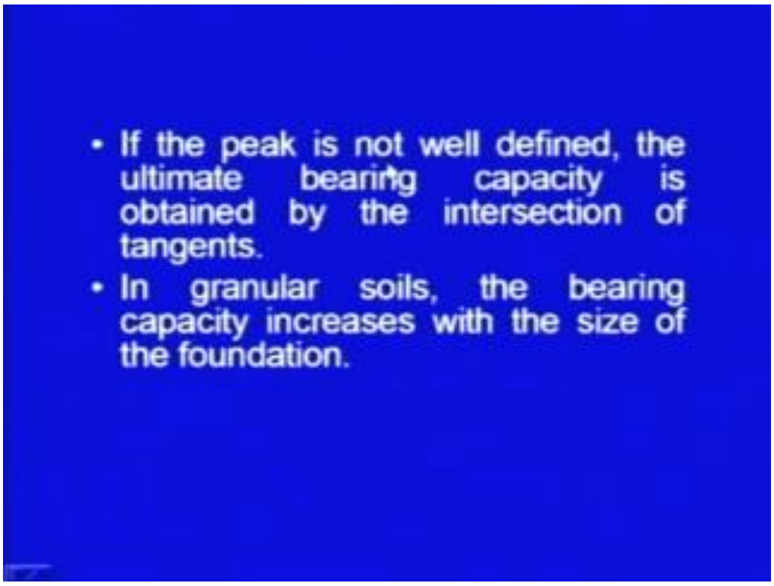

If the peak is not well defined, the ultimate bearing capacity is obtained by the intersection of tangents, this also I have shown you, that using two tangents, double tangent method. You can find out the ultimate bearing capacity, if it is not a well defined peak and in granular soils, please you must remember the bearing capacity, should increase, it increases with the size of the foundation.

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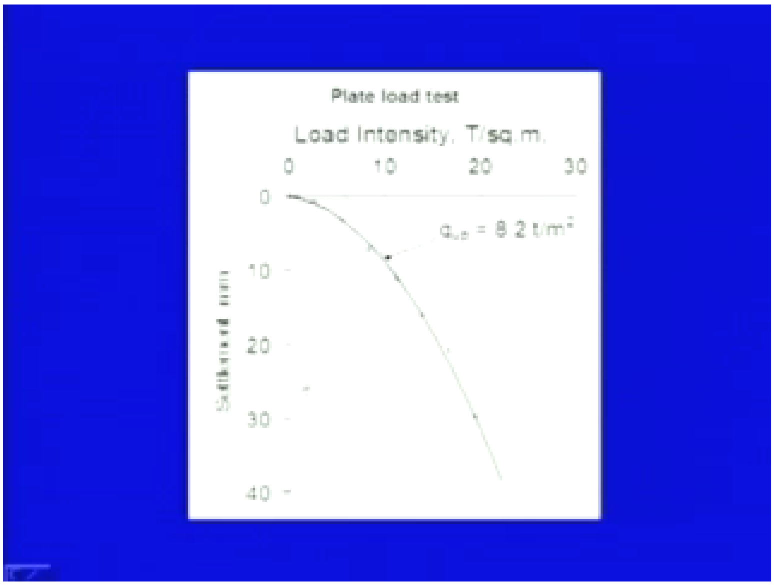

So, here I again, I have shown a graph, a plot and here I have shown how double tangent method can be used to find out the ultimate bearing capacity of the plate.

