Foundation Engineering
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Module - 02
Lecture - 10
Pile Foundations - 5

Hello viewers, good evening to all of you, we were dealing with the Pile Foundations in that one in the last class we saw, that what are the various tests that are to be required to be done in situ, as per as the estimation of pile load carrying capacity under compression is concerned. In that sequence we saw that two types of tests were there, that is initial test and then the routine test, initial test were carried out on test piles and routine tests were carried out on working piles.

Test piles were the piles, which were not taking any part in sharing the load which is coming from the super structure. However, working piles were doing the same, in that order when we proceeded further we started our discussion with cyclic pile load test. In that one we saw that the only difference was that from the earlier case was that the loading as well as the unloading has been done, simultaneously in case of cyclic plate load test. So, what are the various features of this cyclic pile load test that we will see in this particular lecture.

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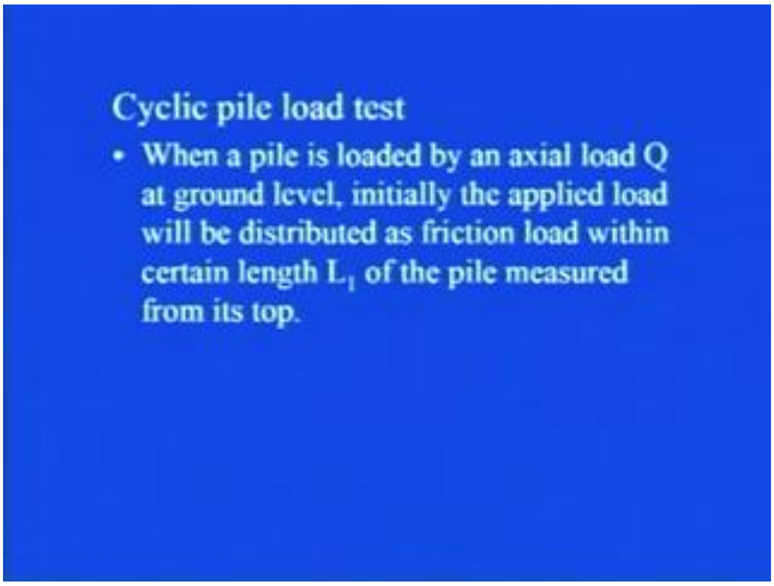

So, the first is that when a pile is loaded by an actual load Q at ground level, initially the applied load will be distributed as friction load within certain length, say L1 of the pile measured from it is top. See when we were discussing the concept of skin friction resistance and point bearing resistance, then also I explained you that how the load transfer mechanism takes place, as soon the load from the super structure starts coming from the super structure to the pile.

So, what happens when the pile is getting subjected to this load from the super structure, that is this let us say the actual load Q at the ground level in this case. Then, what happens is that before going to point bearing resistance, first it mobilizes the skin friction resistance along certain length of the pile. See, at one instance if the friction resistance does not get mobilized all along the length of pile shaft, earlier some small length of the pile incorporates this resistance.

However, with the increase of this load this length goes on increasing towards the pile tip. So, as the load is increased greater lengths of pile shaft will be involved in mobilizing frictional resistance to resist applied load, this in the same lines we can explain this.

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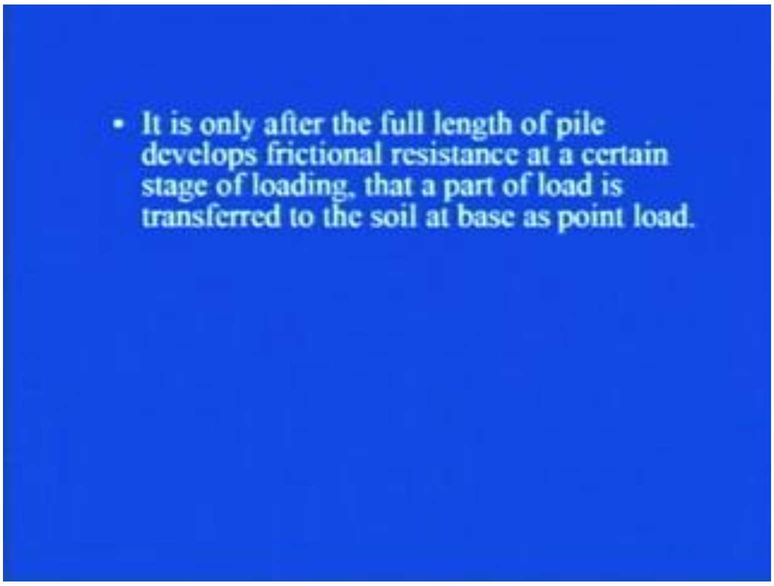

It is only after the full length of the pile develops frictional resistance at a certain stage of loading, that a part of load is transferred to the soil at base as point load. See, when the load is coming on the pile from the super structure, first it is getting mobilized friction, resistance along some particular length of the pile. As that particular load from the super structure goes on increasing, the length on which this frictional resistance is getting mobilized will also go on increasing.

And one situation will come, where the load which is coming from the super structure to the pile will become just equal to the skin friction, which is getting mobilized that is the ultimate skin friction resistance. And once the this total skin friction along the total length of the pile has been mobilized for the any further increase in the load from the super structure, that will get resisted by the point bearing at the base of the pile tip.

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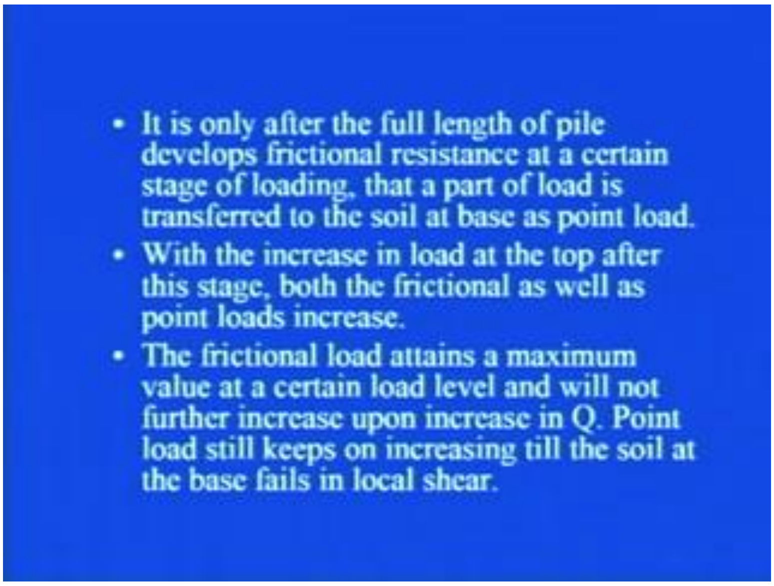

So, with the increase in load at top after this particular stage both frictional and point load will increase. The frictional load attains a maximum value at a certain load level and will not further increase upon increase in Q, see once it has attained that particular value which is resisting all along the pile shaft length, then beyond that, that value cannot increase. So, this there this is no increase in frictional component, once this ultimate skin friction value has been achieved.

So, point load still keeps on increasing till the soil at the base fails in local shear; obviously, whatever load will be coming if you go on increasing, once this has attained that ultimate skin friction resistance; obviously, it will then be going to the point bearing resistance till the resistance of the soil at which is lying at the base of the pile tip.

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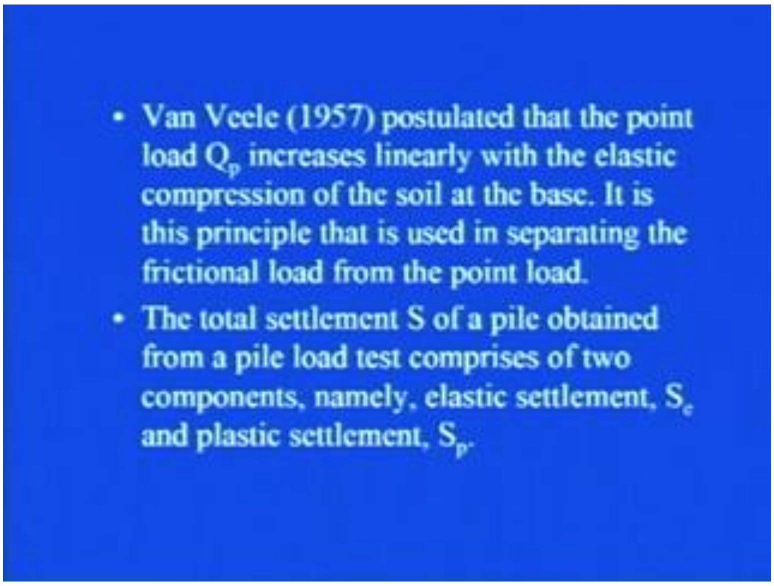

Van Veele in 1957 has postulated that the point load Q P increases linearly with the elastic compression of the soil at the base. It is this principle that is used in separating the frictional load from the point load as far as cyclic pile load test is concerned. As I mentioned you earlier, that this cyclic pile load test is carried out in the situation, where it is necessary to separate out the skin friction resistance and point bearing resistance.

So, Van Veele in 1957 gave a postulation that this Q p increases linearly with the elastic compression of the soil at the base. So, what happens is that, this means that to know this value of Q p we need to establish a relationship between Q p and the elastic settlement of the soil at the base. Because, they have the linear relationship that is they in this Q P increases linearly with this elastic compression, so we need to know this elastic compression of the soil at the base of the pile.

