Foundation Engineering
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Module - 02
Lecture - 09
Pile Foundations - 4

Hello viewers, good afternoon to all of you, in the last class we discussed that how we can calculate or estimate load carrying capacity of a pile under compressive load. Today before starting with another topic, we will be first is seeing the two examples related to this. That is how you can estimate the load carrying capacity of a pile, using static pile load formulae.

In the last class we also saw that there are four categories that these pile capacities can be estimated, first was static pile load formulae, second was pile load test, then third was dynamic pile load formulae and then fourth will was the correlation with penetration data; we discussed the first one that is static pile load test formulae in detail. So, let us take up an example of a pile, which is driven in sand and then we will take one example, when the pile is driven in clay. And let us, see that how we can estimate the load carrying capacity of pile under compression.

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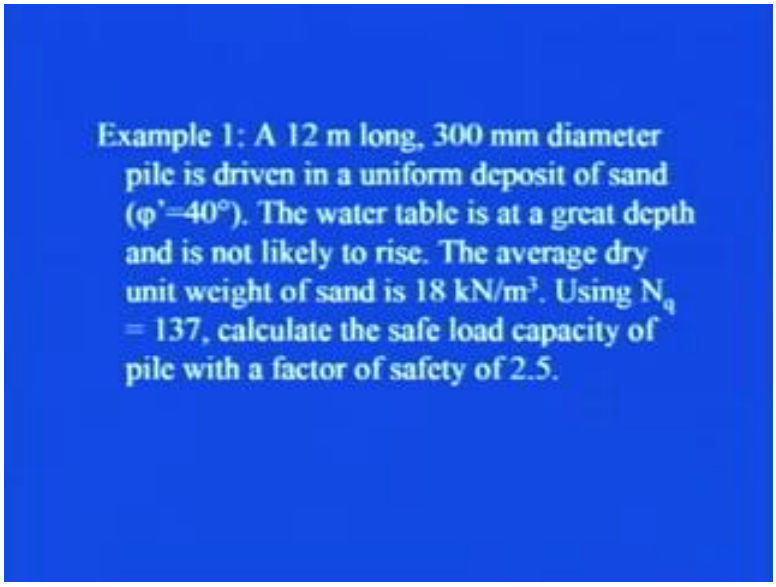

For the first example, it says that a 12 meter long, 30 mm diameter pile is driven in a uniform deposit of sand and the property of sand, which is given as 40 degree that is

cohesion is 0 and angle of internal friction is 40 degree, the water table is at a great depth and is not likely to rise. The average unit weight of sand is 18 kilo Newton per meter cube using N q equal to 137 calculate the safe load capacity of pile with a factor of safety of 2.5.

So, you see here in this case that the pile has to be driven in cohesion less soil, that is c is equal to 0 and phi value is present, which is in this case is equal to 40 degree, N q value is given to be 137. In case if this N q value is not given then you know how to calculate this N q value. I S code method we have discussed in the last class, simply you can pick the corresponding value of N q for a value of phi is equal to 40 degree from the standard available chart.

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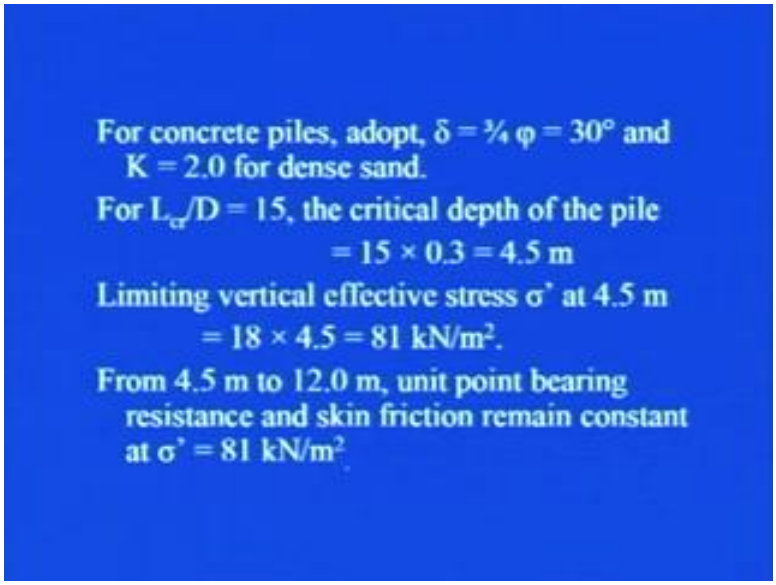

Let us see step by step how it works, you know that in case of sand or granular soil critical depth concept is there. So, we will be using that concept and then by with the help of this example, it will become more clear to you that what exactly do we mean by critical depth, when we were discussing that particular concept. I gave you an standard table, that how you can adopt the angle of friction between the soil and the pile material and then the coefficient of lateral earth pressure.

So, in this case the pile is getting driven in dense sand, if you refer to that table you can pick for concrete piles delta that is angle of friction between soil and pile material to be equal to 3 4'th of phi, phi is 40 degree in this case. So, this delta will result to be 30 degrees and k is equal to 2 for dense sand, now since it is sand critical depth concept will

come into picture. So, if L critical by depth ratio as I told you, that it varies from 15 to 20. So, for L critical that is L c r by d to be equal to 15 the critical depth of pile will be 15 into 0.3, where 0.3 is the diameter of the pile.

So, that becomes 4.5 what does this mean, that from the ground surface till a depth of 4.5 meter the effective overburden pressure will be increasing linearly and beyond this depth of 4.5 it will become constant, that is what do we mean by critical depth concept. So, limiting vertical stress effective stress sigma prime at 4.5 meter will be simply gamma into z, where gamma is given to be 18 kilo Newton per meter cube. So, that will become 18 into 4.5 which will result into 81 kilo Newton per meter square.

Now, from 4.5 to 12 meter this unit point resistance and unit skin friction will remain constant and at this average effective over burden pressure equal to 81 kilo Newton per meter square. Because, till critical depth only it will increase linearly and beyond that it will remain constant.

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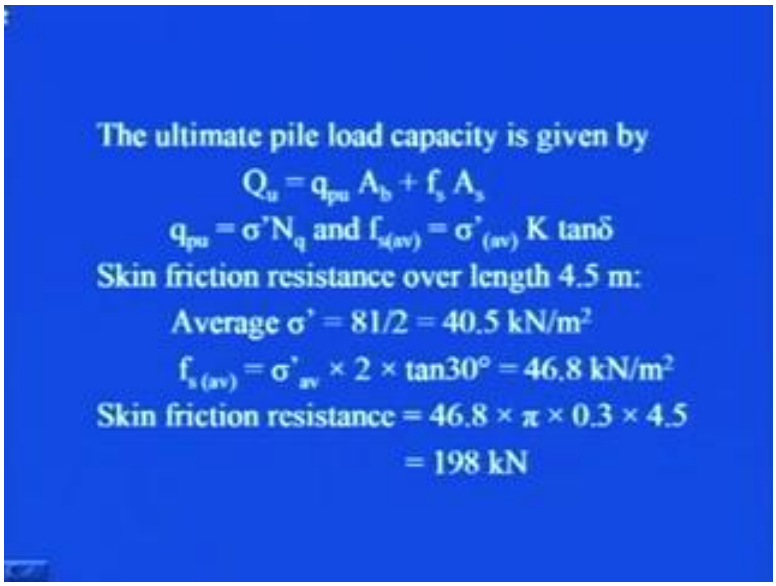

The ultimate pile load capacity is then given by this general equation which is Q u is equal to q p u into A b plus f s into A s. Where, this q p u is sigma prime into N q plus and your f s average is sigma prime average into K tan delta, that we have seen studied in detail in the last class. So, the skin friction resistance over length 4.5 meter will be governed by the average overburden effective pressure up to the depth of 4.5 meter that is from ground surface to 4.5 meter and beyond that it will remain constant.

So, over a length 4.5 meter this average sigma prime will become 81 by 2 because, at the ground surface this sigma prime value is equal to 0 and at 4.5 meter depth it is 81 kilo Newton per meter square. So, the average value over that particular depth will be 40.5 kilo Newton per meter square and then accordingly this f s average will become sigma prime average into K, which is 2 into tan delta, delta which we have taken to be 3 4th of phi, phi was 40 degree, so delta worked out to be 30 degree.