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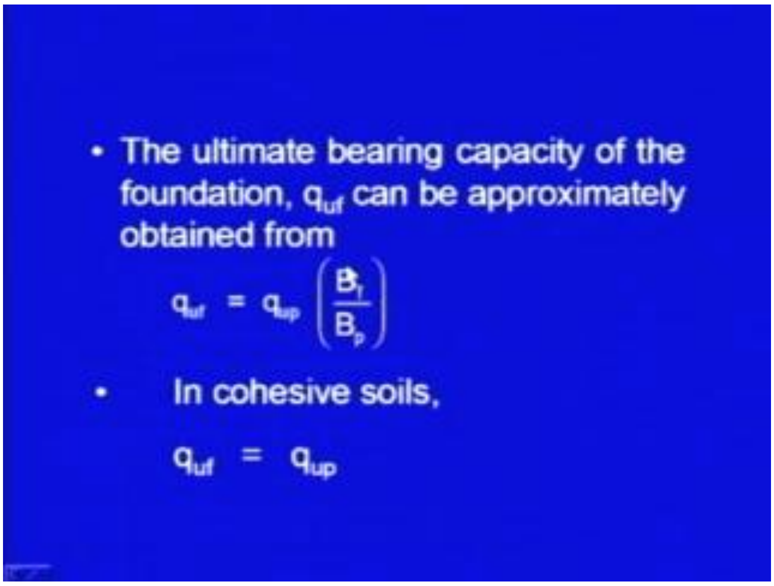

Once, this ultimate bearing capacity is available, then ultimate bearing capacity of the foundation q u f, it is obtained by this expression q u f is equal to q u p, B f upon B p. For cohesive soils, this is the rough relationship, but again as we told that cohesive soils, the governing criteria will be settlements from consolidation. But, these are the expressions which are sometimes used for the cohesive soils.

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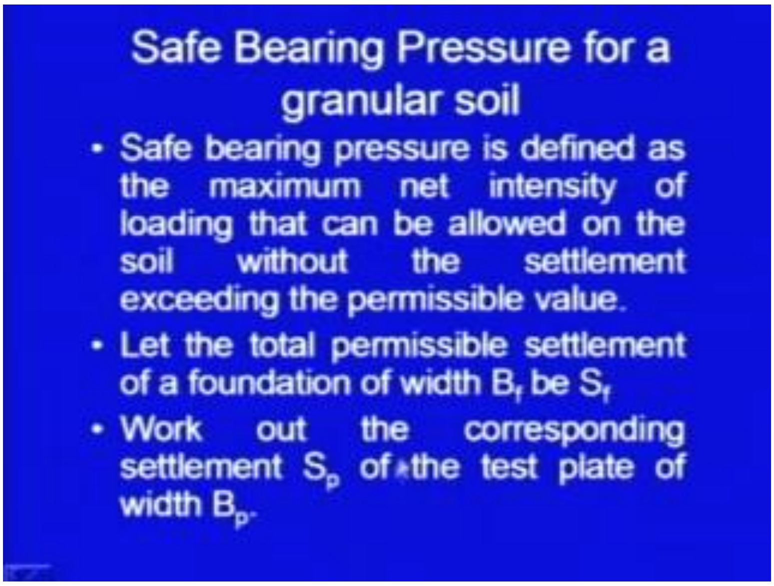

You can also determine the safe bearing pressure for a granular soil; the safe bearing pressure is defined as the maximum net intensity of loading that can be allowed on the soil without the settlement exceeding the permissible value. So, what it means is, that for the foundations for buildings the allowable settlements are known to you. So, if that settlement is known to you, you can also calculate how much will be the safe bearing pressure.

And for that, let the total permissible settlement of a foundation of width B f, suppose it is available with us. Let us say there is a footing and say 50 millimeter is the settlement of the footing permissible settlement. Then, workout the corresponding settlement S p of the test place test plate of width.

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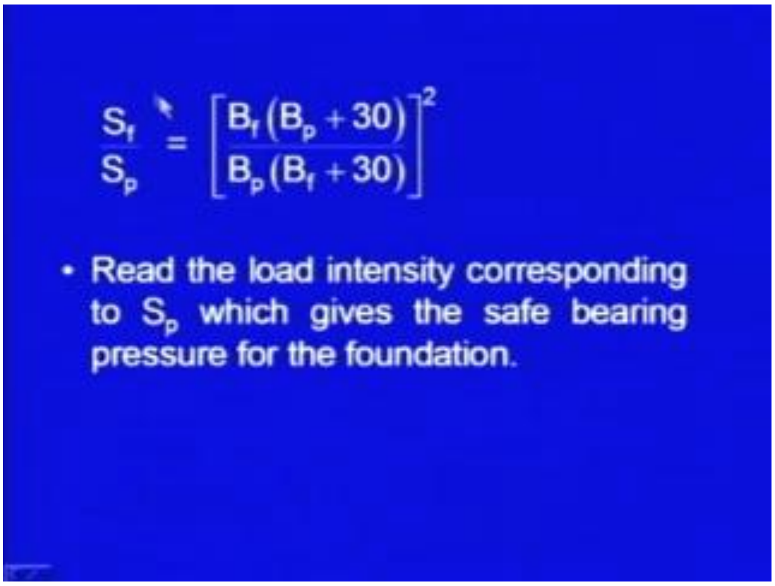

