Foundation Engineering
Prof. Kousik Deb
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture – 35
Pile Foundation – IX

So, last class I have discussed about the pile load test. Now this class I will discuss how I will get the allowable bearing capacity of a pile form the obtain load verses settlement curve based on the IS code.

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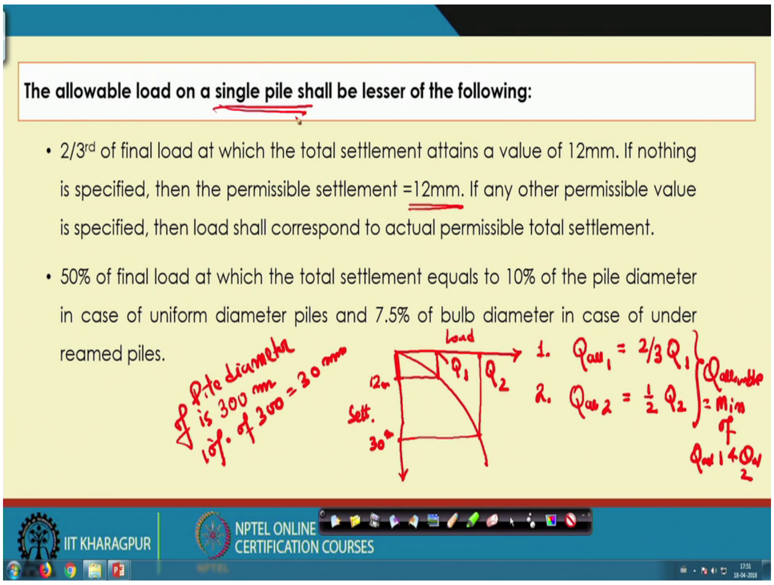

So, as I mention the as per the IS code the allowable load on a single pile shall be lesser of the following. So, carefully you read these 2 clauses that two-third of final load at which total settlement attains a value of 12 millimeter if nothing is c pile then the permissible settlement of a single pile is 12 millimeter. Or if any other permissible value is specified then load shall be corresponding to that actual total settlement.

That means, if we have a load settlement curve like this is load and this is settlement suppose that this is the 12 millimeter settlement. So, you have the corresponding load is Q 1 ok. So, it is saying that first case your Q allowable one is equal to two-third of Q 1, if nothing is specified then 12 millimeter will be treated as a permissible settlement of single pile ok. And thus clause 2 this clause 1; and the clause 2 is 50 percent of final load at which total settlement equal to 10 percent of pile diameter in case of uniform diameter pile or 7.5 percent of bulb diameter in case of under reamed pile suppose if you have a pile diameter of 300 millimeter ok.

So, suppose if the pile diameter is 300 millimeter then 10 percent of 300 millimeter 10 percent of 300 millimeter is equal to 30 millimeter. So, suppose this your 30 millimeter. So, you have the corresponding load is Q 2 ok. So, as per the second clause your Q allowable 2 is equal to 50 percent of that Q 2; so, half of Q 2. So, your Q allowable will be minimum of Q allowable one and Q allowable 2 ok.

So that means your Q allowable load carrying capacity of the pile minimum of these two load. So, this is the clause as per the IS code. So, will use this clause to determine the allowable load carrying capacity of a single pile, this is the clause for the single pile ok.

Now, next clause for the group pile, this for the group pile.

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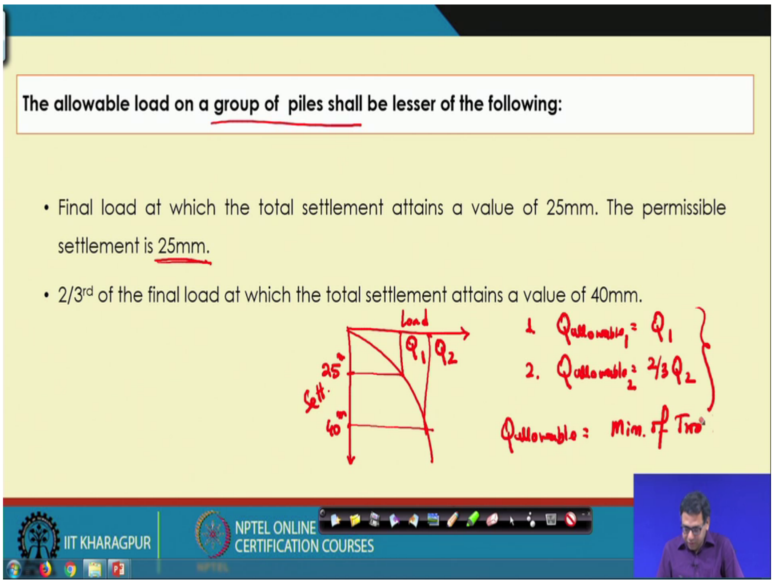