And if you put this sigma average equal to 40.5 here in this expression, this will result into f s average to be equal to 46.8 kilo Newton per meter square. Now, this is what is unit skin friction, now if you multiply it by the area on which this particular resistance is acting, you will get total skin friction resistance. And you know, that this skin friction acts over surface area of the pile shaft, which is A s in this case.

So, you see here that f s into pi d into L that is this particular pressure that is 46.8 kilo Newton per meter square is acting on the pile shaft surface of the depth between 0 to 4.5 meter. So, that works out to be 198 kilo Newton.

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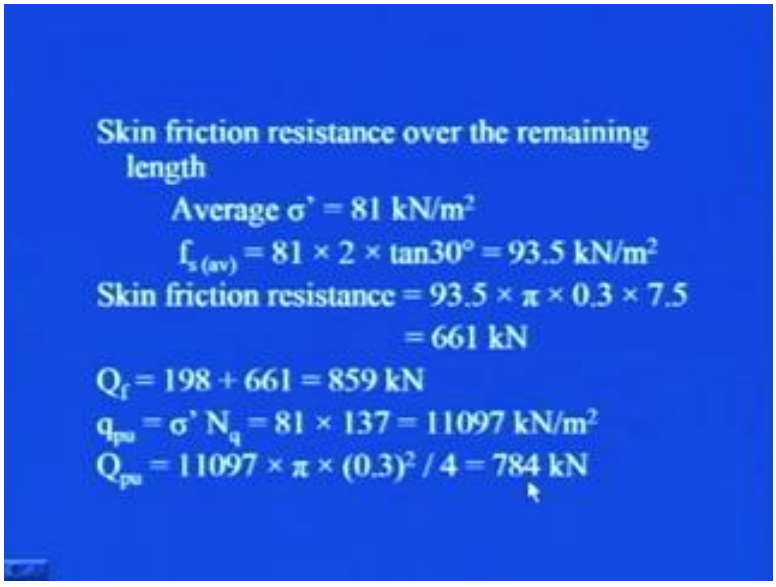

Then, skin friction resistance over the remaining length, so beyond 4.5 meter till the length of the pile, this average sigma prime will be constant which is equal to 81 kilo Newton per meter square. And so this f s average will become 81 into K that is 2 into tan delta, delta is 30 degree and this will result into 93.5 kilo Newton per meter square.

Then, in this case skin friction resistance over this length between 4.5 to 12 meter, this will become 93.5 into pi d L, L is in this case 7.5 that is remaining 4.5 we already have

taken into account and the remaining 7.5 meter will come here in this particular form and this will result skin friction resistance of 661 kilo Newton. So, the total skin friction resistance will be 198 which was contributed by the length 4.5 meter from the ground surface and then plus 661 which is due to the remaining length of the pile.

So, that will work out to be 859 kilo Newton, then Q p u will be this, this is related to your skin friction resistance law. Now, if we want to find out that point bearing resistance, so unit point bearing resistance is sigma prime into N c because, c is 0 in this case. So, this expression will be having only one term that is sigma prime into N q, so sigma prime because, it is at base, so at base you see here, that from depth 4.5 and beyond that the sigma prime is going to be constant, which is equal to 81 kilo Newton per meter square.

So, at the base this sigma prime will remain as it is, it will not increase beyond 4.5 meter due to critical depth concept. So, this value will be 81 into 137 which will be equal to 11097 kilo Newton per meter square, how where this value will be acting at the base of the pile tip. So, if you multiply this value by the area of the base of the pile tip, then you will be getting the point bearing resistance, so you see here the diameter of the pile is 0.3. So, here I am multiplying it by the area of the base of pile that is pi d squared by 4 d is 0.3 in this case and this gives the value of 784 kilo Newton.

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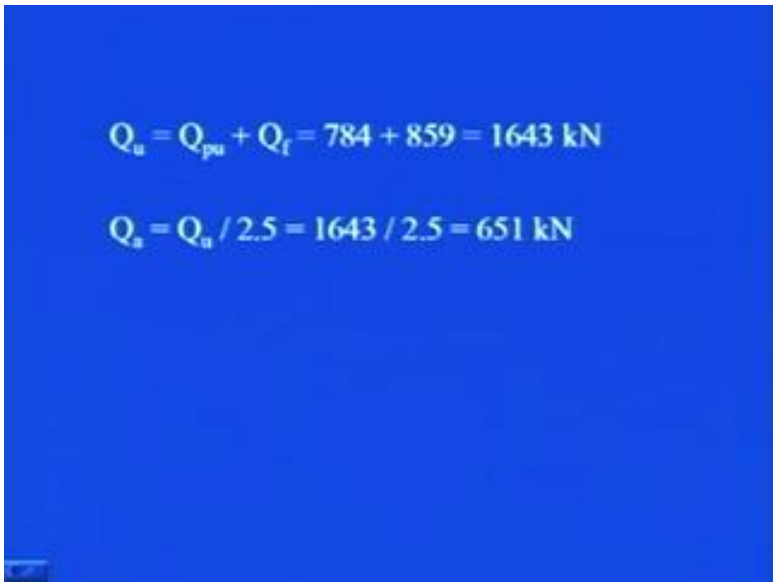

So, the total ultimate load carrying capacity becomes point resistance plus skin friction resistance, which is 784 plus 859 results into 1643 kilo Newton. So, Q allowable will be

Q ultimate divided by the factor of safety, which is 2.5 in this case and this will give that the pile has allowable capacity as 651 kilo Newton. So, you saw that in case thus pile has to be driven in the sand, critical depth concept has to be used and how it can be incorporated, I hope that it became clear to you with the help of this example.

Now, let us try to take another example, which deals with the piles to be installed in clay, then how you can find out the ultimate load carrying capacity of the pile in clay.

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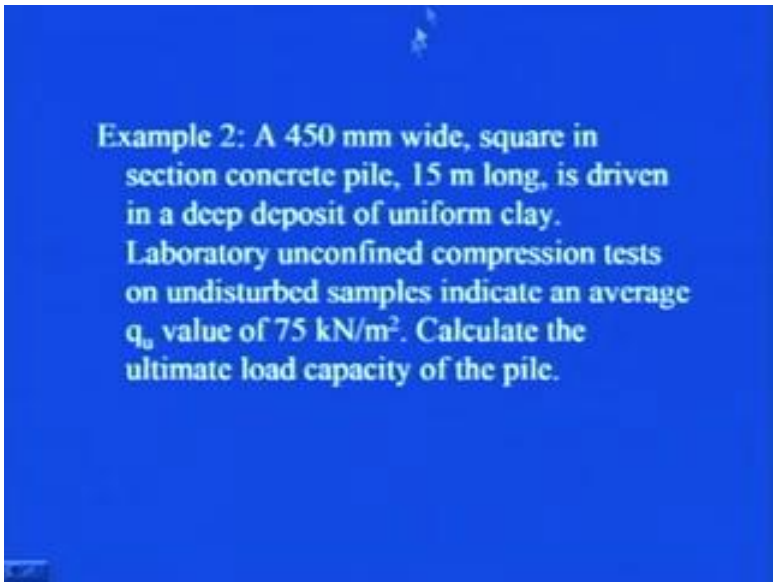

Here, in earlier case it was 300 mm diameter; however, here in this case it is as 450 mm wide square in section concrete pile 15 meter long is driven in a deep deposit of uniform clay, here it is clay not the sand. So, laboratory unconfined compression tests on undisturbed samples indicate an average q u value of 75 kilo Newton per meter square, calculate the ultimate load capacity of pile.

So, here this unconfined compression tests have been conducted on undisturbed samples and then they resulted in the this q u value that is unconfined compressive strength value to be equal to 75 kilo Newton per meter square, so this will give you that what exactly is the value of undrained cohesion.