How we do that, that we will see in subsequent slides, so the total settlement of the pile obtained from a pile load test comprises of two components, one is its elastic settlement which I am representing as S e and another is plastic settlement which I am noting by S p. So, this total settlement S will become the summation of these two that is elastic settlement of pile plus plastic settlement of pile and in expression form that becomes S is equal to S e plus S p.

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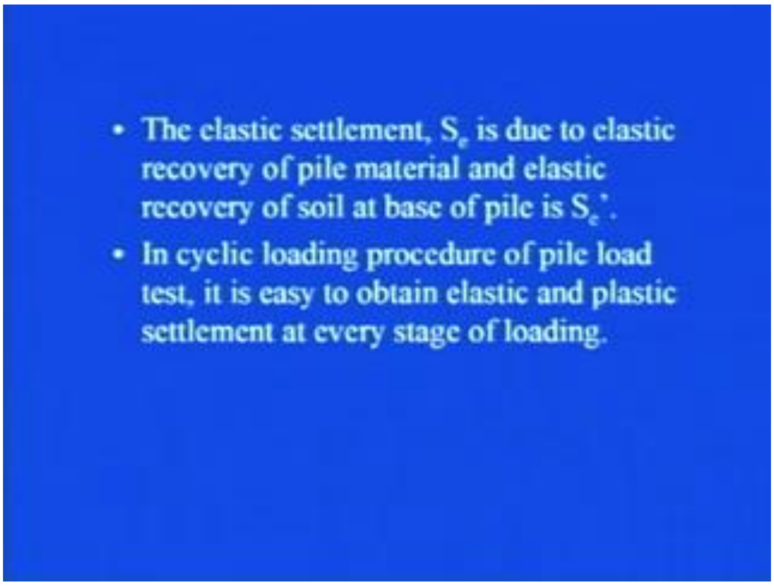

The elastic settlement, it is again having two components that is first is due to the elastic recovery of pile material and then the another one is elastic recovery of soil at the base of pile that is S e prime. So, total settlement of the pile is having two component, one is elastic settlement of pile another is plastic settlement of pile, further this elastic settlement of pile has two component one is elastic recovery of pile material, that is let us say if it is concrete then elastic recovery of the concrete, if it is of timber elastic recovery of that timber material plus whatever is the soil lying at the base it is elastic recovery, that is say S e prime which I am calling in this particular case.

In cyclic loading procedure of pile load test, it is easy to obtain elastic and plastic settlement at every stage of loading. See, you when you are loading you are noting down the deformation corresponding to each load increment, when you are unloading, you are noting down the recovery or whatever is the corresponding settle deformation of the pile in that particular process. Simply, you can plot load settlement curve and then you can get very easily that what exactly is the elastic recovery at every stage of loading.

How it is done, I will show you a pictorial view in the subsequent slide, then it will become more clear to you. If the load on the pile is greater than a particular value say Q s, a part of load will be transferred to soil at the base of the pile and the rest to the soil which is around the pile. See what happens is, once this load Q is coming on the pile, first the skin friction is getting mobilized, when this skin friction is getting mobilized along the full length of the pile shaft, in that case I am calling that as ultimate skin friction resistance that is what is this Q s value.

So, when the load on the pile is becoming more than this particular value some of the load will be shared by point bearing also. So, that is what is written here that a part of the load which is applied to the pile will be shared by this skin friction and remaining part will to the soil at the base of the pile.

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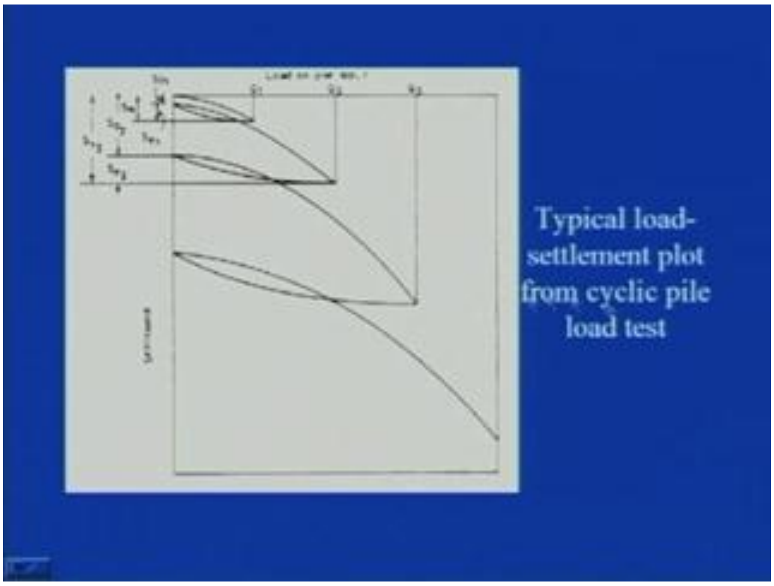

You can see here, this is the typical load settlement plot from cyclic pile load test, this figure I have taken from the relevant IS code. So, it is available there, but I will just show you that you see this is what is the first loading cycle, where this load on the pile top is Q one. Then, once it attains at this particular load, this is the total settlement from 0 to this particular point here on y axis it is settlement, so this much is the total settlement as far as this loading is concerned.

Then, as I told you that in cyclic pile load test loading and unloading both takes place simultaneously. So, after this loading part unloading is done along this path, let us say that unloading is following this particular path, so what is happening, if the behavior of the pile material is purely elastic. Then, during the unloading process the settlement which is coming out to be this much here, this point should have been at 0, that you know that for any elastic material if it is within elastic limit, if you release the stresses which have been applied to that particular thing, then it attains it is original position, here it is not doing.

So, because it is not following this particular path, but it is following this path, so which tells us that it is not purely elastic material, there is some plastic nature also that is why the total settlement of the pile comprises of two component, one is elastic component and an another is plastic component. So, corresponding to this load Q 1 the settlement which was attained was this much and when the unloading has been done, it is coming down to this one; that means, that this much part has been recovered.

So, the point from here to here which has been recovered, this particular part is known as the elastic settlement of pile a for the first loading cycle. However, the remaining one is the plastic settlement, which cannot be recovered, now from here the next increment of the load has been applied to the pile, that is this one. Let us say, that that load increment corresponds to the value Q 2, now for this Q 2 again you will be getting some of the deformation and when the unloading is done, let us say that it is following this particular path, this path.

So, what is the recovery that is from where it is from started, so this becomes the elastic recovery that is corresponding to this maximum settlement, whatever it has recovered. So, this becomes the elastic recovery that is S e 2 for the second cycle and remaining one becomes the plastic settlement of the pile and similarly, for all the loading cycles you can find out, once you plot this load verses settlement curve, you can easily estimate that what is the elastic recovery of the pile.

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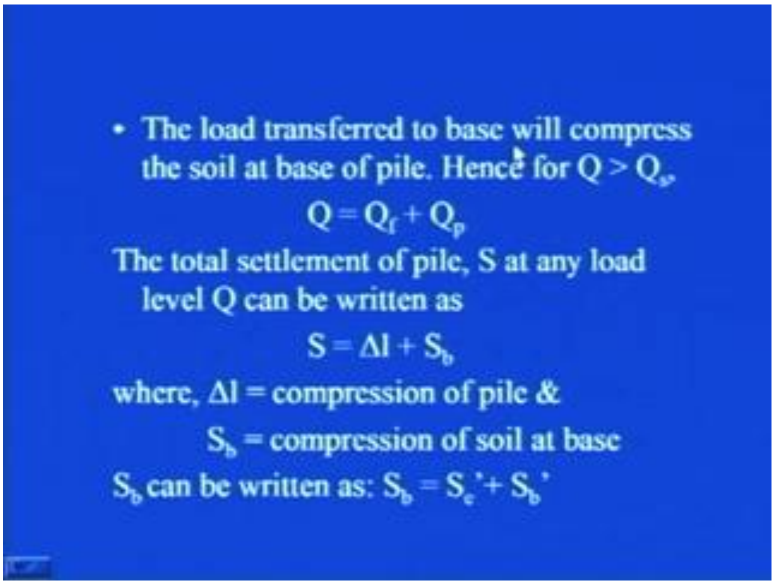

The load transferred to base will compress the soil at the base of the pile; obviously, when the load which is coming on the pile is getting resisted by the pile shaft and then it is coming to the pile base. So, the load; obviously, will be transferring to base will try to compress the soil, which is lying at the base of the pile tip, so hence for Q is greater than Q s that is then only some point bearing will be mobilized, your Q will become Q f plus Q p this is what we have already studied.

The total settlement of the pile, S at any load level Q can be written as S is equal to delta l plus S b, what is delta l is the compression of the pile and S b is the compression of soil at the base. See, whatever is the vertical settlement will be taking place will be due to the compression of the soil, which is lying at the base plus the compression of the pile itself, the total will comprise of the settlement of the pile.