The similar type of piles, the final load at which total settlement attains the value 25 millimeter; if nothing is specified the permissible settlement for the group you can take as a 25 millimeter.

So that means, that suppose you have a load buts the settlement curve ok. So, this buts load verses settlement. So, you have this is say 25 millimeter. So, this is the Q 1. So, as per the clause 1, your Q allowable is equal to Q 1 as per the clause 1. And two-third of the final load at which total settlement value is 40 millimeter. Suppose this is 40 millimeter, so, this Q 2 as per clause 2 Q allowable is two-third of Q 2 ok. So, your actual Q allowable, this is Q allowable 1, this is Q allowable 2 is minimum of these two ok. So, minimum of these two will be your Q allowable; so, this for the group pile.

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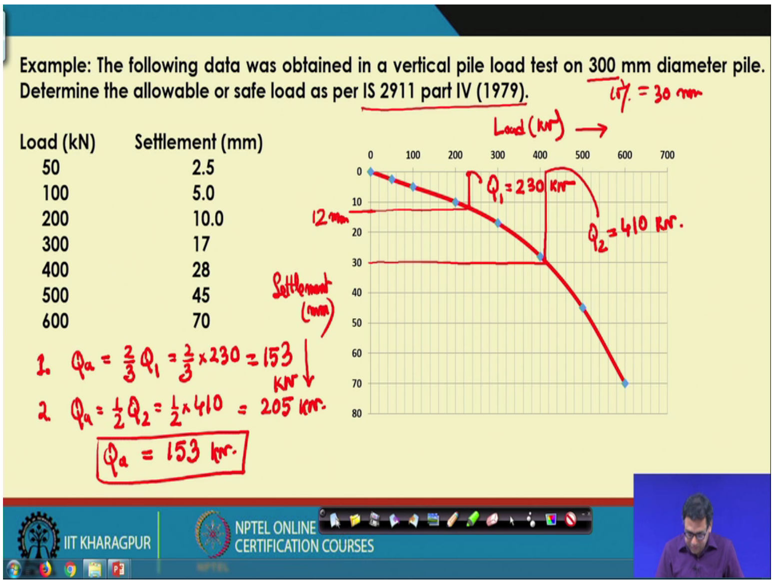

So, now, I will solve the one problem on a single pile. That the example problem is the following data was obtain in a vertical pile load test on 30 millimeter diameter pile. Determine the safe the; determine allowable or safe load as per IS to 911 part 4 1979, though those clause are form this code ok. So, those clauses form this code.

So, this is the load which was applied 50 00, 200, 300, up to 600 and this is the major settlement ok. So, I have drawn this curve. So, this is the load which is kilo Newton and this is the settlement which is millimeter ok. So, this is the kilo Newton in this side settlement in down word direction. So, this is the curve you can see corresponding to 600, this is the 70 millimeter is the settlement.

So, my first clause as per IS code is that two-third of 12 millimeter, I mean load corresponding to 12 millimeter, we will take two-third of that. So, my 12 millimeter is this is the 220, this is 20. So, 12 millimeter is somewhere here ok. So, this is 12 millimeter ok. So, this is 12 millimeter. So, corresponding load is this one. So, my Q 1 is equal to 230 kilo Newton. So, the clause 1, I will take that my clause 1 the Q allowable is equal to two-third of Q 1. So, two-third Q 1 is 230. So, this equal to 153 kilo Newton this is clause 1, Now second clause the 50 percent of load corresponding to the settlement of

10 percent pile diameter. So, pile diameter is 310 percent of the that is 30 millimeter it is 300 millimeter 10 percent is 10 percent is equal to 30 millimeter. So, 30 millimeter is here. So, the corresponding load is here. So, this is the corresponding load or this is the Q 2 which is equal to 400 this is 400 this is 10 410 kilo Newton. As per clause 2 Q allowable is equal to 50 percent of Q 2, so, this half into 410.So, that is equal to 205 kilo Newton ok.