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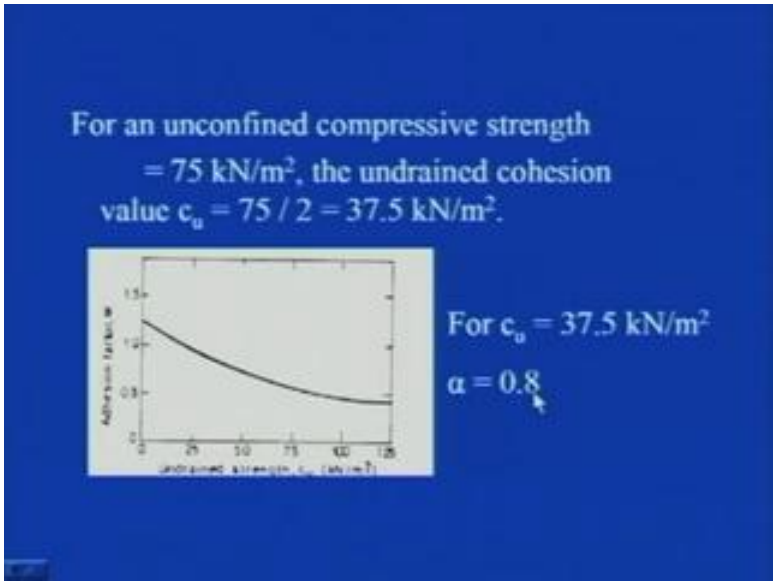

So, for an unconfined compressive strength of 75 kilo Newton per meter square, the undrained cohesion value which is c u, that will become half of this unconfined compressive strength, which will become 37.5 kilo Newton per meter square. And as we discussed in the last class, that research workers have given the standard chart to know the value of adhesion factor, which has to be used in the calculation or in the estimation of load carrying capacity of pile in clay corresponding to this value of undrained cohesion.

So, if you remember that we used this kind of chart, so here if you say that it is c u is 37.5 on x axis it is c u. So, you can pick a value 37.5 here on x axis, draw a vertical line wherever it intersects this particular curve, you draw a perpendicular line or projection to this y axis. And so the you if you can read that value of alpha, that is corresponding value of alpha that will be corresponding to the particular c u value that is undrained cohesion value for the considered problem.

So, in this case c u is coming out to be 37.5 kilo Newton per meter square and correspondingly, if you read from this particular chart alpha will work out to be 0.8.

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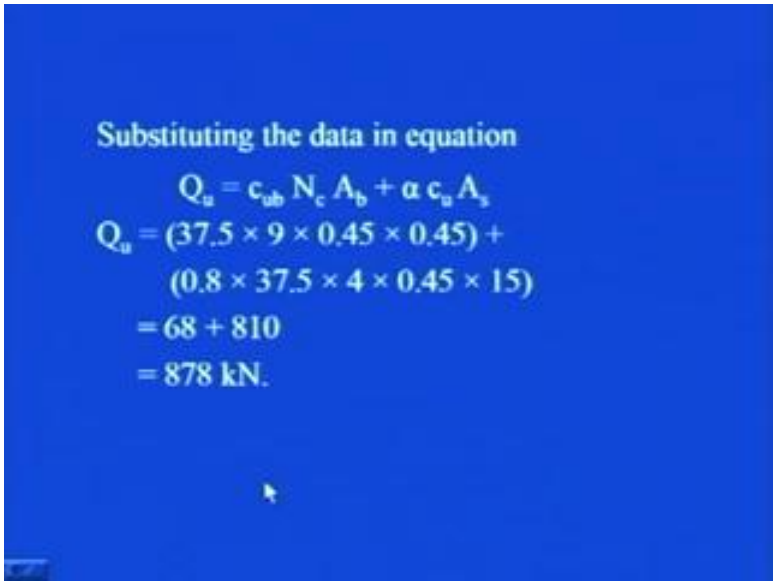

Then, you have the standard equation for load carrying capacity of pile in clays that is equal to Q u which is equal to c u b into N c into A b plus alpha c u A s. So, c u b we have found out that is 37.5 N c I told you that for in case of pile foundation, usually we take it to be 9, A b it is a square pile of 450 mm size, so the area of the base will be 0.45 into 0.45 plus alpha times that is 0.8, 37.5 is your c u and this A s that is the surface area of the pile on which that adhesion is acting, that is adhesion pressure due to adhesion of soil on the pile material which is acting.

So, that becomes pi d L, so you can see here that is pi d is your circumference, in case of the circular pile, but here it is square pile. So, the perimeter of that pile will become 4 times it is side of the pile, so you see here that surface area to know the surface the area of the base and then multiplied by it is length. So, 4 into 4.45 into 15, so the first term will be 68 plus 810 and this will result into 878 kilo Newton.

So, you see that how you can find out the ultimate load carrying capacity or allowable load which a pile can take, whether it is driven in the sand or in clay, you how you can estimate that. In the last class we saw the theory behind that, that how this load transfer mechanism takes place and today we saw with the help of two examples that how numerically it can be worked out.

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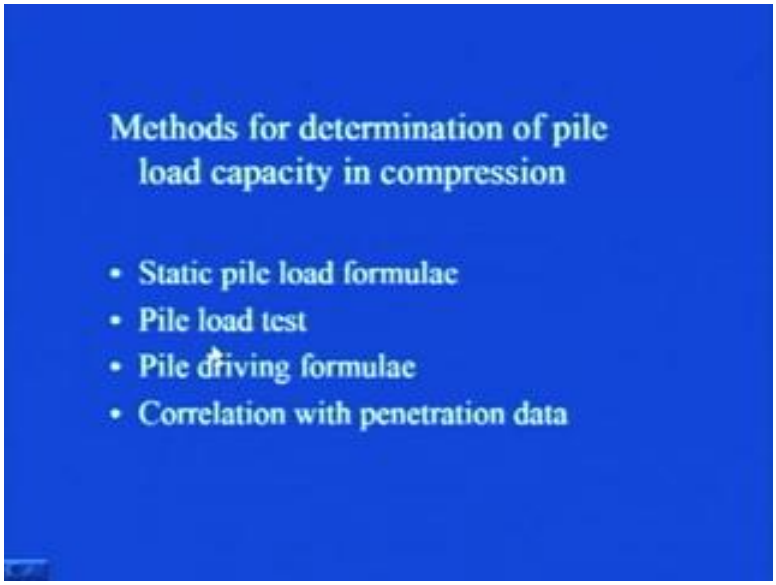

Then, we were discussing for the method of determination of pile load capacity in compression, in this under this heading, we discussed this static pile load formulae, now second comes that pile load test. So, in that we will be seeing that there are two types of tests that are conducted that is two types of piles that are being tested in the field. So, these are more reliable because, they present or they represent the actual condition in the field.

Because, they are in situ test we are not stimulating or modeling them in the field or in the laboratory, that is why the results from pile load test are quite reliable. So, coming to pile load test these are the only direct method for determining the allowable load on piles.

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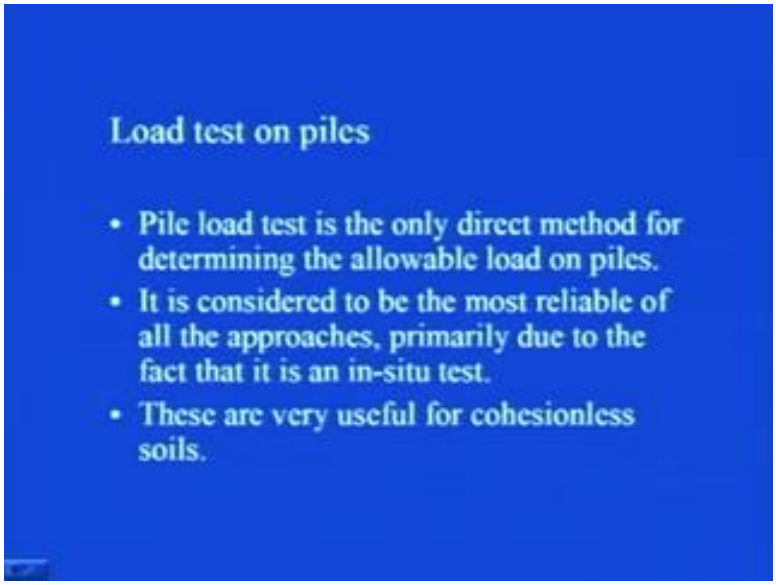

You see why we are calling it the direct method, you have seen that in case of static pile load formulae. First, we computed that how you can find out unit skin friction resistance and then skin friction resistance by multiplying that unit skin friction resistance by the area, on which it is acting. And then we found out unit point bearing resistance and when we multiplied that by the base area of the pile, we got point bearing resistance of the pile.

We sum them up and then we got the total ultimate load carrying capacity of the pile; however in case of load test on pile, these are the only methods from where you can get the direct value of the ultimate load, which a pile can carry. Because, it is a load that you apply in the field on the pile and then you take the settlement out of that use, you can simply plot that load settlement curve and can get the directly the value of this ultimate capacity of the pile.

It is considered to be the most reliable of all the approaches, primarily due to the fact that it is an in situ test, in situ test they always represent the actual field condition. So, the reliability of in situ test becomes more in that particular case because, you see if you stimulate any particular case in the laboratory, first of all that all the conditions that you will be generating in the laboratory, there will be an assumption to the situation which exists there in field.