You can use the same relationship, you have S f, S p, B f, B p you have the relationship between all these parameters. So, for given S f, you can find out corresponding settlement of the plate and read this load intensity corresponding to S p, which gives the safe bearing pressure of the foundation.

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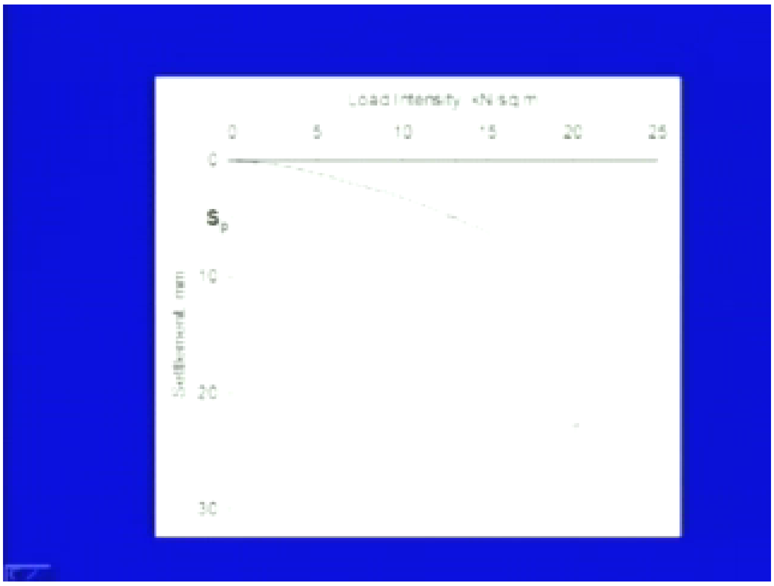

So, what you have to do is, this is the curve let us say, you have calculated S p, the settlement of the footing plate and corresponding to this, then you can read, this will be the allowable pressure. This will be the pressure at which the footing is expected to have that much settlement.

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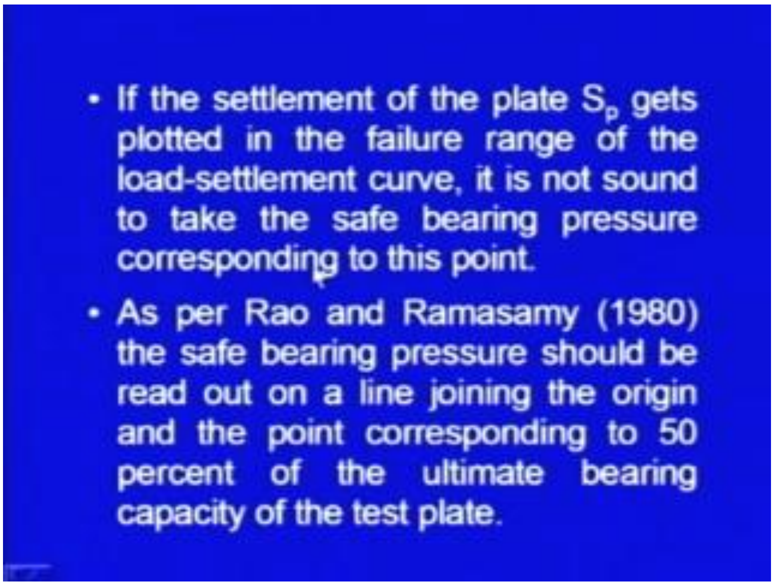

Now, if the settlement of the plate S p gets plotted in the failure range of the load settlement curve, it is not sound to take the safe bearing pressure corresponding to this point. If suppose, S p is somewhere here and you are getting a point here, so it is not sound to take in this failure reason, because this is a plot for the plate, not for the foundation.