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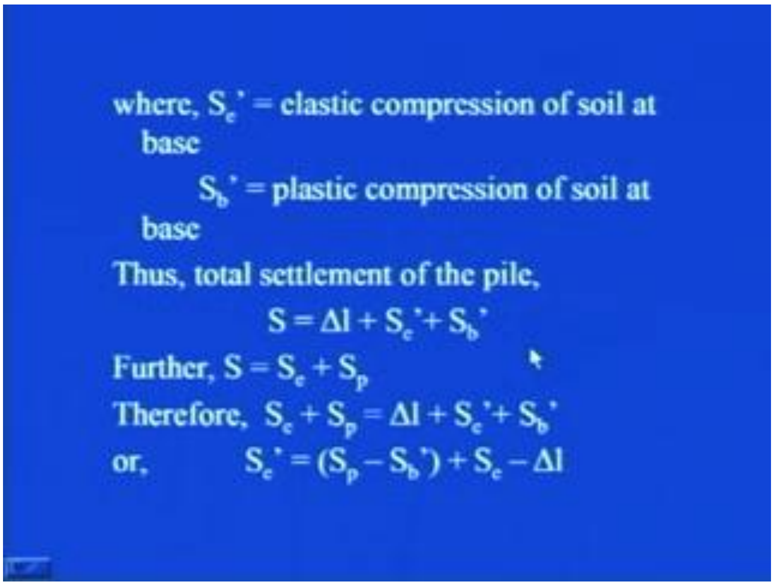

So, and then your S p can be written as S e prime plus S b prime, where S e prime you have seen is the elastic compression of soil at base, S b prime is plastic compression of soil at base. So, your total settlement which was delta l plus S b, S b if you replace by this particular expression, so the total settlement will become delta l plus S e prime plus S b prime. Further, we have seen that the total settlement of the pile comprises of two component, that is elastic settlement of pile which we denoted as S e and plastic settlement of the pile, which was S p.

So, we have this further expression that S is equal to S e plus S p, now let us equate these two, because these two are the same quantities, it is just that we are talking in two different aspects, but magnitude vice they have to be same. So, here see what we are doing is we are trying to find out this delta l because, once we know this delta l which is the this one ((Refer Time: 15:50)) your compression of the pile and we have seen that your Q p is linearly function of this compression of the pile.

So, to know that value of Q p this delta l has to be known and that is why we are doing all these exercise. So, from here we can find out this S e prime, which is equal to your S p minus S b prime see I am combining the plastic component of the settlement together plus S e minus delta l.

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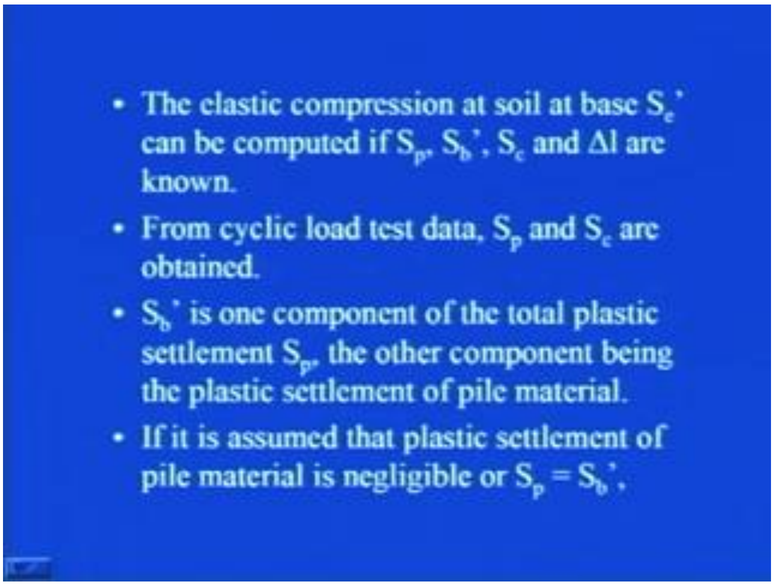

So, the elastic compression at of soil at the base S e prime can be computed if you see here ((Refer Time: 16:34)) it can be computed if all these quantities are known that is S p S b prime Se and delta l. So, from that cyclic plate load test data we can estimate this S p and S e directly, but how about this S b prime and delta l how we can find that out. So, S b prime is one component of the plastic total plastic settlement, which is S b the other component being the plastic settlement of pile material.

And then, if it is assumed that the plastic settlement of the pile material is quiet negligible, then in that case I can say that S p becomes equal to S b prime. So, we can get S p, S e and then S b prime also which I can assume to be equal to S p in case the plastic settlement of pile material is negligible.

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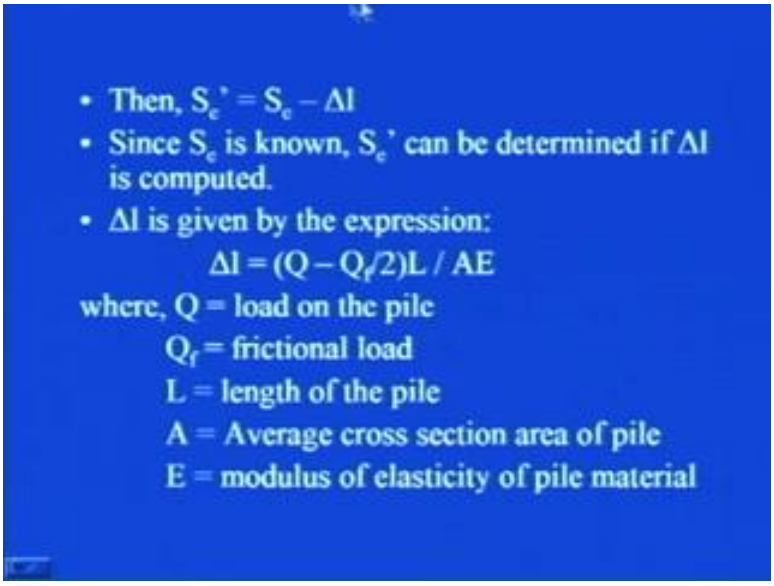

In that case your S e prime will get resulted into S e minus delta l ((Refer Time: 17:39)) you see here that you had four terms, this is known, this is known from and cyclic pile load test data, then this and this was the problem. So, this I assume that it is equal to S b prime, so the resulting settlement that is S e prime will become S e minus delta l. Since, this S e is known S e prime can be determined if delta l is computed, so now how to calculate this delta l.

Delta l is given by the expression Q minus Q f by 2 into L by A E, where your Q is the load on the pile Q f is frictional load, L is the length of the pile, A is area of cross section of the pile that is average area. Usually, the pile is provided which are provided usually they are uniform in cross section, but if it is not uniform then you have to take the average area of the cross section.

And E becomes your modulus of elasticity of pile material, in case if it is concrete that will be the E young's modulus or the modulus of elasticity for concrete, in case of timber it is it will of timber, in case of steel, it will be of steel.

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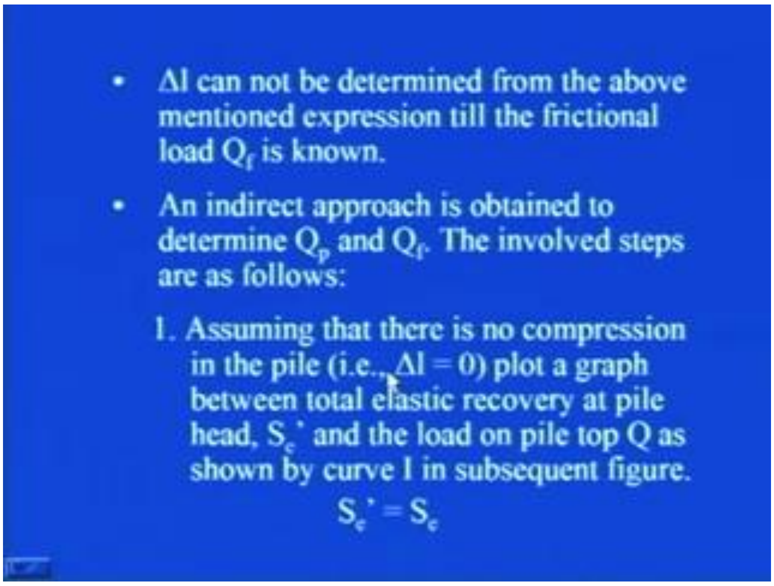

Now, this delta l cannot be determined from the ever mentioned expression till the frictional load Q f is known. ((Refer Time: 19:04)) You see here, this is what is the expression, what we are doing we know only Q we want that Q p and Q f to be known separately. So, to know this delta l we need to know this Q f separately, so how we can do that, that is being explained here. that an indirect approach is adopted to estimate this Q p and Q f separately.

So, some of the steps that we need to follow to know or to separate out these two components. So, the involved steps are first is that assuming that there is no compression in the pile, that is the compression of the pile I am assuming to be 0, which is delta l that is delta l to be equal to 0. We plot a graph between total elastic recovery at pile head which becomes S e prime now, and the total load on the pile top which is shown by curve 1 in subsequent figure.

So, in that case your S e prime will become S e, which you can find out easily from the cyclic pile load test data, as whatever is the settlement which has been recovered during the unloading process that is your S e as I explained you with the help of earlier figure.