However, the test which you conduct in the field they are the actual conditions and they give you the actual and realistic picture of any particular problem. So, in case of this whatever is the capacity of the pile, that will be there when these piles will be in

functional form, you will be getting exactly the similar test data. So, that is why they are more reliable, these are very useful for cohesion less soil, so more reliability in case of cohesion less soil.

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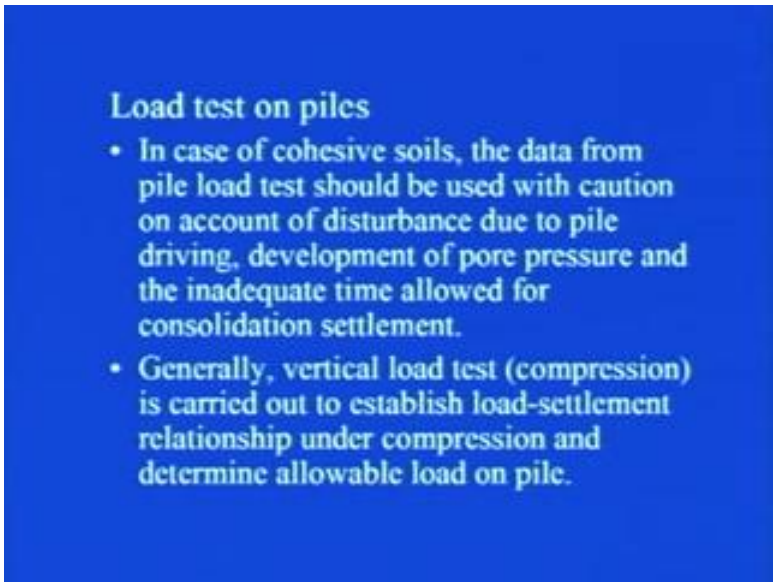

In case of cohesive soils, the data from pile load test should be used with caution on account of disturbance due to pile driving, development of pore pressure and the inadequate time allowed for consolidation settlement. You see, in the last class when we were discussing this particular aspect in detail, we discussed that when we go for piling in clay, what happens is in the process of creating a borehole and then filling it with concrete what happens is we disturb the clay, clay becomes in remolded state and it takes some time to regain it is strength due to the reconsolidation of the same.

So, in case of cohesive soil whatever data from the pile load test that you get, you have to use it with proper caution, that you have to give sufficient time for the clay to regain it is strength regain it is shear strength, which it has lost during the process of boring. Generally, vertical load test that is in compression is carried out to establish load settlement relationship under compression and then determine allowable load on pile.

You know you have studied this in case of shallow foundation also, that how you can find out the ultimate load, which any particular foundation can take by with the help of this load settlement curve. So, in case of this pile also when the pile is tested in the field, what happens is the load is being applied and then the corresponding settlements are measured. So, that the load settlement curve can be plotted and then from that particular

curve, you can directly get the ultimate load capacity of the pile and then subsequently by dividing that by factor of safety, you can get the allowable load on pile.

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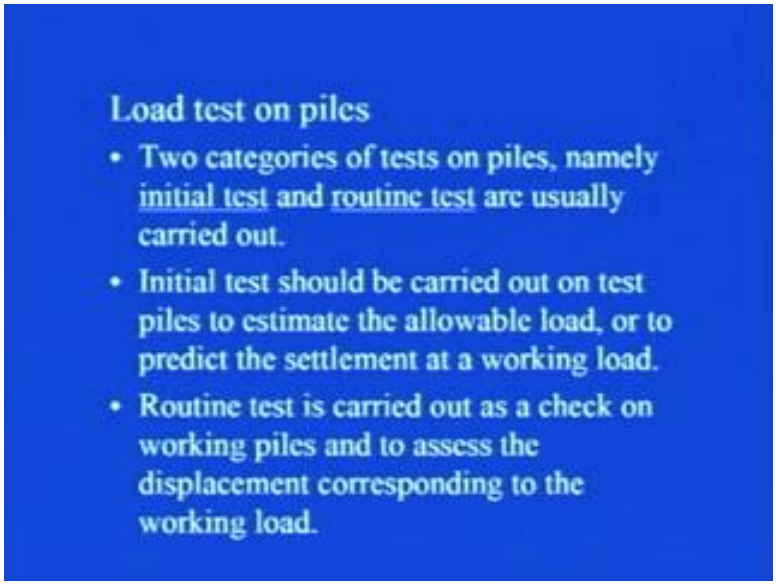

So, as I mentioned you the two categories of test on piles, they are initial test and routine test, usually these two type of tests are carried out. Now, let us try to see that what exactly is the difference between these two type of tests, what is the difference in the piles that are being tested as initial test or as routine test. Initial test should be carried out on test piles to estimate the allowable load or to predict the settlement at a work working load.

So, here we are introducing a term the test piles, so initial test they always been used on the test piles. So, what are the characteristic of test pile, how they are working, how they are different from the working piles, let us try to see and then the routine test is carried out as a check on working piles and to assess the displacement corresponding to working load. So, first this the difference between initial test and routine test, you must understand properly, that initial test is being carried out on the test pile to estimate the allowable load or to predict the settlement at a working load.

So, test pile is a pile which is not a working pile, that is which is not taking any part in load sharing, which is coming from the super structure. However, the routine test which is carried out on working piles, so working piles they are the piles which are going to share the load which will be coming from the super structure and then they assess the displacement corresponding to working load.

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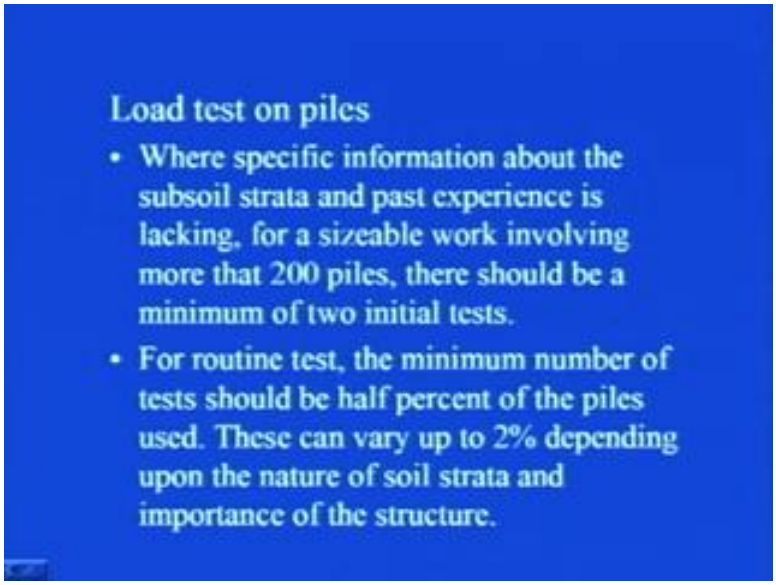

So, where specific information about the subsoil strata and past experience is lacking, for a sizeable work involving more than 200 piles, there should be a minimum of two initial tests. So, you must be wondering that why how many test, that how to decide upon, that how many initial test, how many routine test that one must conduct, so depending on the experience and engineering judgment, some of the general guidelines are available in a standard text book.

So, we will be discussing those and out of them one is that, when the subsoil information about the subsoil strata is not available to that extent, which is required. And the past experience is also lacking that is the experience from the neighboring structures or experience, which you might have had in the past history of that particular site. And in case, if you are working with more than 200 piles, then it is recommended that minimum of two initial test has to be conducted, it is good to have more than that, but minimum two initial test should be there.

For routine test, the minimum number of tests should be half percent of the piles used, that is if you are using 100 piles, let us say you are using 100 piles. So, half percent of 100 piles, those many tests you must conduct on the working pile as far as routine test are concerned. These, can vary up to 2 percent depending upon the nature of soil strata and importance of the structure, let us say very some sophisticated structure is coming up or the subsoil strata is not that good.

So, that those number of test can be increased from 0.5 percent to 2 percent, depending on what exactly are the conditions at site, that is what is the subsoil strata or what is the importance of the structure.