So, what is suggested for this is, the safe bearing pressure should be read out on a line adjoining the origin and the point corresponding to 50 percent of the ultimate bearing capacity of the test plate. So, what we do here is, this is the ultimate bearing capacity find out it is 50 percent corresponding to that value take a point here, join it extend it and corresponding on that line.

Then you can read, you can get the ultimate bearing capacity, you can read the safe bearing pressure.

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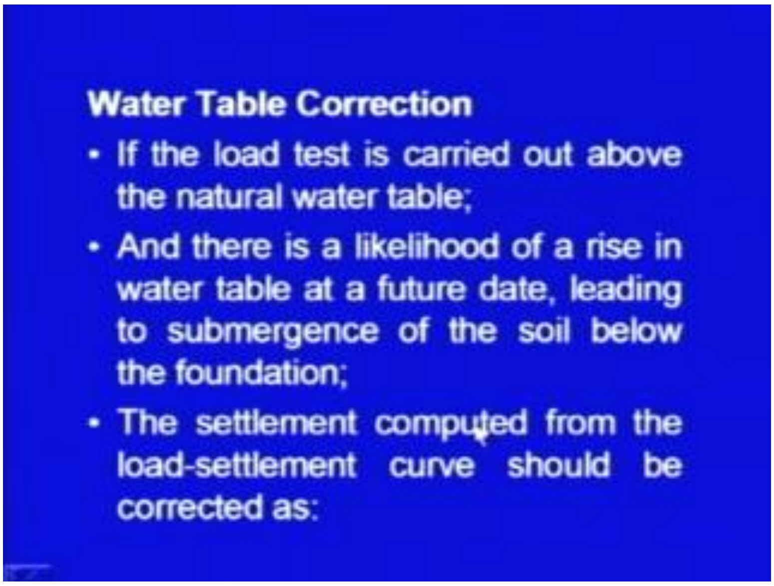

Now, if the water table is present there, it will affect the settlement and if the load test has been carried out above the natural water table and there is a likelihood of a rise in the water table at a future date. Then, leading to a submergence of soil, below the foundation this will lead to the submergence and the settlement will increase, the settlement computed from the load settlement curve should be corrected.

So, in fact, what you are getting, you have done a test, where the water table was not there and now the water has come up. So, those settlements will have to be corrected.

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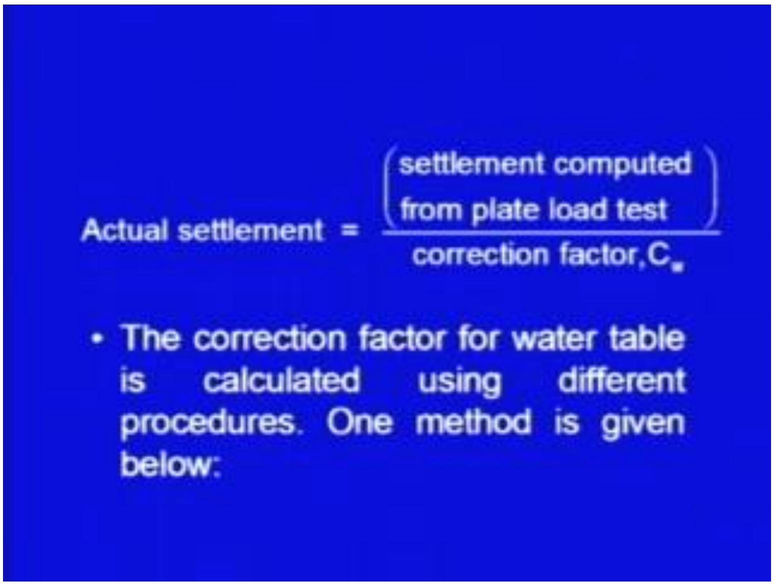

And here is one method for correcting the computed settlements, for the water table correction, actual settlement will be equal to settlement computed from test plate divided by this correction factor C w.