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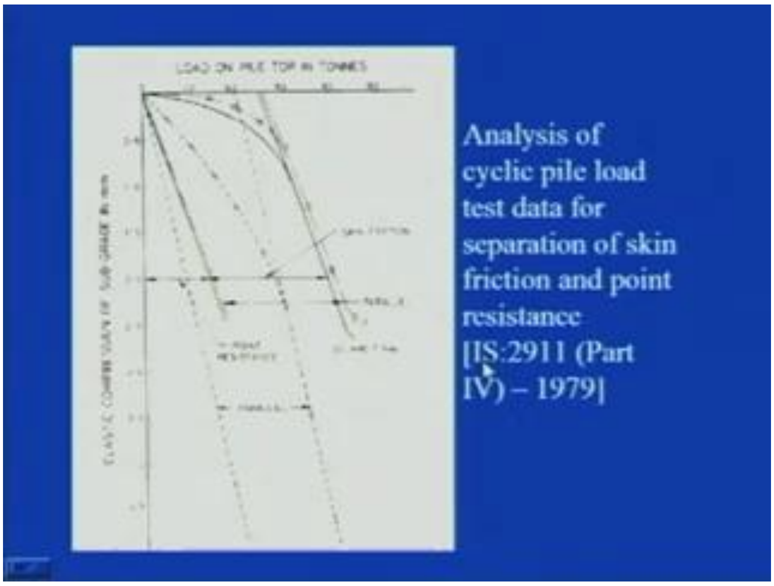

So, you can see here this is a figure which has been taken from IS 2911 part 4, 1979, so this is what is the title is analysis of cyclic pile load test data for separation of skin friction and point resistance. I will say just read out what are the things in this particular figure, on x axis the load on the pile top has been plotted in tonnes; however, on y axis it is elastic compression of sub grade in millimeters.

So, what happens is that ((Refer Time: 21:05)) for the first one we are assuming that there is no compression in the pile, that is delta l is equal to is equal to 0. Then, what we can do, we can plot the curve in with elastic recovery of the pile head and the pile load on the top, this corresponds to a curve 1 you see here, this is what is your curve 1 when you are assuming that no compression in the pile material, this is what is your curve 1.

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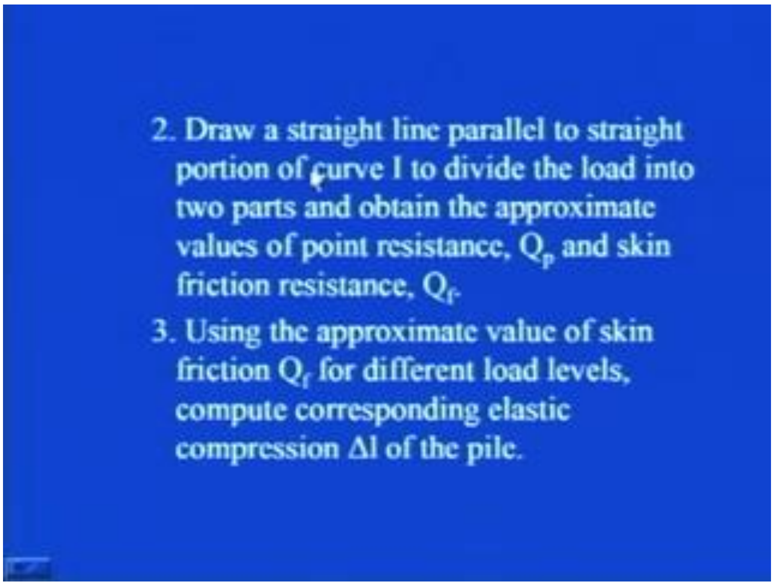

Then, what needs to be done is that draw a straight line parallel to straight portion of the curve 1 to divide the load into two parts and obtain approximate values of point resistance, Q p and skin friction resistance, Q f ((Refer Time: 21:56)), Let us once again come to this particular figure, this is what is Q curve 1, what the second point says is I have to draw a parallel line, which is parallel to this straight portion of the curve. So, you see here the later part of the curve, which is a straight line I draw a line parallel to this one, which is passing from the origin.

So, this much part will be represented by the point resistance and the remaining part between this parallel line and your actual curve will give me the part, which is shared by the skin friction. So, you see you take any particular compression of the sub grade, you take this particular path, which is the point bearing that is at this particular level you see this is what is the point bearing and the remaining is skin friction at that particular point.

So, this how approximately we are separating out Q p and Q f, now using the approximate value of skin friction Q f for different load levels compute corresponding elastic compression of the pile. You remember, that elastic compression of the pile delta l was equal to Q minus Q f by 2 into L by A e, so there Q f was not known, so earlier we assumed that delta l is equal to 0 and then approximately we found out that what is value of Q f.

Now, once we know this approximate value of Q f we go for another iteration that is assuming this approximate value of Q f and putting in that particular expression for delta l we can estimate the value of delta l at different load levels. ((Refer Time: 24:03)) So, you see here this is what is your point bearing and the remaining part is the skin friction, since earlier we do not know that what exactly is the case.

So, delta l has been assumed to be 0 and this curve one has been plotted, then a line parallel to the straight part of this particular curve has been drawn in this case like, this the intercept of between this axis and this particular parallel line gives me the value of point resistance and the remaining part gives me the approximate value of skin friction resistance.

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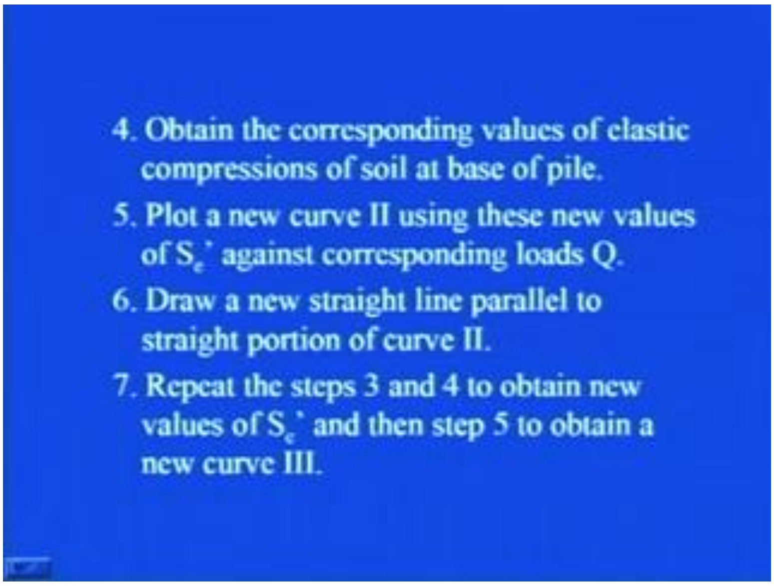

Now let us what are the further steps, once we know this delta l at different load levels, we can obtain the corresponding values of elastic compressions of soil at the base of pile that is S e prime because, while we were finding out that S e prime, the problem was that how we can calculate the value of delta l. So, now we have the value of delta l., so we can easily compute the value this elastic compression of the soil at base.

So, with is new value we can plot a new curve 2 that is using these new values of S e prime against corresponding loads. ((Refer Time: 25:24)) I will show you that how exactly it is there, you see here this is once you know this was the curve 1, you can see here that knowing the next two values you have this particular curve which is curve 2, you see these new values. So, the curve 2 has been plotted, then in the similar manner as we did for the case of curve 1, here also new straight line which is parallel to the straight portion of this curve 2, has been drawn from the origin.

Then, you can separate out corresponding Q p and Q f value that is point bearing resistance and skin friction resistance in this case also. And then, you can repeat the step from 3 and 4 to obtain the new value of S e prime and then you can again plot another new curve that is let us say 3 in this particular figure that I will be showing right now. ((Refer Time: 26:24)) In this particular figure, if you see this is what is curve 2 you draw a line which is parallel to this particular curve, you see here this line, this is the one that is dotted line.

So, this much particular part will be point resistance and this one will be skin friction resistance. So, again now you have got new set of values of Q f, so correspondingly you can find out the new set of values of delta l and subsequently S e prime, then with these new values what you can do, you can plot this curve 3, you see here this is what is your curve 3. And if you can see here that curve 2 and curve 3 they are, so close to each other and when you draw a line parallel to the straight portion of this curve 3, that is this firm line if you can see in this figure, that these line which was parallel corresponding to curve 2 and the line parallel corresponding to curve 3 they are quiet close to each other.

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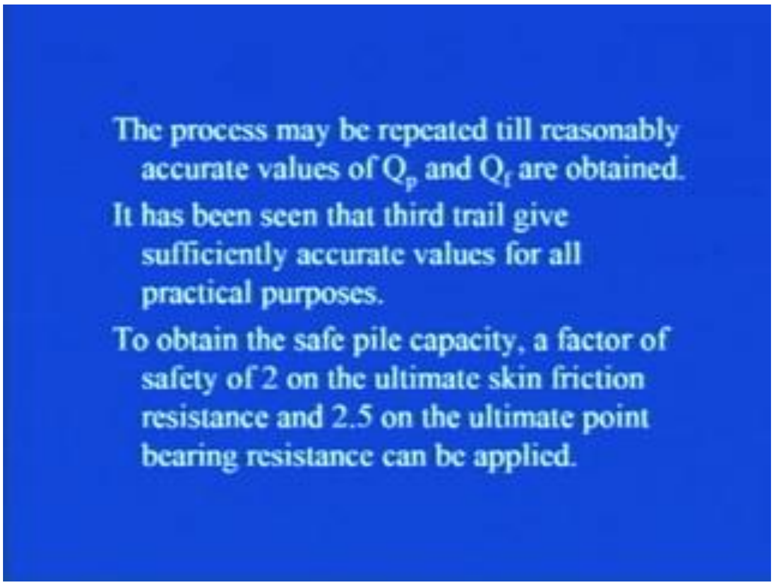

So, usually this third iteration gives me the proper value, so this process may be repeated till reasonably accurate values of Q p and Q f they are obtained, it has been seen that the third trail gives sufficiently accurate values for all practical purposes. So, first trial was done using delta l is equal to 0 and then approximate value of Q f was estimated from that approximate value another set of delta l value was estimated and then another set of S e value was estimated.