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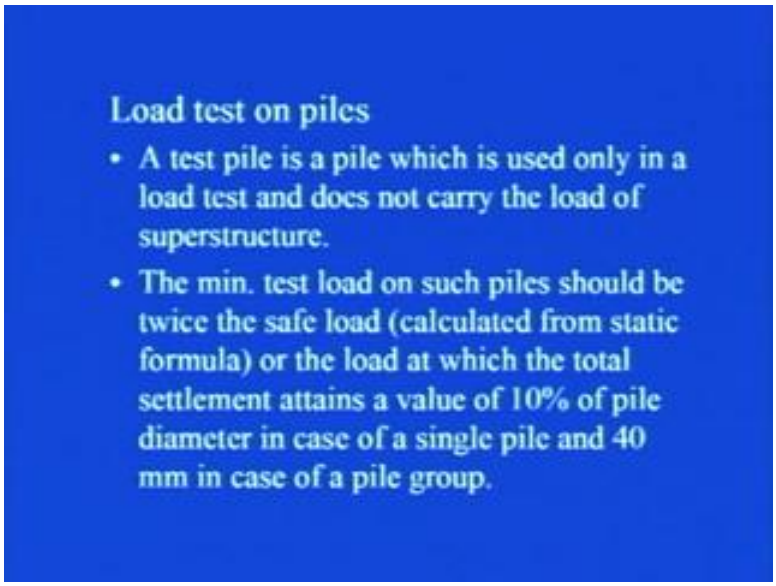

Now, what is the test pile, the test pile is a pile which is used only in a load test and does not carry the load of superstructure. So, it is being constructed, being installed just for the purpose of testing or conducting initial test, that is initial pile test it does not carry any load from the super structure. The minimum test load on such piles should be twice the safe load, how you will be knowing the safe load, you have already studied that how you can find out the load carrying capacity or safe load using static pile load formulae.

So, in that case you can estimate from the capacity from static formula and estimate roughly the safe load. So, the minimum test load on this pile should be twice the safe load or the load at which the total settlement attains a value of 10 percent of pile diameter, in case of a single pile and 40 mm in case of a pile group. So, you see here this is let us say if the pile is having a diameter of 1 meter, then 10 percent of 1 meter that is 0.1 meter.

Whenever, you achieve that 0.1 meter of the settlement, that much load you should apply in case of a single pile and if it is a pile group, then in that case 40 mm is the criteria. So, wherever you achieve either of these two either in case of single pile or in case of pile group respectively. So, there you must stop I mean that much is the maximum load that test pile should be subjected to...

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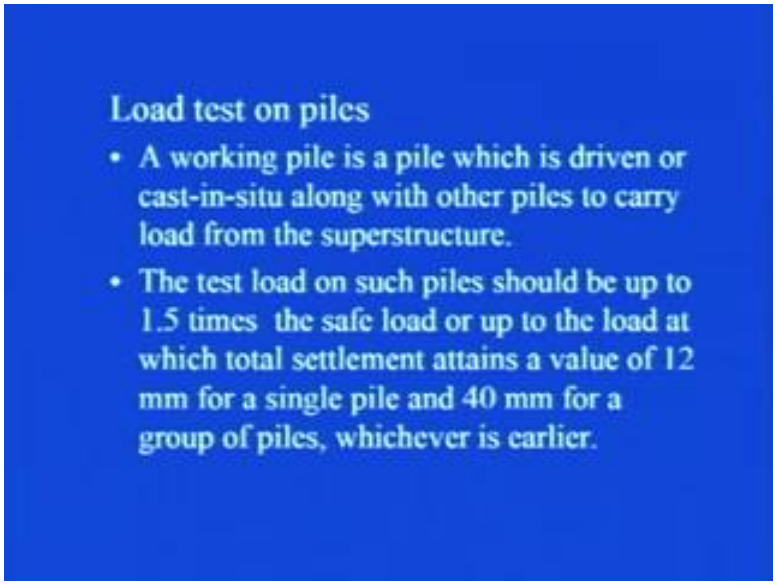

Then, a working pile is a pile which is driven or cast in situ along with other piles to carry the load from the super structure. So, you see here the working pile is taking part in sharing the load, which is coming from the super structure; however, the test pile was not taking any of the load in that was just for the purpose of conducting initial test. The test load on such piles should be up to 1.5 times the safe load, in case of initial test it was two times the safe load here in this case it is 1.5 times the safe load or up to the load at which the total settlement attains a value of 12 mm for single pile and 40 mm for a group of piles whichever is earlier.

So, two things are there for let us say if I talk of a single pile, then there are two criteria that either 1.5 times the safe load, which you have found out from static pile load formula or the load corresponding to which it has attained 12 mm settlement. So, whichever is the condition, whichever occurs earlier that much load you should, this working pile should be subjected to; however, in case of group of piles the two criteria are either 1.5 times the safe load or 40 mm vertical settlement.

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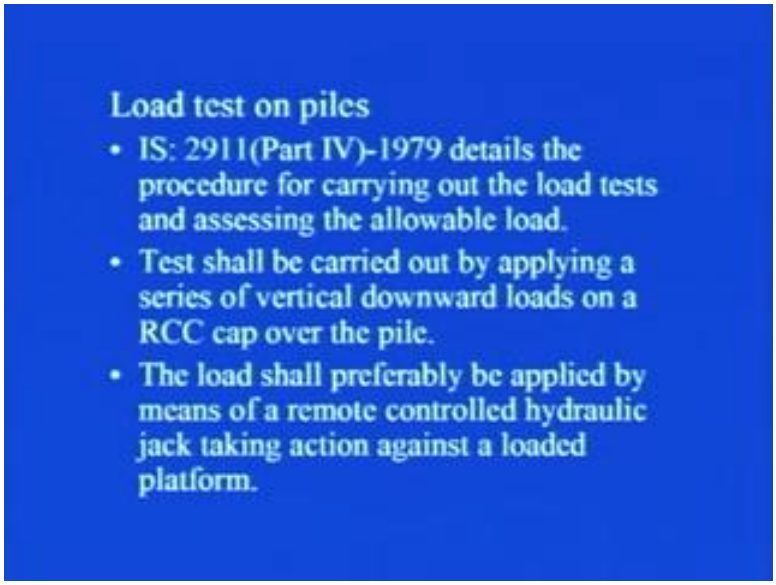

So, this IS 2911 part 4 1975 deals with the details of the load test on the piles, that is it gives the procedure for carrying out the load test and assessing the allowable load, that is the in first how to carry out the test, what are the various specifications of the test and then what how you can interpret the test data. It says, the test shall be carried out by applying a series of vertical downward loads on RCC cap over the pile.

So, you have to provide the RCC cap, that is some of the part of the pile should be above the ground surface to act as RCC pile, RCC cap or separately this RCC cap should be casted monolithically with the pile to conduct the test. The load shall preferably be applied by means of a remote controlled hydraulic jack taking action against a loading platform the or loaded platform. But, this is what is the case that it should be, now that the question is it how it is conducted there at site.

So, I have been to one particular site where this initial test was being carried out and what was the arrangement made for the for mobilization of the load and how the load is being applied because, there this remote control machine was not available to apply the load. So, the load was applied with the help of a hydraulic jack, so how it is done I will just show you to give you a feel of the same.

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So, you see here this is what is the loading arrangement for pile test, you can see here that the girders are placed in this at regular interval to frame a loading platform. And on which these bags filled with soils they are placed, you know that in usual language they labors they call it as ((Refer Time: 30:48)) So, all these bags, they are filled up with soil and the weight of each bag is approximately 30 kg's or so.

Then, you can see that how systematically and nicely they have been put over one another, you can imagine that it is of the height of a 4 storey building. So, even though a one particular bag slips on the another one and if there is little bit of the what should I say, the relative movement of these 2 bags. Then, how catastrophic it can be because, the test or the test arrangements are to are done below approximately in a 2 meter test pit, which as a like 2 meter deep test pit, there this pile cap and then loading arrangement and dial gauges, they are being done I will show you in the subsequent slides.

So, you see how important it is to have I mean to have this kind of arrangement and the proper arrangement. Because, even slight relative movement of these bags can cause big accident, first thing is that there should not be any relative movement of these bags, then there the load which is coming from this particular arrangement to the loading platform, which is this one it should be uniform, there should not be any eccentricity.

Because, as the eccentricity is there the whole thing will get collapsed and the persons who are working in that test pit which is 2 meter deep, it can become catastrophic for them. Then, you see that once they place this first layer, then you see that they make an

arrangement to go what exactly is that arrangement to go till the top, they just put two you know bamboo ((Refer Time: 32:49)) here, they put the soil bags on top of that to make a platform and then they go on putting bags one over the other.

