Foundation for Offshore Structures
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Module 1
Lecture 11
Pile Foundation 2

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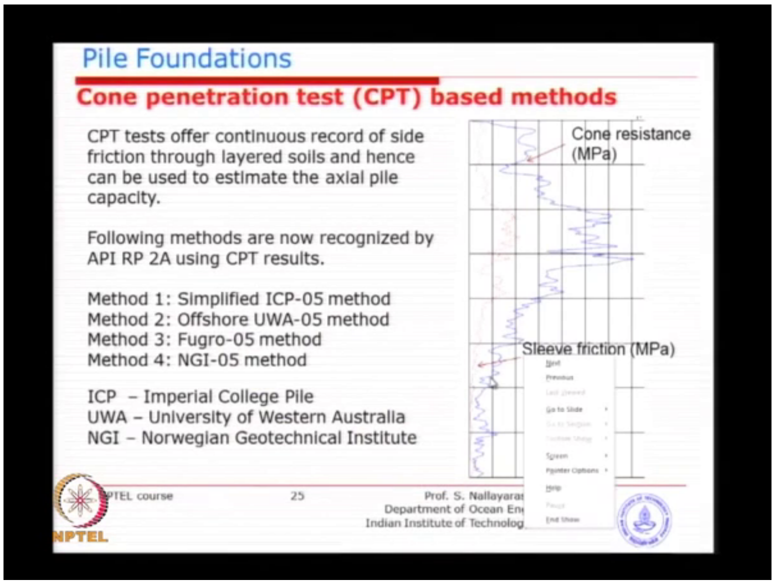

Okay, so the last week we were looking at the CPT results so typical record of measured you know the sleeve and the cone friction is given in this type of diagram so basically this will be the output from the country's recorded CPT test. So what we were looking at is the several methods of integration based on the localized in fact this the reason why so many methods are there because its (())(0:42) the empirical coefficients of different cones and basically the integration methods.

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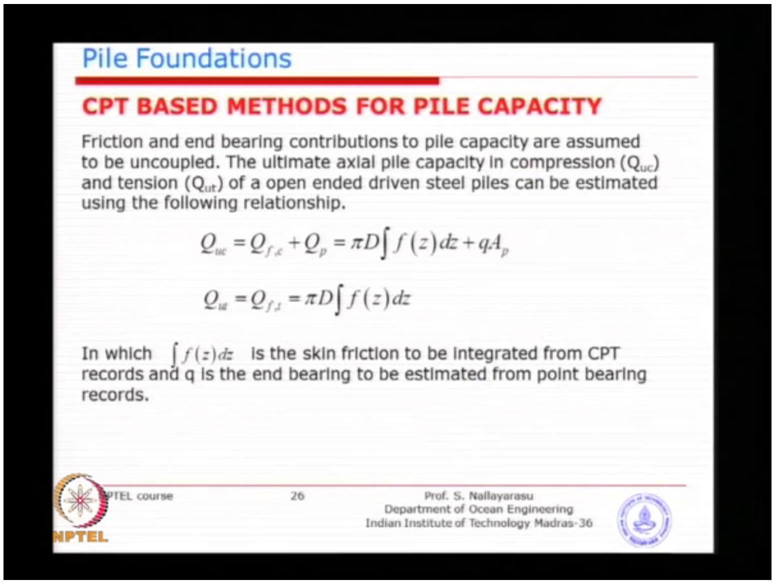

And you will see here that the calculation is very similar to what we were doing if you are having a strength profiles as layered size here we have a continuous resistance for skin friction and the end bearing and basically you are trying to two integration from the depth to depth from starting to end and you have compression and tension capacity in terms of tension capacity you do not have the end bearing, so basically it is coming out.