And again that the load settlement curve was plotted that was curve 2 and from there the line parallel to the straight portion of the curve 2 was drawn. And then repeating the earlier steps, which was followed for the curve 1, you could found out that what is the point bearing and the skin friction resistance in corresponding to this curve 2 also. And then using the new set of values of Q f and then you can find out the new set of values of delta l and S e prime and it has been seen that third trial gives you reasonably accurate values of Q p and Q f for all practical purposes.

Then, to obtain the safe pile capacity a factor of safety of 2 on the ultimate friction resistance and 2.5 on the ultimate point bearing resistance can be applied. Usually, for all practical purposes we usually apply the exactly the same factor of safety for both skin friction resistance and point bearing resistance. However, in case where it becomes necessary to get Q p that is point bearing resistance in Q s that is the skin friction resistance separately, there in that case you can use factor of safety of two for ultimate skin friction resistance and 2.5 for ultimate point bearing resistance.

Now, let us try to see with the help of an example, that how this data from cyclic pile load test can be interpreted and analyzed.

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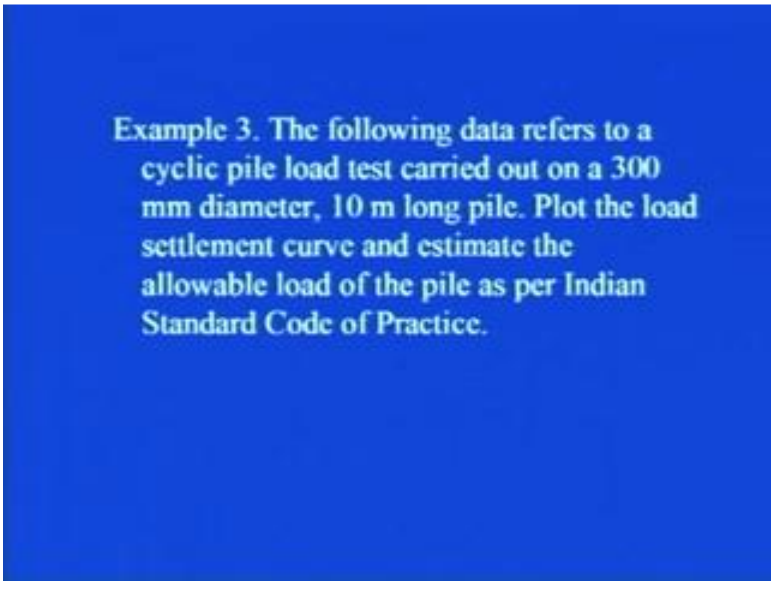

So, let us try to see with a help of an example that how this cyclic pile load test data can be interpreted and analyzed further to estimate the load carrying capacity of the pile. So, the statement of the example goes like this, that the following data refers to a cyclic pile load test carried out on a 300 millimeter diameter 10 meter long pile. Plot the load settlement curve and estimate the allowable load of the pile as per Indian Standard Code of practice.

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Load on pile top (kN)	150	200	250	300	400	500	600
Total Settlement of pile top (mm)	1.45	2.25	2.75	3.60	5.75	10.75	30.00
Net Settlement of pile top (mm)	0.40	0.65	0.80	1.00	1.70	5.25	22.80

So, this what is the data which has been given you in the problem., that you see here load on the pile top it is 150, 200, 250, 300, 400, 500 and 600 and then total settlement of the pile top corresponding to 150 kilo Newton is 1.45, then 2.25, 2.75, 3.60, 5.75, 10.75 and 30 millimeter. Then, net settlement of the pile top is 0.4, 0.65, 0.8, 1, 1.7, 5.25 and 22.8 mm, now this total settlement of the pile top is given and net settlement is also given.

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So, from this one we can find out that what is the total settlement corresponding to various loads.

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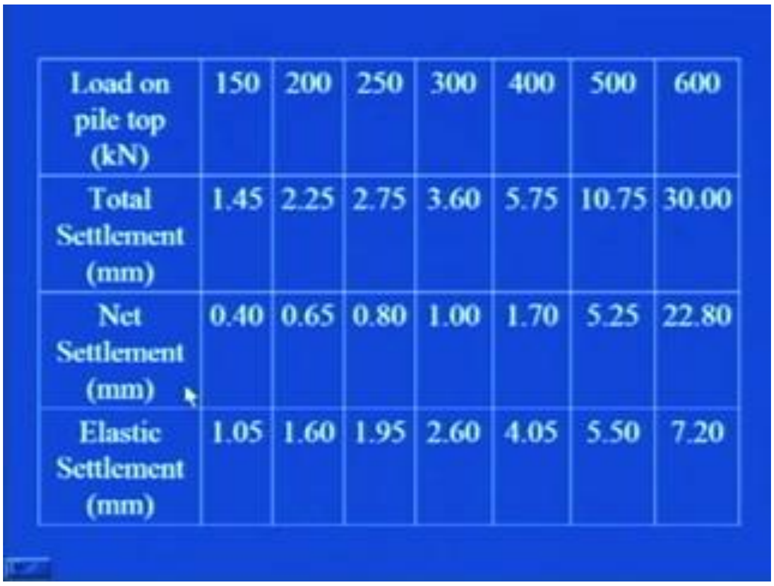

Load on pile top (kN)	150	200	250	300	400	500	600
Total Settlement (mm)	1.45	2.25	2.75	3.60	5.75	10.75	30.00
Net Settlement (mm)	0.40	0.65	0.80	1.00	1.70	5.25	22.80
Elastic Settlement (mm)	1.05	1.60	1.95	2.60	4.05	5.50	7.20

And which have been shown in this particular slide, that you see the load on the pile top this is what is given, total settlement is also given, net settlement is given. So, elastic settlement you can find out the total settlement minus net settlement, so from 0 to 150 corresponding to this 150 kilo Newton, the elastic settlement is 1.05 for 200 it is 1.6 then 1.95 you see 2.75 minus 0.8 is 1.95 corresponding to 250 kilo Newton. Similarly, you can see here the 10.75 minus 5.25 is 5.50 which corresponds to the elastic settlement to this load of 500 kilo Newton on pile top.

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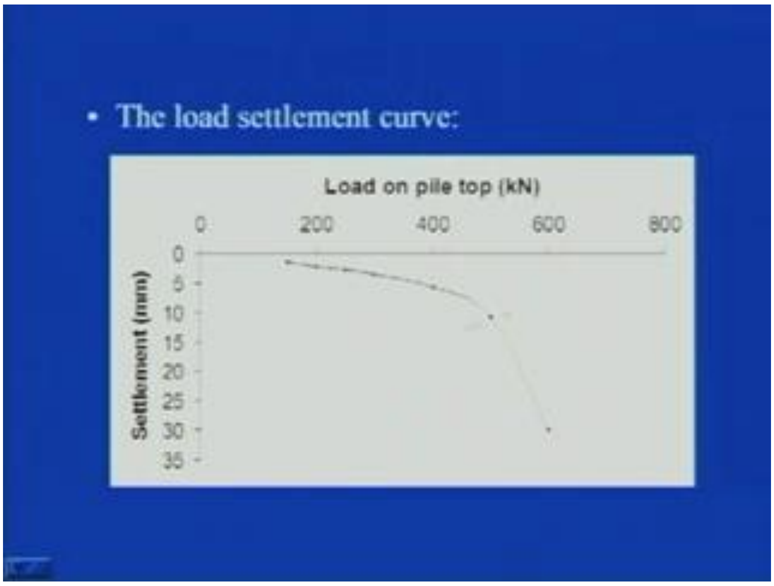

So, this is load on pile top in kilo Newton settlement it has been plotted, which follows this particular curve. So, it has been asked in the question that you have to plot this load settlement curve, so this is how you can plot the load settlement curve, first you find out the elastic settlement and then correspondingly simply using may be graph sheet or this I have done in excel, there you can plot this load settlement curve.

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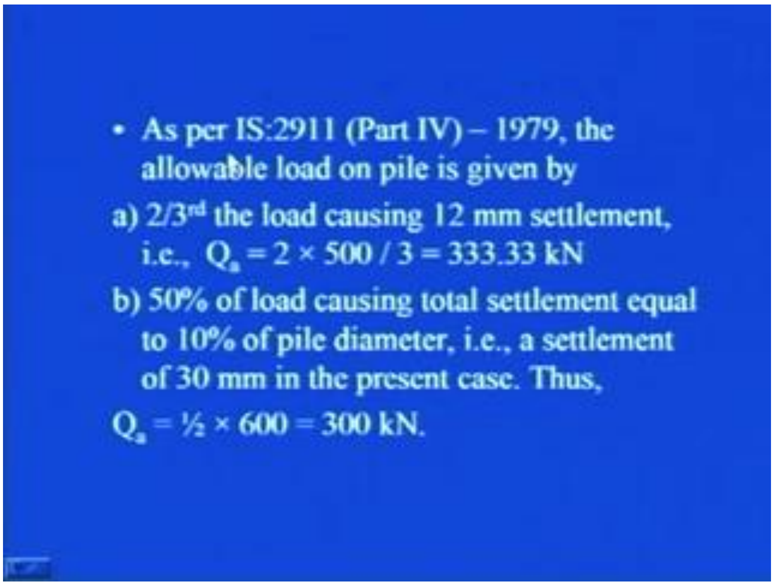

Then, as we discussed in the previous lecture that what are the different guidelines given in Indian Standard Code and different engineers or research workers also. So, here this I am dealing with because, you have to find out this allowable load on the pile as per Indian Standard Code of practice. So, whatever are the guidelines which are available in IS code, that you have to take care of here in this case that as per IS 2911 part 4, 1979 the allowable load on pile is given by 2 3rd the load causing 12 mm settlement ((Refer Time: 33:36)).