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You see this is another view of that loading arrangement because, you know at a time you have to mobilize lot of I mean quite heavy amount of load, depending on the type of the structure, this is what is in the test conducted at a site, where the cement plant was coming up. So, in case of cement plant all the heavy structures they come up, so load coming on the pile they are quite high, so you have to mobilize that much high load, so for that you have to have that much of the bags.

So, that the total load of this bag is such that, that the whole of the load when it is mobilized, that should be sufficient enough for the pile. Such that, it can reach till the 1.5 times the safe load capacity or it can attain 12 mm vertical settlement in case of a single pile.

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This is another view, so you can have a feel here, that here is this, this is the ground surface, where this jack has been placed. And then from there some of these bags have been made from all the sides, all the four corners and then on top of that these girders have been placed in both the direction, that is one particular direction and then the in perpendicular to that particular direction. And then, these bags are systematically placed there should not be any eccentricity to avoid any kind of accident.

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Then, here you see I am showing this with the help of this arrow, as I told you that it should be remote control machine to mobilize this particular load, but usually those

sophisticated machines are not available in India. So, this is what is the hydraulic jack and a person mobilizes this load from this particular loading, pattern to the pile which is their below the 2 meter deep pit. So, with the help of these hydraulic jack, there is one dial gauge which is here from there you can read that how much load is being mobilized to the pile.

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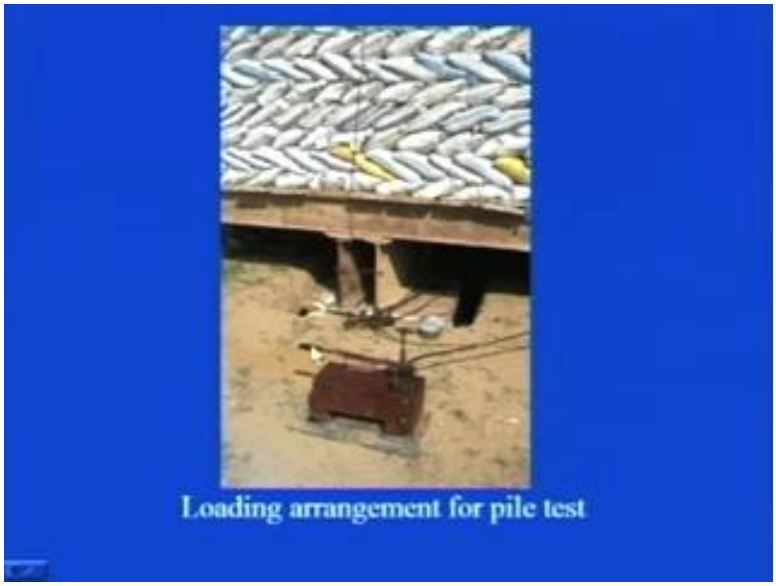

So, you can see here this is a closer view of that, hydraulic jack this is what is a dial gauge. So, as you press this lever again and again as this fellow is doing you see he hill just press it down again and then lift it up and press it again, so in this particular case you see this is the lever by doing that particular process of lifting the lever again and then pushing it down. The load is mobilized from this particular assembly to this and then with these girders to the pile arrangement over there, and then whatever load is being mobilized you can read from this particular dial gauge.

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So, you can see here earlier you saw the arrangement which has to be done for conducting this initial test, above the ground surface. Now, how that particular load is being transferred to the pile that you can see here in this particular picture, that this is what is the pile cap that is above the existing ground surface over here, in the pit and then minimum of three dial gauges are to be provided to measure the settlement corresponding to any particular load.

So, you see here one dial gauge one two and then third one is mounted here, it is not visible in this particular view. However, it is here, this tube is used for transferring or mobilizing the load from top to this pile cap, this plate has been placed just on top of this pile cap. So, that when the load comes from the top it gets uniformly distributed on that pile cap, and then you can see that another plate is being provided here on top of these two hydraulic pumps to have the uniform pressure distribution, just to have uniform pressure distribution.

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This is what is another view, you see now this third dial gauge is visible here in this case, while the other two are not. Exactly, in the similar manner this is what is your pile cap, you know we have to go inside from the ground surface to inside that pit and then it is I mean it poses great difficulty to read all the three dial gauges. Because, you have to have proper, light arrangement over there to read them and then you always have a danger because, that much of the load is there on your top, and then this is another view of the same that is test arrangement with dial gauges.

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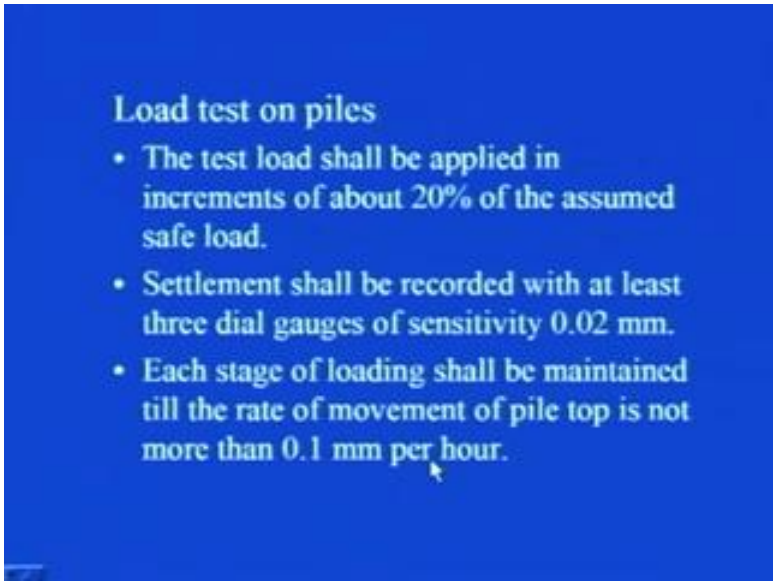

So, this was what was the arrangement, now how it works let us discuss that, the test load shall be applied in increments of about 20 percent of the assumed safe load. See, what happens is it is not that, let us say the safe load is around 500 kilo Newton, so it is not that in one particular go you apply all the 500 kilo Newton, you have to apply that in steps. Then, only you first you apply in one step, you give some time to pile to settle once it stops settling and then only you have to apply another increment.

So, how you can decide upon those increments, some guidelines have been given that the test load which is to be applied in increments of about 20 percent of the assumed safe load. So, if 500 kilo Newton is your assumed safe load, then 20 percent of that you have to applied in first increment, then you have to wait for some times, so that the pile can attain the whatever is the settlement corresponding to that 20 percent of the increment and then you have to apply next 20 percent of the increment.

Then, settlement shall be recorded with at least three dial gauges of sensitivity 0.02 mm, so you have seen that usually four dial gauges should be placed. But, minimum three they are required and you have seen that how they are to be mounted there on the plate and the pile cap. So, that they can measure directly the settlement the vertical settlement of the pile cap, each stage of loading shall be maintained till the rate of movement of pile top is not more than 0.1 millimeter per hour.

So, as I told you earlier that after every loading you have to give the pile sufficient time, so that it can settle down and then the further settlement of the pile, under that particular load should not occur. So, for that matter how will you decide upon that now the vertical settlement or the total settlement at that particular load has already taken place.

So, for that a guideline has been given, that when each stage of loading after it each stage of loading, you have to maintain the load till the movement of the pile it is not more than 0.1 millimeter per hour. So, till the point it is more than 0.1 millimeter per hour, you have to keep on waiting after applying that particular load increment.

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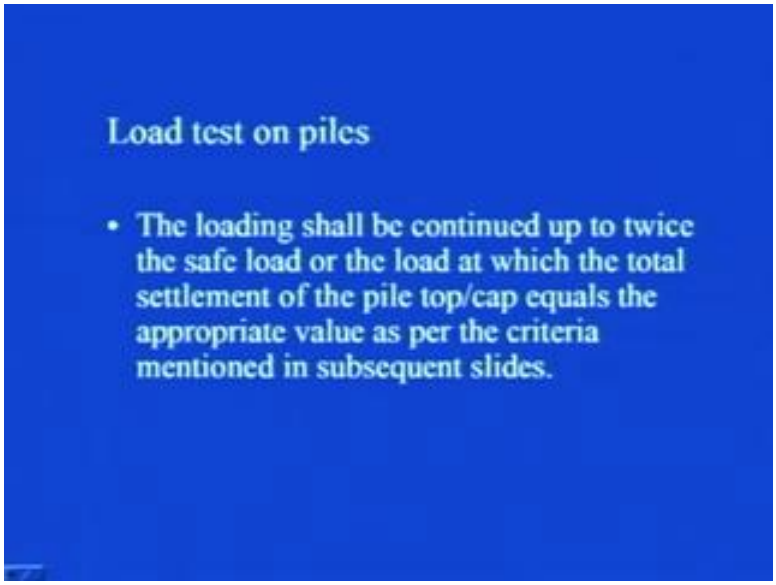

Then, the loading shall be continued up to twice the safe load or the load at which the total settlement of the pile top or cap equals the appropriate value as per the criteria, which is mentioned in the subsequent slides. So, the thing is that till what point we can go on increasing the load on the test pile or for the load for the initial test. So, there are some guidelines, which are available by IS code or may be by experience of different research workers, engineers, etcetera, what are they let us try to have a look on them.