So, your Q allowable will be equal to minimum of this two, so, 153 kilo Newton. So, form the pile load test I am getting the Q allowable value directly is 150 ton; 150 kilo Newton ok. So, this similar way we can determine the allowable load carrying capacity of group pile also ok. But these test are only continuous test, because here data is continuous you can see. So, here I will get only the Q allowable, but I do not know; what is the contravention of tip resistance and the friction resistance separately in this 153 kilo Newton. But if I want to know the separately the friction and the tip resistance then I have to take the help of the cyclic pile load test data ok.

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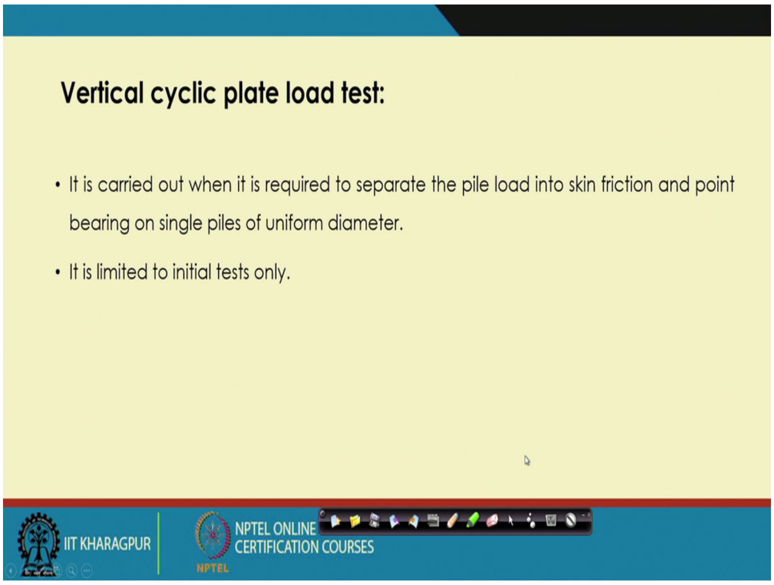

So, the next part I will discuss that how I will use the cyclic plate load test data and from there I will get the friction and the tip resistance separately ok. So that means, it is required when it is carried out when it is required to separate pile load into skin friction and point bearing ok, that mean the skin friction resistance or instance form the skin friction and the bearing on a single of uniform diameter it is limited to the initial test only ok.

So that means it is on the test pile only. So, what is the process and how I will cyclic pile load test.

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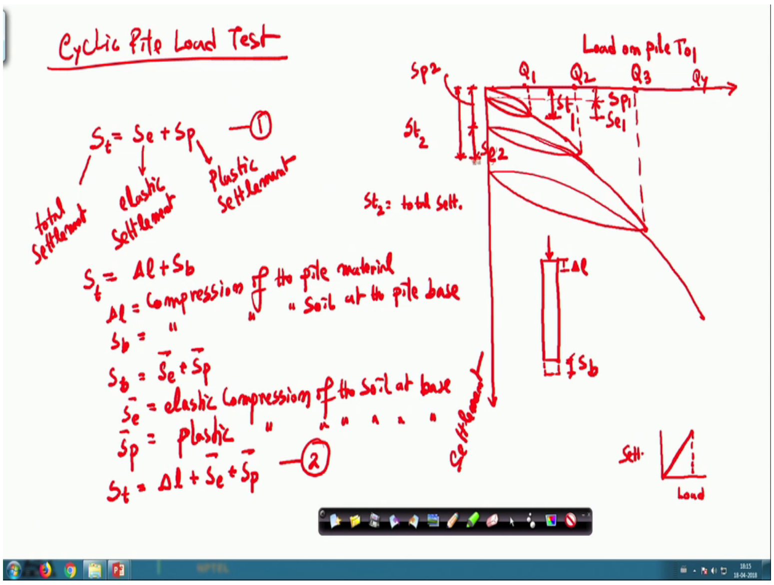

So, we have suppose this is our load verse settlement plot ok. So, this is the load which is applied on pile top and this is the settlement ok. So, as I mention that you are applying the first increment. So, that increment is a Q 1, Q 1 is the first increment. So, your load will be this is the loading part. Now you will go for the unloading part you are load that Q 1, then will apply the second increment that is Q 2, again you apply the loading ok, then again you will unload this part. Then you will apply the third increment Q 3 ok. So, you applied the third increment again you will unload that and so on.