So, you see here go back to this particular curve, see it is very important to draw first this load settlement curve, once you have drawn this half of work is over. So, 12 mm settlement was given since no specification has been given in this particular problem, so you have to consider 12 mm of the settlement. So, here 12 mm settlement will be some were here you go here read accordingly, so you will see that it will be some were here in this and that load is 500.

So, 2 3rd of the load causing 12 mm settlement. So, from this particular curve you can read that what is the load at 12 mm settlement it is coming out to be 500 in this case. So, 2 3rd of 500 will become three 333.33 kilo Newton, then the second guide line was that 50 percent of the load causing total settlement equal to 10 percent of the pile diameter. So, in this case your pile diameter is 300 mm, so 10 percent of that will become 30 mm. So, in present case it is 30 mm, so whatever is the load corresponding to this 30 mm settlement you have to take 50 percent of that as allowable settlement.

So, you see here the settlement of 30 mm ((Refer Time: 35:03)) and if you go back to this particular figure, this 30 mm you take draw a line parallel to this axis. So, 30 mm you come here and then read this value corresponding to this particular point, where the line intersects this particular load settlement curve. And then, you can see that here that you are getting a value of 600 kilo Newton corresponding to a settlement of 30 mm in this particular case.

So, Q allowable from this particular consideration will be half of this 600, which is 300 kilo Newton. And as I told you earlier, that out of these different considerations you have to pick the minimum value which you are getting, so from one consideration you are getting 333.33 kilo Newton, from another one you are getting 300 kilo Newton, so the minimum is 300 kilo Newton.

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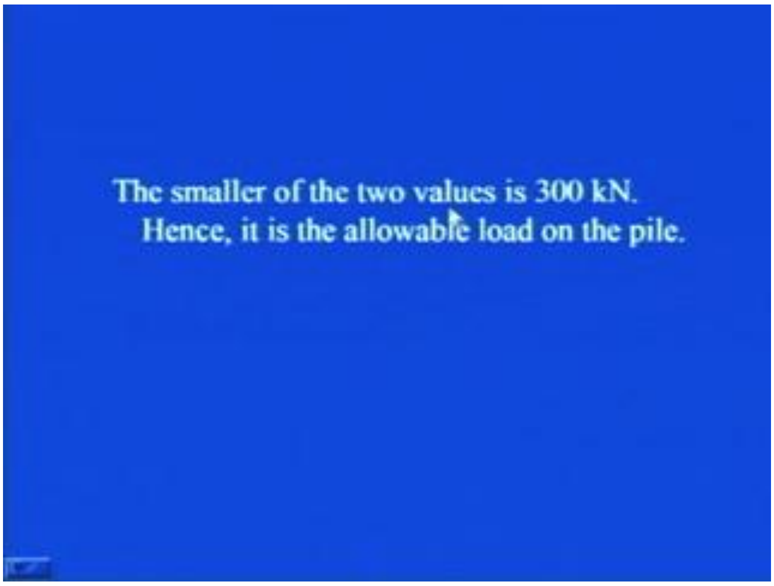

And so you can safely say that a smaller of these two values is 300 kilo Newton and hence it is the allowable load on the pile. So, you saw that when we were discussing theoretically it was looking little bit difficult, but if you follow them properly then it is not at all difficult, once you draw load settlement curve after that things become very easy. Simply, you have to follow whatever are the guidelines which are given in IS code or may be if you are using, let us say if you are in some other country and trying to find out this allowable load.

So, whatever is the relevant code in that particular country, you pick that there will be some guidelines exactly on the similar lines to estimate this allowable load on the piles. Simply, you have to follow those guidelines pick the minimum value whatever that you get from different consideration and that will be the allowable load on the pile. Now, this was all about that how you can estimate the load carrying capacity using pile load test, we have already seen the static pile load formulae, then we saw pile load test.

Now, coming to the third method that how we can estimate the load carrying capacity of pile under compression, the third one is pile driving formula.

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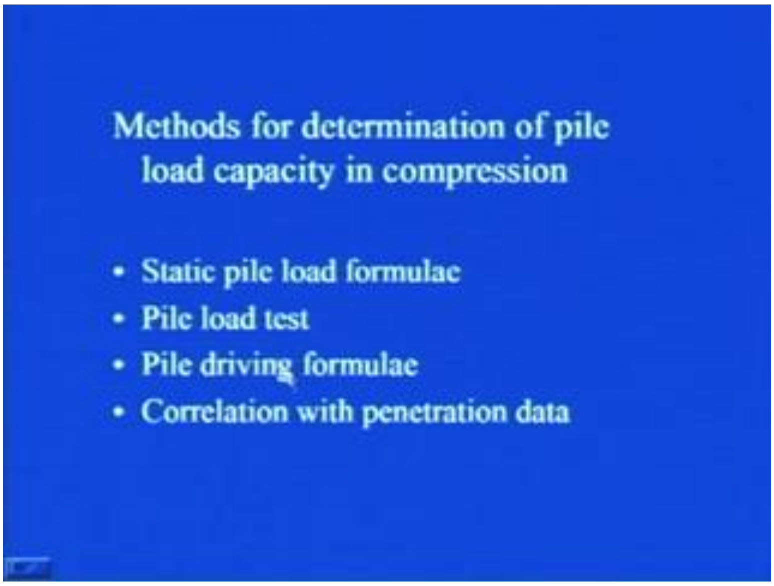

As we are we see that here this word static has been used and you know that when we were discussing the two types of method of installation of pile. Once, is driving the pile and other is by boring and in that driving one we saw that it is done with the help of mechanical hammering or giving vibrations and all. So, here basically dynamics comes into picture, in the first case it was a static pile load formula.

However, in this third one usually dynamics that what exactly is the type of hammer, what is the weight of the hammer, what is the efficiency of the total machine that you are using for hammering the pile for driving, then what exactly is the it is eccentricity and all other things that you need to see. And let us see that what are the various aspects of this particular type to know the load carrying capacity of pile.

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Sometimes they are termed as dynamic pile formulae also why it is, so you will be appreciating this particular name, after studying little bit detail of this particular type. These, formulae are based on the laws governing the impact of elastic bodies, I hope that you are familiar with the coefficient of restitution, that you must have studied in your B Tech first year class, while you studied your applied mechanics and that engineering mechanics thing.

So, the input energy of a hammer blow is equated to the work done in overcoming the resistance of the ground to the penetration of the pile. So, this is what is the main principle on basis of which this dynamics pile formula has been derived, we will be not be going into detail of the derivation of this particular formula. However, it is very much necessary for you to know that what exactly is this formula, what are the various terms which are used in this particular formula, what are their physical meaning that how exactly they represent any physical parameter.

So, you should always remember that in the case of pile driving formula it is what is the mechanical work and this particular principle, that input energy of a hammer blow is equated to the work done in overcoming the resistance of the ground to the penetration of the pile, it is equated and this is the basic principle of the dynamic pile formula.

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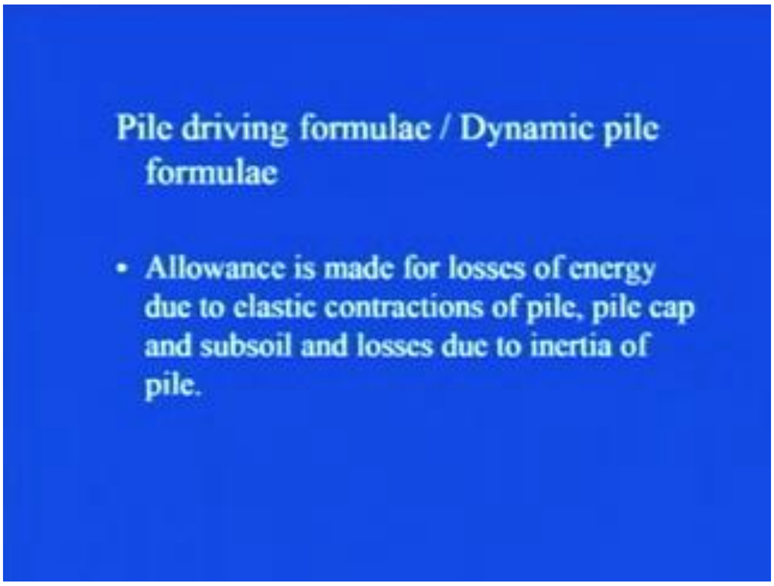

Allowance is made for losses of energy due to elastic contractions of pile, pile cap and subsoil and losses due to inertia of pile. You see, when the energy is being imparted from the hammer to the pile, as such we say that the whatever energy we gave the there is conservation of the energy of that particular law is there. So, whatever is the energy that you give either it will just dissipate and some of the energy will get dissipate and rest all will be taken by the pile in resisting it is movement within the ground.

So, in that particular process when the hammering takes place there are losses of energy due to the elastic contraction of the pile. That means, that we just have to take into account the energy, which is being used by the pile for the resisting the vertical movement. So, whatever is the energy losses some allowance in this particular formula has been done.