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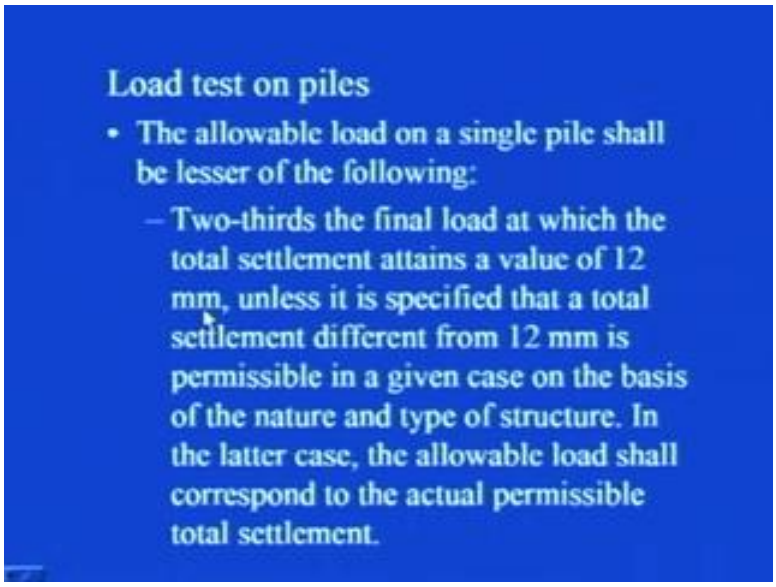

So, when it is a single pile, so the allowable load on a single pile shall be lesser of the following. See, these are all the things that you do not need to remember, it is just said

whatever I am telling you just go on noting them down because, all these things are available in standard text book. So, you do not have to remember all the things, first is 2 3rd of the final load at which the total settlement attains a value of 12 mm, unless it is specified that a total settlement different from 12 mm is permissible in a given case on a basis of nature and type of the structure.

What does this mean is that, whatever is the final load that is whatever is the safe load that you have estimated from static pile load formula 2 3rd of that load, at which that total settlement attains a value of 12 mm. Now, this 12 mm is not a hard and fast rule if there is nothing mentioned as far as any pile load test is concerned, you should take the value of settlement of to 12 mm. But, if depending on the type of the soil and the type of the structure, if this settlement value is being mentioned, that instead of 12 mm you have to take that mentioned value.

In the later case the allowable load shall correspond to actual permissible total settlement. So, if 12 mm settlement is not mentioned that is the total settlement of something else, some else magnitude that is let us say for say 20 mm or 30 mm is mentioned depending on the type of structure and type of soil, then in that case you have to take the allowable load corresponding to that particular settlement, not the 12 mm.

So, whatever is mentioned you have to take the load corresponding to that, if nothing is mentioned, you take corresponding to the 12 mm settlement. And if some settlement value has been mentioned depending on the type of soil and the structure, you have to take allowable load corresponding to that much of the settlement.

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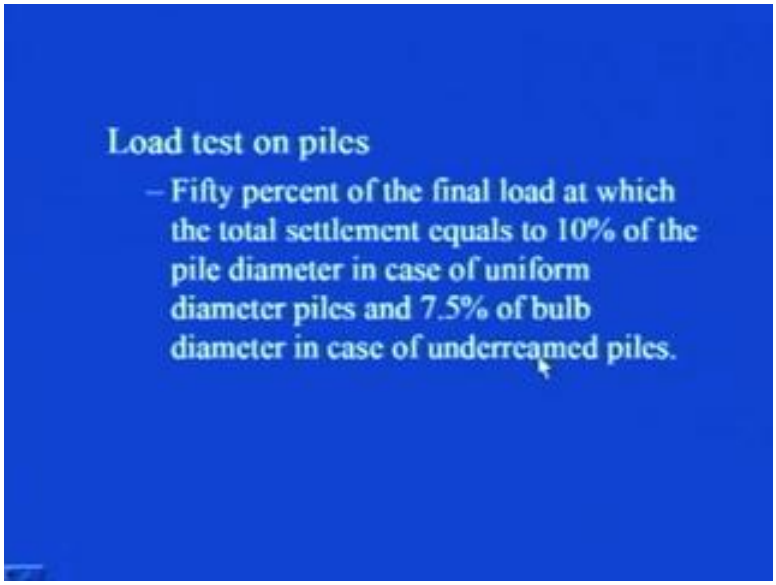

Then, 50 percent of the final load at which the total settlement equals to 10 percent of the pile diameter, in case of uniform diameter piles and 7.5 percent of bulb diameter in case of under reamed pile. So, first case was that 2 3rd of the final load, the second condition is 50 percent of the final load at which the total settlement attains equal to the value of 10 percent of the pile diameter.

So, if the pile diameter is 1 meter, then in that case point whenever you achieve that 0.1 meter settlement and the 50 percent of the load corresponding to that, that much you should take as allowable one. And in case of under reamed pile where you provide bulbs, there this is 7.5 percent of bulb diameter.

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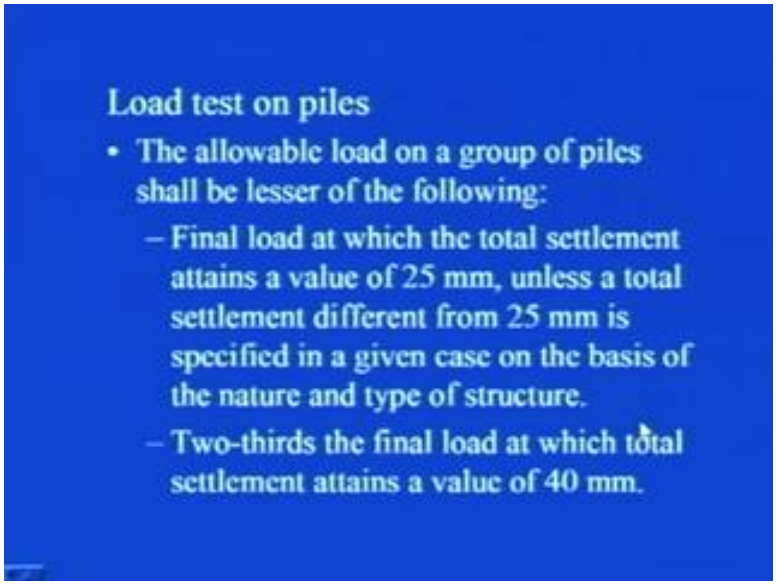

Then, the allowable load on a group of piles, earlier we discussed for single piles in this case group of piles. So, what can be the thing, the lesser of the following that is as we discussed that there were two points in the case of single piles, likewise here also you have few points. And then, from these different, different criteria you will find out the allowable load corresponding to each criteria, and then whatever is the lesser value of out of these values, that you will pick as allowable load on the pile.

So, final load at which the total settlement attains a value of 25 mm, unless a total settlement different from 25 mm is specified in a given case on the basis of nature and type of structure. As it was 12 mm in case of single pile, in case of group of pile this settlement value is 25 mm, so whatever is the final load where the pile has achieved this 25 mm of settlement or whatever is mentioned depending on the type and nature of the structure, that final load you can consider to be the allowable load as far as this particular criteria is concerned.

Now, let us see what exactly is the other criteria, that is 2 3rds the final load at which total settlement attains a value of 40 mm. See, you are going on applying the load on the pile and then you are measuring the corresponding settlement, so you see that in case the pile settlement has reached to 40 mm. Let us say, that at that particular settlement that is at the settlement of 40 mm, the pile has achieved or the pile is undergoing a load of Q then 2 3rd of the final load at which the total settlement attains a value of 40 mm.