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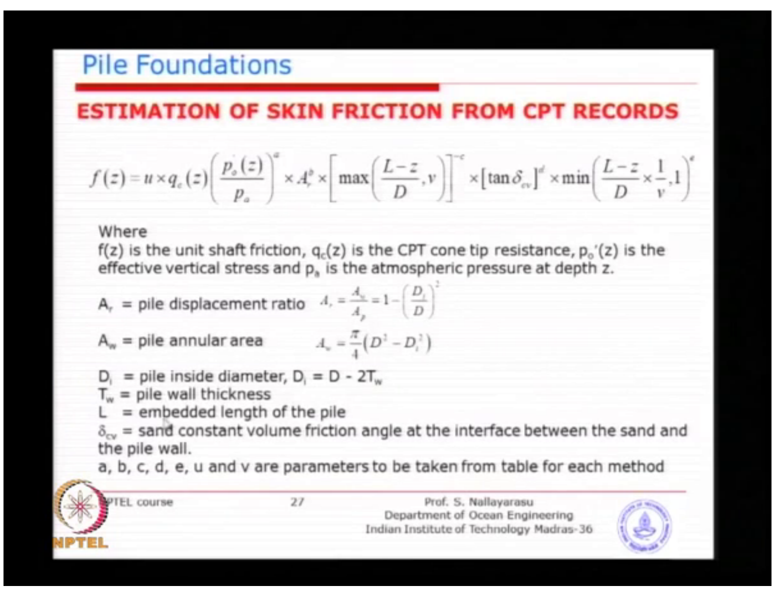

And the idea of getting this fz from the method cone sleeve friction this is the sleeve friction the red color one is to get the idea of fz, fz is the frictional resistance.

Now when we look at the various methods alpha method, beta method which we are just last classes we were looking at alpha is a fraction of you know the undrained shear strength beta method is the fraction of the overburden pressure you know we were looking at this f value as representative of each of the type of soil whether it is clay or sand.

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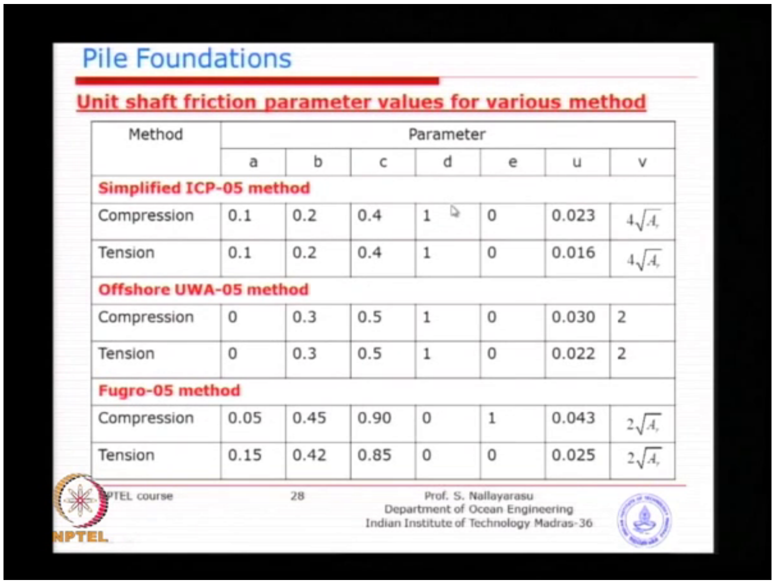

Method	Parameter						
	a	b	c	d	e	u	v
Simplified ICP-05 method							
Compression	0.1	0.2	0.4	1	0	0.023	$4\sqrt{A_r}$
Tension	0.1	0.2	0.4	1	0	0.016	$4\sqrt{A_r}$
Offshore UWA-05 method							
Compression	0	0.3	0.5	1	0	0.030	2
Tension	0	0.3	0.5	1	0	0.022	2
Fugro-05 method							
Compression	0.05	0.45	0.90	0	1	0.043	$2\sqrt{A_r}$
Tension	0.15	0.42	0.85	0	0	0.025	$2\sqrt{A_r}$

Here you have f of z is to be integrated using this with the recorded you know the profile of the sleeve friction with several coefficients involved you can see here A, B, C, D and E also u and v which are given in this table for different methods you can adapt by various locations like simplified ICP or UWA approach or Fugro is a private company but they have been involved in soil investigation for almost 5 decades in various parts of you know around the globe they have established the offices.