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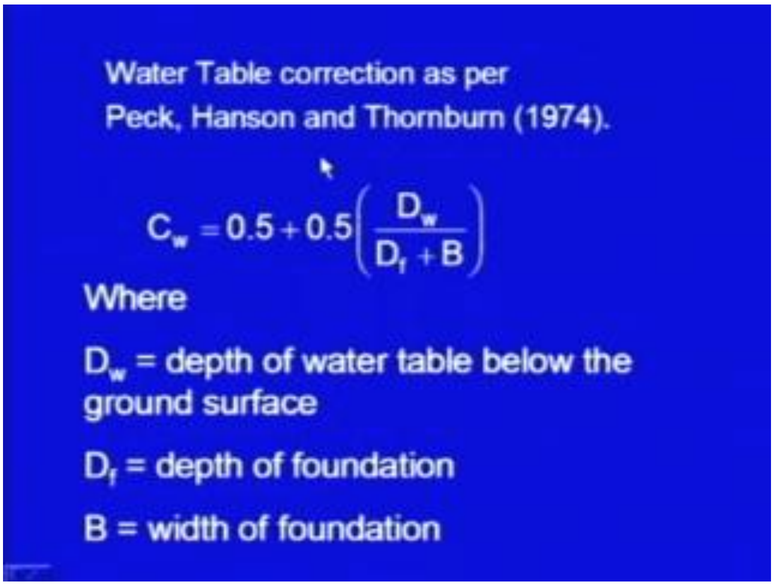

And this C w, there are several expressions available, we are giving here only 1, it is given by Peck Hanson and Thornburn. The correction factor is given as 0.5 plus 0.5, D w upon D f plus D b, D w is the depth of water table, below the ground surface, D f is the depth of foundation and B is the width of foundation.

So, if D w is equal to 0, D w is equal to 0 means depth of water table is 0, so the water table is at the ground surface itself. So, if this value becomes 0, C w will be equal to 0.5 and when it is 0.5, if you put it here, the actual settlement will be just double.

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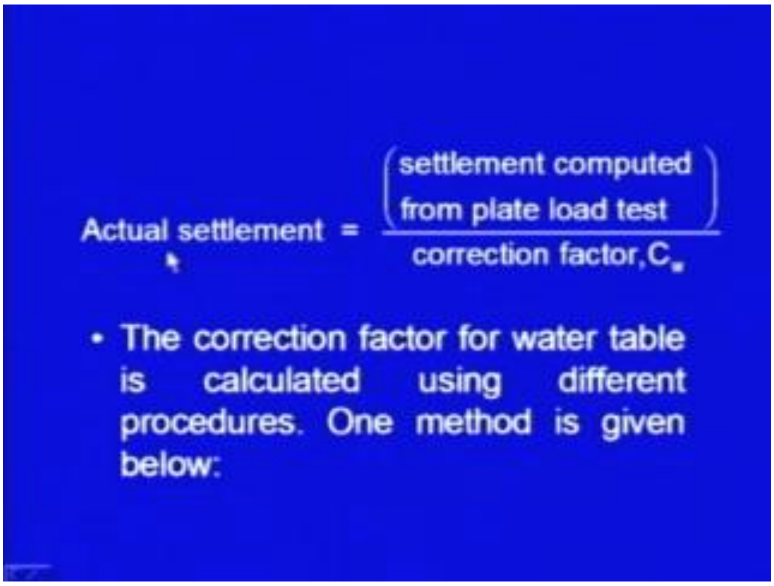

So, this correction has to be applied.