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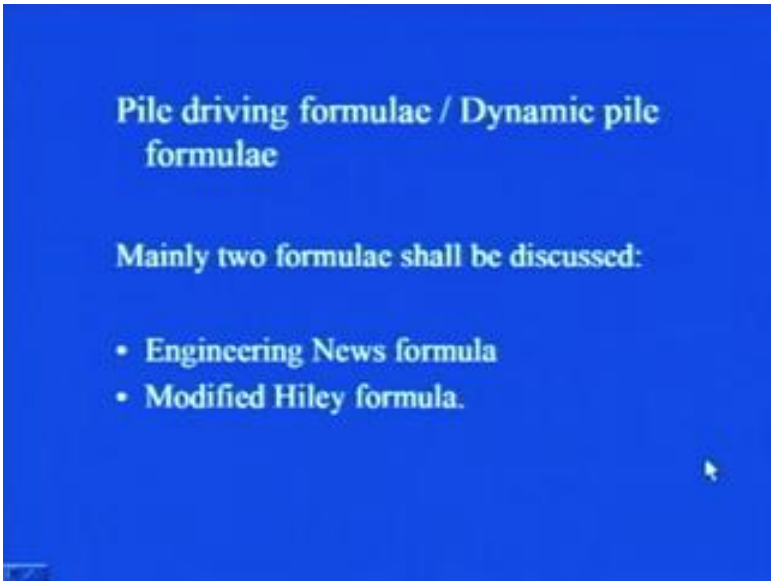

Usually, two formulas we will be discussing, first one is engineering news formula, second is modified Hiley formula So, let us first discuss the salient features or what exactly is this engineering news formula is a very well known that ENR we call that in abbreviations.

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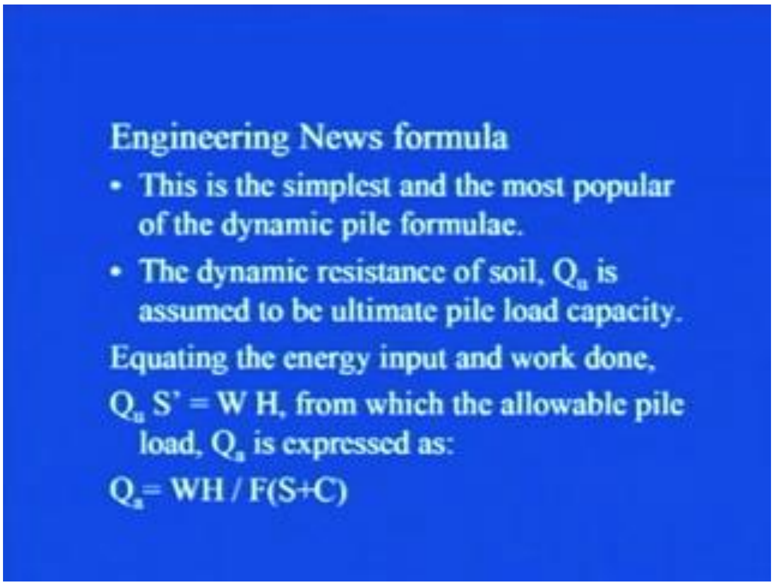

That is this the simplest and the most popular of the dynamic pile formula, the dynamic resistance of the soil say Q u is assumed to be the ultimate pile load capacity, in this particular formula. So, equating the energy input and work done as I told you that for all the dynamic formula you have to keep this in mind, that whatever is the energy that you are imparting through hammering to the pile, that has to be equated to the work done by the pile against the movement in the ground.

So, exactly on this that similar principle equating the energy input and work done, so your input energy is Q u into S prime is equal to W into H from which the allowable pile load Q a is expressed as W into H divided by this F S plus C. Now, what are these differ which is falling through a height of H, S is real set per blow, C is is a empirical factor allowing reduction in theoretical set due to energy loss.

As I told you that some are the other compensation or allowance has been will be done, as far as the loss of energy due to the dissipation in let us say there is some compression of the pile itself, some dissipation of energy due to the soil which is surrounding that it is done.

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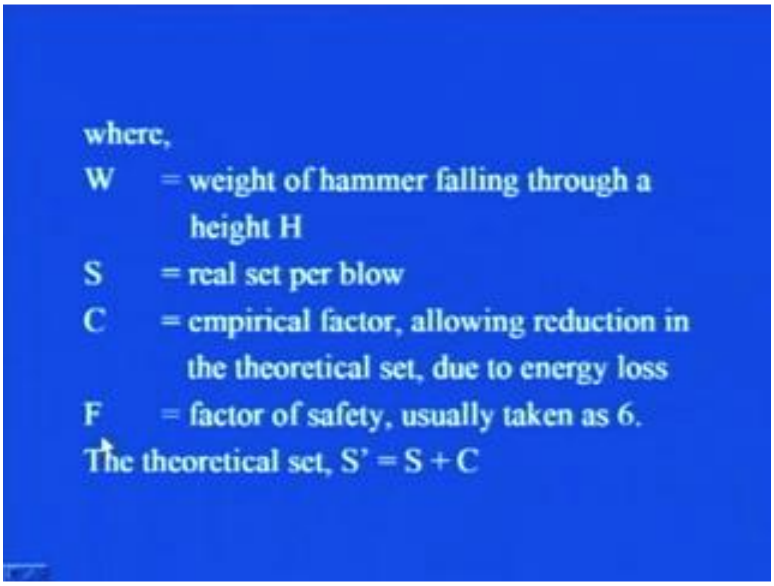

So, this empirical factor C takes care of those allowances, F is factor of safety which is usually taken as 6, you can see here, that such a high factor of safety has been taken into account. However, in case of a static pile load formulae that was of the order of 2.5 and in case of cyclic pile load test data, while analyzing the test data it was two for skin friction resistance and 2.5 for point bearing resistance. However, in this case in case of dynamic pile formula, this factor of safety is usually taken as 6, so the theoretical set which is S prime is equal to S plus C.

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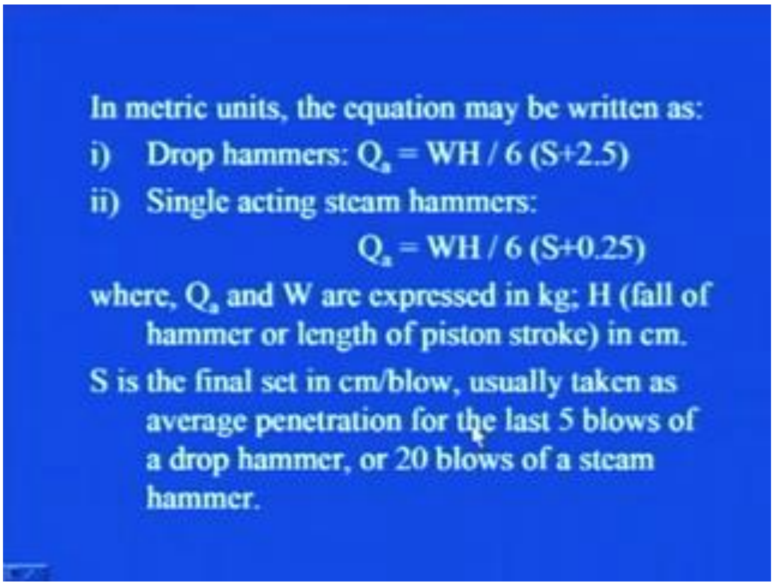

In metric units how you can find out, that what exactly is this empirical parameter and using this factor of safety to be equal to 6. So, in metric units the equation may be written as for drop hammers, see as I told you that we will not be going into much detail of the mechanical aspect of this particular dynamic test. However, we will be concentrating on that how we can estimate the allowable load carrying capacity using these formula.

So, you must be knowing from some of the courses that you have done as far as mechanical engineering is concerned, that what exactly do we mean by drop hammers or single acting, steam hammers, etcetera. So, in case the drop hammers has been used while driving the pile Q a that is allowable load capacity of the pile becomes W H divided by 6 S plus 2.5.

However, in case of single acting steam hammers it is W H by 6 S plus 0.25, where Q a and W they are expressed in kilogram, it is not in Newton's this kilogram H is fall of hammer or length of piston stroke in case of single acting steam hammers it will be length of piston stroke in centimeters, S is the final set in centimeter per blow. What exactly do we mean by this S that we are calling as set, it is usually taken as average penetration for the last 5 blows of a drop hammer or 20 blows of a steam hammer.

So, let us say that you are going on hammering on the particular pile, so how you can estimate this set is that. That, this final set is usually taken to be equal to average penetration for the last 5 blows of a drop hammer and in case you are using single acting steam hammers, in that case last 20 blows I mean corresponding to last 20 blows what exactly is the average penetration, that is being taken as S and it is unit is centimeters per blow.