So they have a large experience than anybody else in fact so that is why they have proposed this particular method based on what the results they have got in fact they have got plenty of data in terms of laboratory test as well as the field test so they have enough information to propose something like this so basically also can be used but you can see here the coefficient vary reasonably from 0$4 to 0$9 for if you look at the each category you can see here is 1 here 0.

So that is why these are specific to areas of interest you know mostly Fugro results are applicable to middle east because they have lot of work on middle eastern areas like UWA is predominantly in Australian region.

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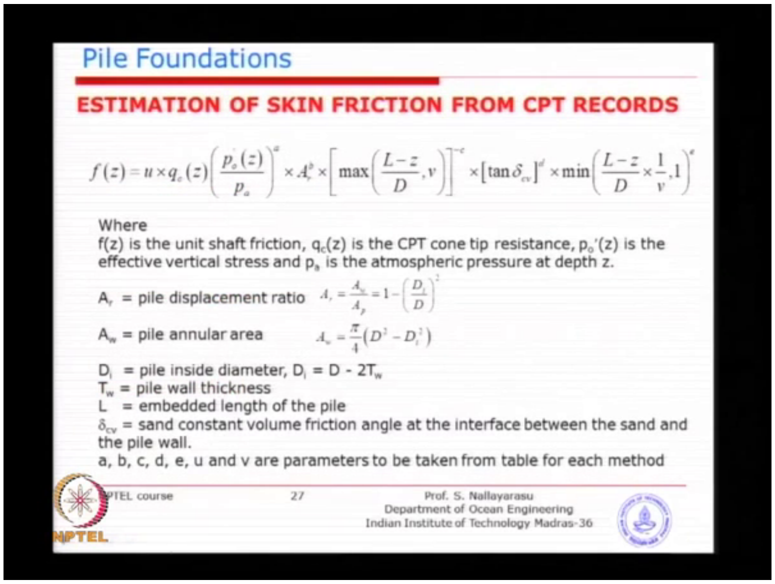

So once you have the fz value for each of the point that you have got using the value of qz, so basic idea is you can use this fz value and do a integration here to obtain your total capacity. So the whole matter rest on how you get the values of fz with the measured profiles of sleeve friction and the cone resistance.

The idea is these methods are now recognized as an official methods which can be adapted by any design project because of API also recommends these methods as long as in (())(04:01) profiles you are having this the method sleeve friction and the cone resistance but very (())(4:08) people do it because in deeper water depth as well in deeper bore holes is quite difficult to do it because the cone penetration requires lot of effort sometime you may not get a continuous penetration what will happen is because the cone can penetrate say 10 meters you will stop after that you will excavate that soil then you will start restart the cone penetration.

So then you need to actually interlink the top penetration versus the bottom one so little bit difficulty is there but established companies like Fugro they have profile they have methodology to connect them continuously.