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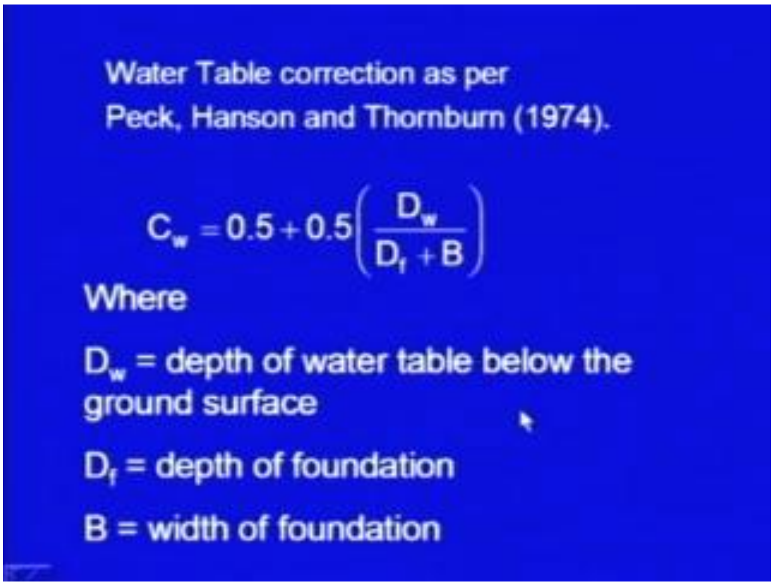

So, friends I have discussed the plate load test in detail, please remember this test basically is for cohesion less soil and we try to simulate the actual behavior of the footing in the field, we take a test plate, that plate is loaded the settlements are recorded.

Load versus settlement relationship is drawn and from that load versus settlement relationship.

You can work out, what is the bearing capacity or you can also work out, if the permissible settlement is available for the foundation, you can work out, what should be the allowable pressure, let me illustrate the method by using an example.

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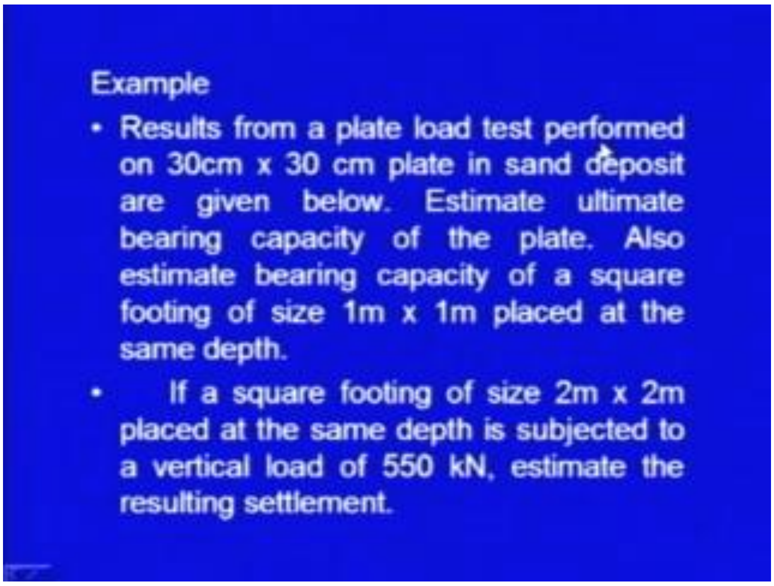

It is given to you that results from a plate load test, performed on 30 centimeter by 30 centimeter plate in sand deposit are given below. You have to estimate number 1, ultimate bearing capacity of the plate, number 2, also estimate bearing capacity of a square footing of size 1 meter by 1 meter placed at the same depth.

And number 3, if a square footing of size 2 meter by 2 meter placed at the same depth is subjected to a vertical load of 550 kilo Newton, estimate the resulting settlement. So, all these three things, I am explaining to you.