That means, that the allowable load on that particular pile can be 2 3rd of the Q, which where the Q is the load corresponding to the settlement of 40 mm. So, these are the two criteria, that first one is whenever this achieves this 25 mm or let us say for depending on the nature and the type of the structure, if it has been mentioned that particular settlement is 30 mm.

Then, you have to consider the final load corresponding to that 30 mm or and that second one is 2 3rd of the final load at which the total settlement attains a value of 40 mm. All these things will become more clear, when we will solve one or two example based on these load test.

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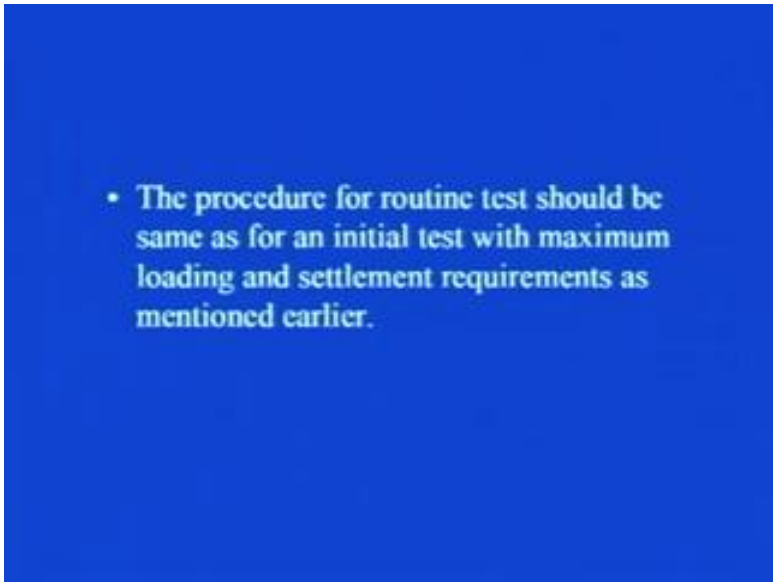

The procedure for routine test should be same as for an initial test with maximum loading and settlement requirements as mentioned earlier. So, this was all the details that we were discussing, they were related to initial test; however, for routine test also exactly the same guidelines to be followed. Now, this was the monotonic kind of load test that we were talking of, now this cyclic pile load test, why it is necessary, why what are the main features of this particular type of test, let us try to see one by one some of the salient features of cyclic pile load test.

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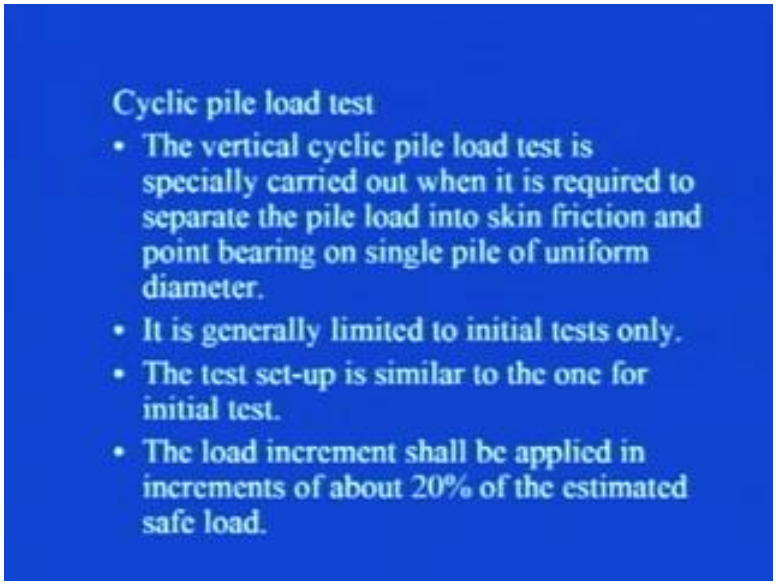

The vertical cyclic pile load test is specially carried out when it is required to separate the pile load into skin friction and point bearing on single pile of uniform diameter. See, many a times it becomes necessary that what exactly is the amount of the load, which is coming from the super structure to the pile is getting resisted by friction resistance and what exactly is the amount, which is getting resisted in point bearing.

So, when these two you need to know separately, then usually the cyclic pile load test is carried out. Further, in the case where the foundation of such a structure is coming up, where the type of the load which is coming on the foundation is cyclic in nature, like foundations for machines there also the cyclic pile load test is conducted.

It is generally limited to initial test only, it is the test set up and everything is similar to initial test is the only difference in which the loading is being done. The load increment shall be applied in increments of about 20 percent of the estimated safe load, as it was there in case of monotonic loading also.

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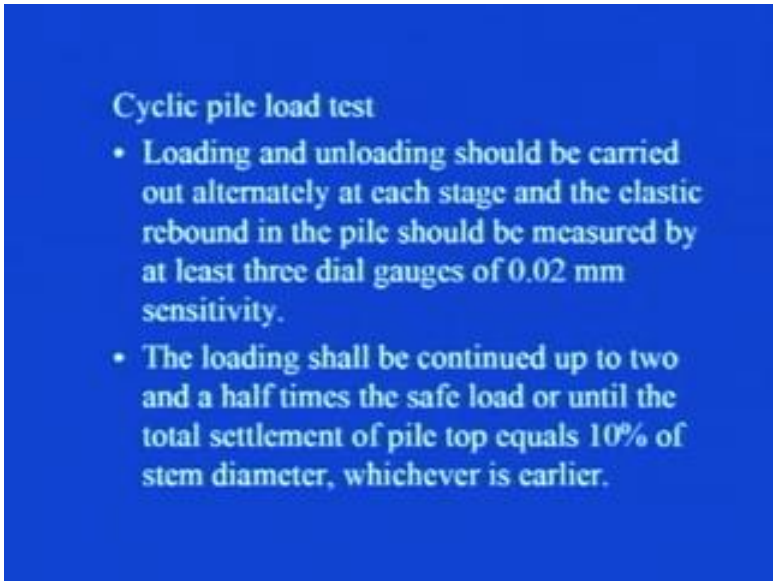

In this case the main difference is that, that once the loading is being done after that unloading is also done. So, the loading and unloading should be carried out alternately, at each stage and the elastic rebound in the pile should be measured by at least 3 dial gauges having 0.02 mm sensitivity. So, once let us say 20 percent of the increment of the load has been applied, once it attains that 20 percent of the load it has to then the load has to come down to 0, that is unloading has to be done.

And once the load becomes 0 from that point next 20 percent of the increment, that is total of the 40 percent of the increment is being applied to the pile and so this cycles are repeated. The loading shall be continued up to two and a half times the safe load or until the total settlement of pile top equals 10 percent of stem diameter, whichever is earlier. So, 2.5 times the safe load which you can find out using static pile load formulae that you can apply, the thing is it all whole of this load you have to apply till in loading and unloading cycles.

So, how will you decide upon that how many loading or unloading cycle that you need to go for. So, for that purpose this guideline that 2.5 times the safe load or until the total settlement of pile top becomes equal to 10 percent of the pile diameter has been given. So, let us say that at two times the safe load you are attaining this 10 percent of the stem diameter or may be that even after 2.5 times the safe load, you have not attained this 10 percent of the stem diameter settlement.

Then out of these condition, whichever is occurring earlier corresponding to that condition the load whatever is the load, that should be the maximum load at the pile top.

If, let us say may be around three times the safe load the settlement, this settlement has not yet reached to 10 percent of the stem diameter, then you have to take this 2.5 times the safe load. And in case if this 10 percent of the stem diameter settlement has already occurred at two times the safe load, then corresponding to that particular settlement you have to take the load on the pile.

So, today we saw the two examples, one was there for pile driven in sand and one was there for pile driven in clay, that how you can estimate the load carrying capacity of a pile in compression using the static pile load formula. Then, we started with the pile load test and we saw that why these tests are more reliable, as far as estimation of capacity of the pile is concerned because, they are in situ test. Then, we saw that two types of tests were there, initial test and routine test, initial test were conducted on test piles; however, routine test were conducted on working piles.

Test piles were the piles, they were not taking any part in sharing the load which was coming from the super structure. However, a working pile shares the load which comes from the super structure, then we saw that what should be the test arrangement, what are the various IS specifications for these type of test. Then I shared some of the some of my experience at one particular site with you, as far as this initial test is concerned.

And then we started with this cyclic pile load test, that why exactly it is necessary and what is the difference between the cyclic pile load test to the monotonic loading pile test. So, we will be seeing more details of the cyclic pile load test in the subsequent lectures.

Thank you.