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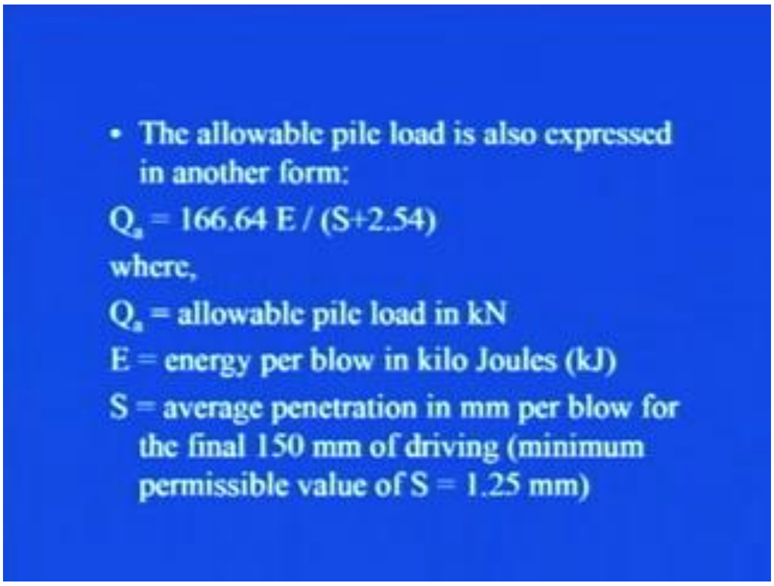

The allowable pile load is also expressed in another form, which is this 166.64 E divided by S plus 2.54 where, these Q a it is in kilo Newton. That is allowable pile load you will get in kilo Newton, E is energy per blow in kilo Joules that is k J, S is average penetration in millimeter per blow for the final 150 mm of driving, the minimum permissible value of the S is equal to 1.25 mm.

So, let us say that in your case this S value that is average penetration per blow for final 150 mm of driving is working out to be more than 1.25, then in that case you have to restrict it to 1.25. So, the permissible value is 1.25, if it working out to be less than that you have to take this 1.25 and if it is coming out to be more, you can go ahead with that value.

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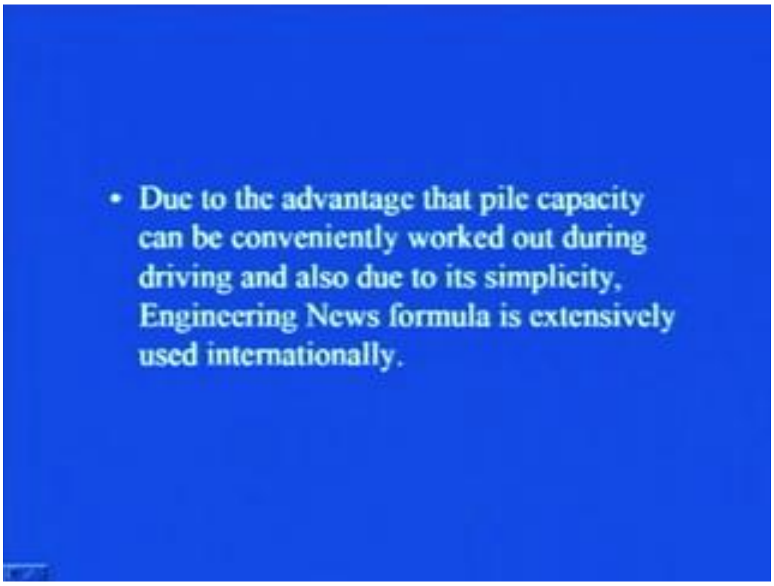

Now, due to the advantage that pile capacity can be conveniently worked out during driving and also due to it is simplicity, engineering news formula is extensively used internationally. You have seen that it is a very simple formula, you just require to have weight of the hammer, height of its fall what exactly is the type of the hammer that you are using it is final set. And then, simply use substitute all these values into that simple formula and you get a rough estimate of allowable load on the pile.

And due to these features of this engineering news formula, it is very popular and used extensively all over the world. Now, let us try to see I told you that there are two formulas, one was engineering news formula, another one is modified Hiley formula. So, let us try to see that what exactly or the salient features of modified Hiley formula, how we can use this particular formula to estimate the allowable load on the pile.

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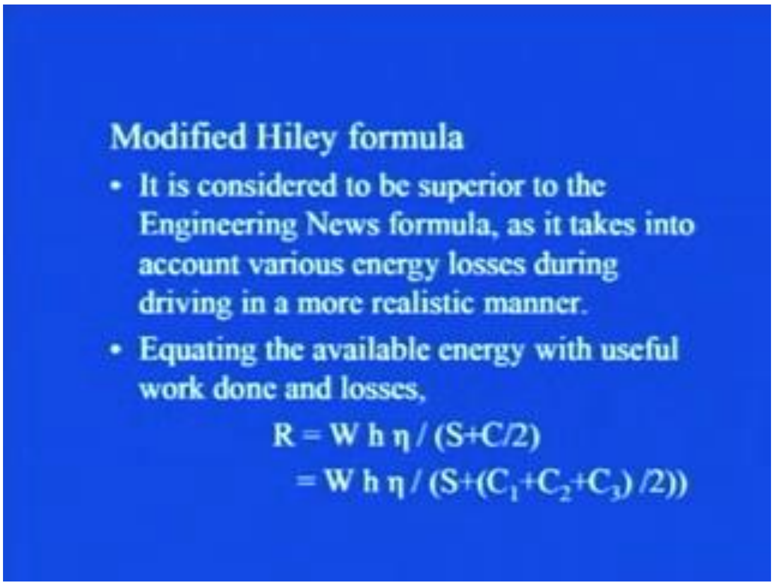

It is considered to be superior to engineering news formula as it takes into account various energy losses during driving in a more realistic manner. Although, in engineering news formula we used an empirical factor that is C with combination of final set of in engineering news formula. However, there it was empirical, but this in modified Hiley formula we take more realistic and more logical factors as far as the losses of the energy in different aspects are concerned.

So, again the principle basic principle remaining the same, that whatever is the energy to be supplied to the pile that is equal to the work done. So, here also equating the available energy with useful work done and losses R is equal to W h eta divided by S plus C by 2, where this C is equal to C 1 plus C 2 plus C 3 and if you substitute that this R will become W h eta divided by S plus C 1 plus C 2 plus C 3 by 2. Now, let us try to have a look that what are these particular parameters, how they can be estimated or what is the recommended values of these parameters.

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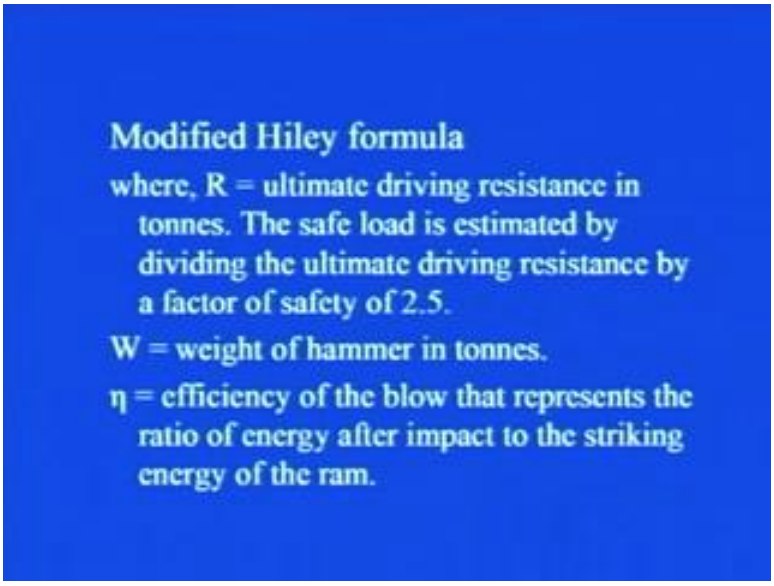

Where your R is ultimate driving resistance in tonnes, so you see since these are the dynamic formulae's every time the units are changing. So, you have to keep a track that in which formula, which type or which type of unit and which particular system of the unit that you have to follow. So, this R is ultimate driving resistance in tonnes, the safe load is estimated by dividing the ultimate driving resistance by a factor of safety of 2.5, in earlier case the factor of safety that is in the engineering news formula the factor of safety was taken to be 6 ((Refer Time: 51:34)).

However, in this case once you estimate the value of this R, you have to simply divided by factor of safety of 2.5 to get the safe load, which can be there on the pile, W is the weight of hammer in tonnes. Then, eta is the efficiency of the blow that represents the ratio of energy after impact to the striking energy of the ram, so eta is the efficiency we will not be actually the thing is that whatever is the type of hammer that you will be using, usually manufacturer provides us this particular value of the efficiency.

However if you go by mechanical principles, then this eta has a definition which is the ratio of energy after the impact to the striking energy of the ram, which is usually the machine is specific. So, whatever is the type of machine that you are using for hammering, the with that particular machine this value will be supplied. Now, what are the other parameters and what are the main features of this particular formula, how you can utilize this, this all we will be discussing in the next class.

So, in this class we discussed that how you can go ahead with a pile load test, then we started with the cyclic pile load test, in that case that only difference was that the loading and the unloading was done simultaneously. Then, we saw that how the elastic recovery can be obtained and how you can and differentiate or separate out the two component of the load, that is point bearing resistance and skin friction resistance, how you can separate them out using the cyclic pile load test data.

Then, with the help of an example we saw, that how this pile load test data can be used to estimate the allowable load or the safe load capacity of the pile. You saw, that there are few guidelines that you need to follow and then once you draw the load settlement curve it becomes, so simple to consider all those criteria and then decide upon that what should be the allowable load on the pile. And then we started with the third method, that is the dynamic pile formula to estimate the load carrying capacity of the pile.

In that one I told you that we will be discussing two types of two formulas, one was engineering news formula and another was modified Hiley formula. In case of engineering news formula, we saw that since it was very simple there was no complicacy. So, that is why because of it is simplicity only it has been used worldwide and then we started with modified Hiley formula, we will be continuing with this particular topic in the next lecture.

Thank you.