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Computations

load, kN	stress kPa	D1	D-2	D-3	D-4	S-1	S-2	S-3	S-4	S-av
0	0	43.5	15.84	33.78	45.6	0	0	0	0	0.00
2.5	27.78	43.3	15.5	33.55	45.2	0.15	0.34	0.23	0.35	0.27
5	55.56	43.2	15	32.53	45	0.3	0.84	1.25	0.51	0.73
7.5	83.33	42.9	14.3	32.5	45	0.58	1.54	1.28	0.58	1.00
10	111.1	42.7	14.1	32.1	44.7	0.8	1.74	1.68	0.85	1.27
15	166.7	41.8	13.03	31.4	43.8	1.7	2.81	2.38	1.73	2.16
20	222.2	40.6	11.7	29.5	42.7	2.9	4.14	4.28	2.82	3.54
25	277.8	39	9.96	27.54	41.1	4.41	5.88	6.24	4.5	5.26
30	333.3	36.9	8.6	25.84	38.8	6.57	7.24	7.94	6.71	7.12
35	388.9	30.7	5.4	23.68	36.7	12.75	10.44	10.1	8.81	10.53
40	444.4	30.4	3.97	20.9	34.4	13.06	11.87	12.88	11.2	12.24
45	500	28.5	23.75	16.7	31.5	14.91	17.09	17.08	14.1	15.79

This was the available data with me, load in kilo Newton; it is these are the load incremental values 0, 2.5, 5 and so on. Then, these were the values of the dial gauges, so here, this value as I discussed earlier also, this is the stabilized value, after applying this much load, this was the stabilized value, so these values also go on changing. So, 43.5, it starts with 43.5 and reaches up to 28.5.

The second dial gauge it starts from 15.84 and there is an interesting point, here you can see it reaches here up to 3.97 and then reading is 23.75. This is a practical field problem, what happens, there is a circular scale and on that scale, when you go on reducing the readings, after 3, it will become 2, then it will become 1, then it will become 0 and after 0 is equivalent to 25 there.

This particular dial gauge was having a capacity of 25 millimeter, so 0 is equivalent to 25, after 25; it becomes 24 and so on. So, you have to be careful, while doing the calculations, so we have done those calculations, we have calculated the settlements. So, these are the settlement values for 1, 2, 3 and 4 and then we have taken the average settlement.

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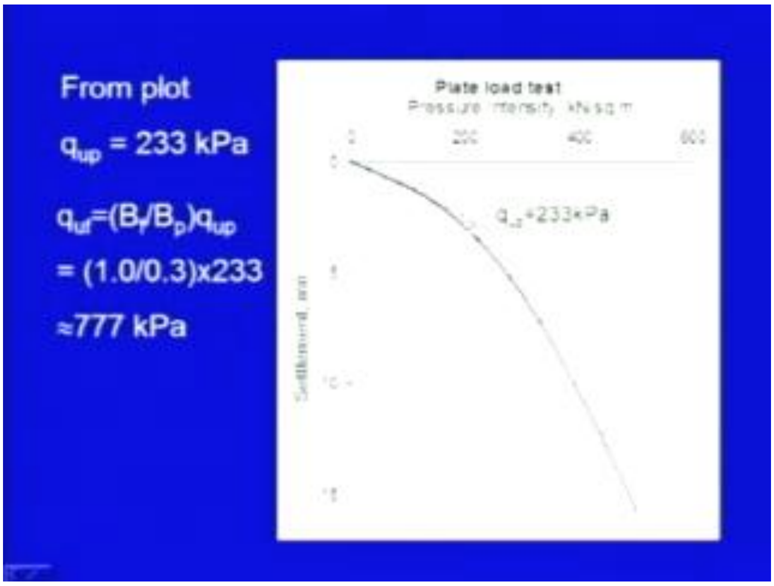

And here, it is the plot on x axis, it is the pressure, loading density and y axis, it is the settlement and this is a straight line portion, these also straight line portion, these are the two tangents. And the Q u p, the ultimate bearing capacity of the plate is observed to be 233 roughly, 233 k P a, so this is the ultimate bearing capacity of the plate.

Now, ultimate bearing capacity of the footing, this was the next part of the question, estimate bearing capacity of a square footing of size 1 meter by 1 meter placed at the same depth. So, it is given by this expression q u f is equal to B f upon B p, q u p and as B f increases, you can see q u f will be increasing. So, using this expression, you know B f is given to you B p is given to you can calculate, what is the q u f ultimate bearing capacity of the footing.