So, this is the cyclic test loading versus the settlement plot. So now this is the; if you look at this settlement plot the load settlements plot that when you are unloading this load some settlement is recovered. Because for example, if I go to the Q 2 part. So, the suppose this is the during the loading your total settlement is this one, if I taking the second part this is the say S t 2; S mean the settlement t is the total, 2 is the first second increment or second applied load.

So, this is the S S t 2 is the total settlement ok. Now, when we are unloading this, now when it is 0, it is not going to the initial position again, there is some deformation. And that is the permanent deformation that is your, this much amount. So, this is and then sum amount is this much amount. So, if the total settlement; so that means, there is some recoverable settlement. So, that settlement is called the plastic settlement. So, and the portion which is recovered is called the elastic settlement.

So, now, if we have say load verses settlement curve. If this is like this and if you unload this then it will come back again then this total settlement is called the elastic settlement ok. So that means, the elastic settlement is the portion which is recovered and the plastic settlement is the permanent settlement which is not recovered ok, it is the permanent deformation. So, here also this total settlement it has 2 part: one is the plastic settlement and one is suppose this S p 2 plastic settlement or then sorry this is S S p 2 is this 1 S p 2 is this 1, this is S e 2 because this is a elastic settlement which is recovered S e 2. Similarly, for 1 also this is the, suppose this is the total settlement S t 1 and this settlement is not recovered.

So, it has 2 parts. So, this one is called S t 1 and this is S e 1 S e elastic settlement means the settlement which is been recovered and plastic settlement the settlement which is not recovered that is a permanent deformation. You can see there is always a permanent deformation as you increase the load ok. So that means, here this portion of settlement is recovered. So, it is elastic and this portion settlement is not recovered which is plastic. Similarly here, this portion of settlement is recover which is elastic and this portion of settlement is not recover which is plastic.

So, I can write that the total settlement is S e plus S p. So, S or you can write S t, S t is the total settlement S e is the elastic settlement, S p is the plastic settlement know this total settlement I can write in this way that is the del l plus S b. Now what is del l? What is S b? So, the total settlement that I am getting I do not know that what is the amount of deformation of the pile and what is the amount of deformation of the soil below the base of the pile, because when I am applying a load on a pile. There is a possibility, the pile material can settle and the soil below the tip of the pile that will also settled. So, this is total settlement in the summation of the pile material settlement and soil below the tip of the pile settlement, ok.

So, that I have written S t is the del l is the where del l is the compression of pile compression of the pile or the pile material on the pile material and S b is the compression of the soil at the pile base. So that means, if this is a pile if we apply the load. So, pile material can settle that is del l and the pile is soil can settle also that is your S b. So, the total settlement is the summation of S b and del l. So, S b can be again S e bar plus S p bar. So, the soil settlement it has also compress elastic settlement part and the plastic settlement part it has 2 component because in the soil also it can be the elastic it can be the plastic.

So that I have written that S b is also the elastic part and the plastic part. So, where your S e bar is equal to the elastic compression of the soil at this or pile base and S p bar is the plastic compression of the soil at base. So finally, I can write that S t is equal to del l plus S e bar plus S p bar ok. So, this is my one first equation number 1; this is equation number 2 ok, this is the elastic settlement of total including. So, what is the difference between S e and S e bar, S e bar is the elastic settlement of the soil only and S e is the elastic settlement of the soil and pile material.

S p is elastic settlement of soil and pile material and S p bar is the sorry, S p is the plastic settlement of soil and pile material and S p bar is the plastic settlement of soil only.