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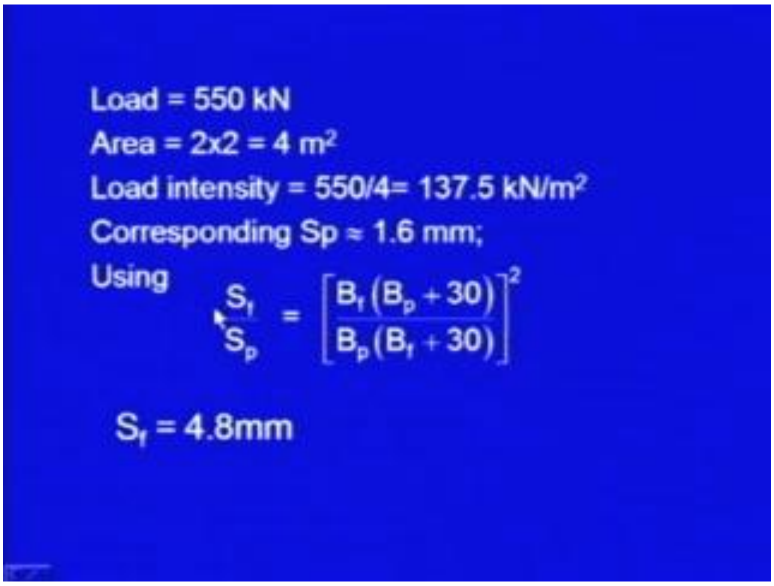

Coming to the third point, it was given that there is a load; this is load on the foundation and estimate what is the settlement of the foundation. So, these are the steps, load is available, area is known to us, load intensity is calculated and corresponding to this load intensity. Then, you can use the curve, this curve and from here corresponding to that load intensity, I have settlement of the S p value and using that S p value in this equation.

Because, if you remember, we discussed that this equation is applicable, when the load intensity is same on the plate and the footing. So, for the same intensity, this is the settlement of the plate from the curve and this value is kept is placed in this equation. All other parameters are known to you and then you can calculate the estimated value of the settlement of the foundation.

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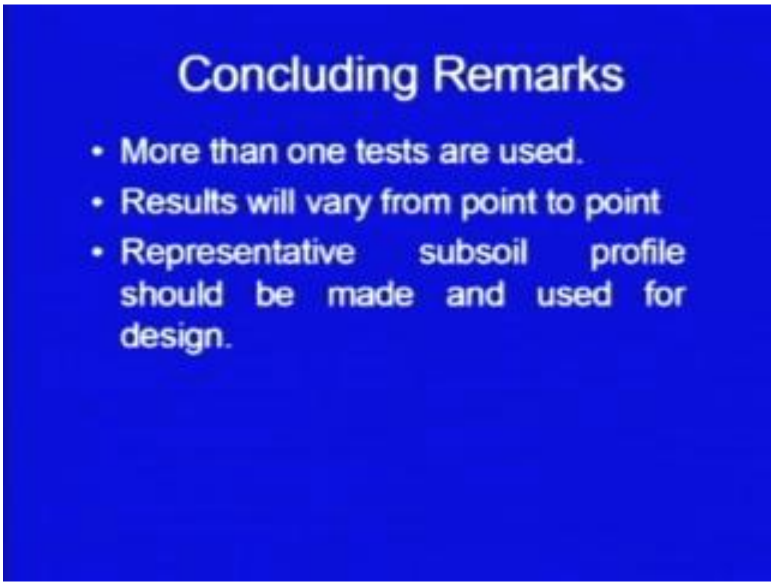

So, let me now conclude, we have discussed several field methods, we have discussed SPT, DCPT, SCPT, pressure meter, plate load, vane shear. All the tests have their own advantages and disadvantages; they are having their own merit and demerit. And it is suggested that in the field, you should not rely on one test there, should be more than 1 number of test.

And also, when you do the test at one point, you do the test at another point, the soil mass, soil is a naturally occurring material, you will be getting lot of variation, so results will vary from one point to the another point. So, based on your experience, your feel then, you have to get a representative subsoil profile, so that subsoil profile, the representative subsoil profile, that should be used for the design.