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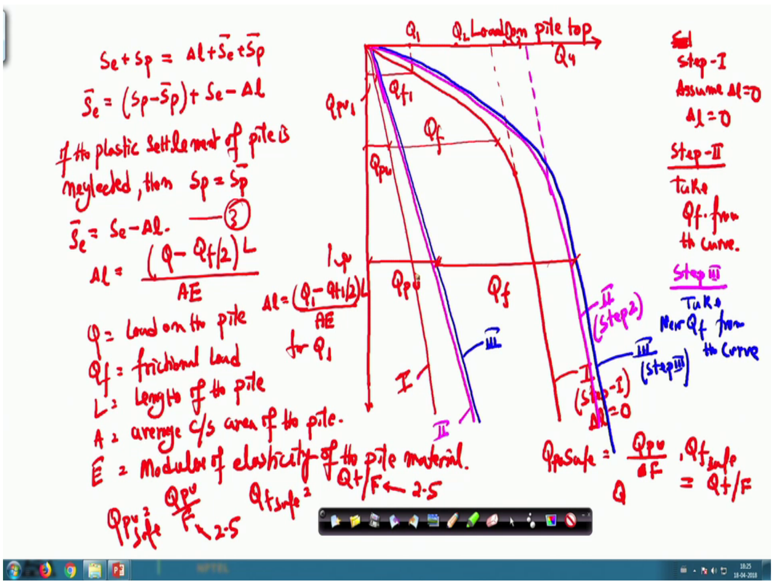

So, if I compare these 2 equation: 1, then I can write that S e plus S p this is equal to del l plus S e bar plus S p bar I can write that ok. So, form here I can write S e bar is equal to

S p minus S p bar plus S e minus del l and it is quite obvious that the when we apply the load on a pile the pile settlement will never reach the plastic step soil because pile is a very rigid material. So, when you apply the load, so, it will never reach to the plastic state it may reach to the elastic generally.

So, that mean the pile settlement is always recoverable ok. So that means, the plastic settlement that you are getting the total plastic settlement that plastic settlement is due to the soil only because pile we are assuming that that pile will never be in the plastic zone. So, that in the so; that means, here pile material. So, plastic settlement if the plastic settlement of pile is neglected name definitely S p will be equal to S p bar because all the plastic settlement is due to the soil plastic settlement.

So, I can write these equation S e bar because this will be 0, S e minus del l. So, S e, I will get from the low settlement curve. So, S e I will get from the low settlement curve corresponding to different cause this is the S e or this S e value for first load increment Q 1. This is the S e value that I will get for the second load increment; this is the S e value. So, this S e value I will get from this curve that I will get from the lost in final product of the cyclic load test. So, S e value I will get from the curve, but del l value how will get the del l is the compression of the pile material ok.

So, del l value I will get by the using this expression del l is Q minus Q f divided by 2 into l divided by A e, where Q is the load on the pile, Q f is the frictional load l is the length of the pile, A is the average cross section area of the pile and E is the modules of elasticity of the pile material which is similar to that apply the E p, apply load t and length is l and A is a cross section is the elastic modulus then you will get that my del l will be p l divided by A E. The similar thing is applied here, but here I have in total load which is Q is apply on the top, but as some friction component is there.

So, it is subtracted that friction component; that means, it is that only that tip component is giving that del l part. So, that is the idea some friction component is deducted. So, that is the expression. So, now, I will do the how I will calculate? I will explain how I will calculate the pile load capacity separately. Now, the next stage; so, what I will do? So, I will take a new curve ok. So, here it will be the load on pile top and here it is S e bar remember that this is S e bar. So, I will get this equation 3, I will get the S e bar S e; I will get from this curve S e, I will get from this original curve and del l I will get from this expression.

So, S e; I am now this curve I am plotting load on pile top versus S e bar. So, first step 1 ok; step 1 assume that that your del l l is equal to 0. The first one assume that del l is equal to 0; that mean del l is equal to 0 if del l is equal to 0, then we have S e bar is equal to S e; S e, I will get from the original curve. So, what I will do? I will draw a graph. So, from the say suppose you have a increment Q 1, Q 2, Q 3, Q 4 and so on. So, form this the original graph corresponding to Q 1, Q 2, Q 3, and Q 4, you will get the S e value that S e value will be equal to S e bar for your step 1 we are assume that del l equal to 0; so, will get this type of curve ok.

So, this is my first curve this is we are getting for step 1 or step 1 I am getting, assuming del l equal to 0, but this is not the actual or correct curve because I have assume the del l equal to 0, but there is definitely some del l value. So, that I have to incorporate in the next trail this is my first trial. I got this curve corresponding to this Q 1, Q 2, Q 3, Q 4, and S e bar. So, what I will do now? So, now, I will draw a line which is parallel to the state portion of this curve. So, we have a state portion of this curve this is the state portion of this curve. So, you draw a line which is parallel to the state portion of this curve.

So this is, draw the parallel to the state portion of this curve fine. So, now, but this is in correct this curve is incorrect because we have assume del l equal to 0. So, this curve this state curve is the parallel curve to the state portion of this curve 1. Now watch this things indicates this thing indicates that for a particular depth this will be your Q p u and this will be the Q f ok, this will indicate this will be this portion of with what does it mean? It means that if you look at this curve that after some certain point this curve is parallel to this 1.

So that means, you are after certain point, your Q f value is not changing only Q p u is changing. So, it means that when you apply a load on a pile first your frictional resistance is mobilized ok, during that portion it is not that u Q p u is exactly 0, but the friction part is first is mobilized then the tip resistance of bearing part is mobilized. So, it you consider depending upon the type of the soil, where you are testing this curve may change is not a drawn it ok. So that means it may not be in the proper scale depending upon which soil you are testing you will get the proper curve.

So, but the procedure I am explaining. So, this is the curves you can see after certain point here suppose these point your friction resistance is the because here the friction resistance, here the friction resistance, this portion the friction resistance, this portion the friction resistance, this portion friction resistance is same. It is not increasing, only the tip resistance is increasing; that means, after this point after this point you are this point your friction is fully mobilized ok. So, then only the tip resistance will increase if you load further. So, this is very important observation that when you up pile a load on a pile first friction is fully mobilized then the tip resistance will starting mobilizing ok. So, that is very important observation.

So, now in the step 2 because this curve is not correct; so what will do in the step 2? Now from this curve at any load, suppose this is my load I can get what is the Q f 1 and what is the Q p u 1 for any loading from this curve? Now you take that Q f for corresponding to Q 1. Now you put this equation; suppose you are doing del l for first loading. So, del l will be Q 1 minus Q f 1 divided by 2 divided by l e and this is l. So, we will get for Q 1 in the step 2 take Q f from the curve. So, corresponding to Q 1 this will be the Q f.

So, you put this Q 1 minus Q f from this curve will take and you will get the new delta 1. Now you put this delta 1 here then you will get a new S e value. Now you plot this curve again ok. So, when you plot this curve again. So, I am using new color. Suppose, if I use the new color, so, I will get another curve which may be like this. So, this is form step 2 and again it has a state line state portion extend that. Then again draw a curve which is parallel to the state portion of this step 2 curve ok. Then in the step 3 again you calculate the f a Q f value from this curve the same way and again you draw another third curve.

So that may be like very close to this one, the blue one is third curve which is getting form step 3 ok, step 3 again take Q f; new Q f this is also a new Q f form the curve and again you draw the state portion of this curve. So, this is number 3 again corresponding to number 3 this is corresponding to 2 this is sorry this is corresponding to 1.

So you repeat this: continue this process always 2 successive curve overlap each other. So, when this is overlap each other, then that is the correct value because you have doing and trial and error process and then any point this things will give you the Q p u and this things will give you Q f; so, will get separately the friction resistance and the tip resistance.

Generally, it is observed that up to after the 3 travels you will get the both the travels are 3 to 4 travels, you will get this; these are overlapping to each other. So, you then from this curve you will get separately what is the Q p u and what is the Q f and that is the ultimate if you will get. If you want to get the safe Q safe Q p u safe then you from this point you multiplied with the factor of safety ok. Similarly, friction also that for the safe you multiply with the frictional force f divided by f ok. So, you multiply it with this force, I have force that you are getting divided with the factor of safety.

So, if you want to get that Q safe then Q p u divided by the f or you can see write here that your Q p u safe will be Q p u divided by the f which is 2.5 and similarly, Q f safe is equal to Q f divided by f which is also 2.5. So, this way we can determine separately that what is the pile resistance, what is the friction resistance and the tip resistance separately for a particular load?

Suppose this is your particular load and from the load this load what is the contribution of the friction and what is the contribution of a tip or bearing that you can get separately from this cyclic pile load test data? So, data discuss and another important thing is that from this study we know that that first your frictional friction resistance is fully mobilized or mobilized then the tip resistance is mobilized that is the very important information you should remember.

So, in the next class this is the pile load test I have finished in the next class. I will discuss the third method by which we can determine the pile load carrying capacity that is the dynamic formula.

Thank you.