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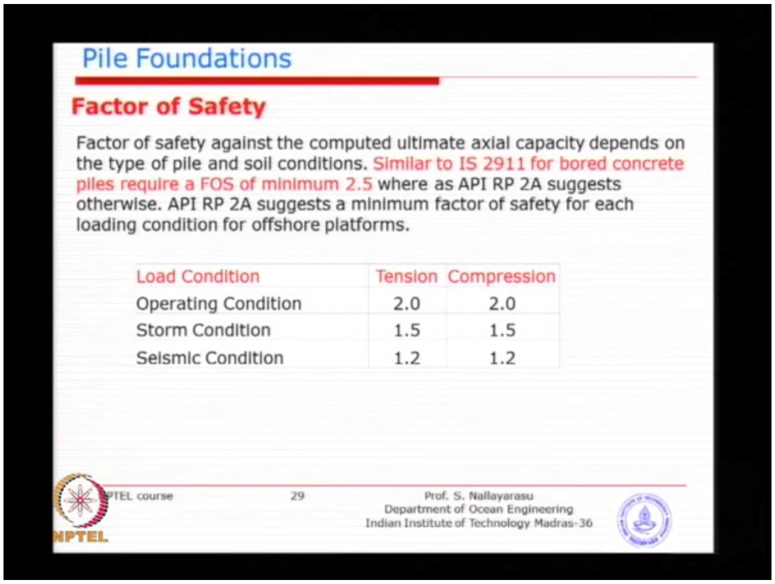

So besides the conventional methods of you know field testing, laboratory testing and this CPT method that also recognizable which can be used.

Now the last one we have seen the capacity calculation involves so many uncertainties you know starting from bore hole and then to soil sampling and strength assessment classification of soil and then to establish the friction and this end bearing. So that is why we have to look at how do we cover these uncertainties that is one parameter, the second one all these while we were looking at the failure of the soil by shear and ultimate that means once the soil is particles are dislocated they will behave plastically.

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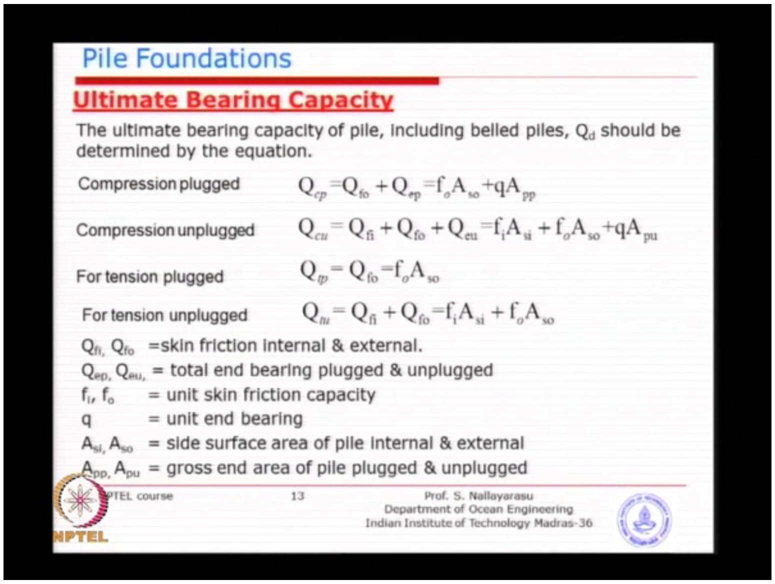

So it is the strength what we have evaluated here we go back to the equation when we were looking at few days back these are ultimate capacities not the I think you are familiar with the working stress methods which we were talking about the design course basically these are ultimate capacities we cannot allow the foundation to fail when you apply the loads to the structure, so basic idea is we need to divide this ultimate capacity by certain fact of safety which we will be taking similar to the strength of steel material from yield strength to we are dividing by 1$6, 1$67 so here we have to divide by certain factor of safety.

Now various course have different methodology of if you look at say for example IS course on foundations predominantly on concrete piles and bold piles shallow foundations they have suggested that factor safety can vary from 2 to 4 2 to 5 and leave it to the designer depending on the type of uncertainties involve in the evaluation of soil to the foundation loads to the capacity you decide whether you want to give a higher factor safety or but for both the piles they suggest at least a minimum of 2 and a half you should provide and you know for a shallow footing sometimes we give 3, 3 and a half depending on what type of you know soil investigation sometimes you do not have much information you better design with a higher factor safety.

So 2 and a half is something that you know most of the pile foundations for costal structures been design for. Whereas API suggests because we have you know the steel tubular piles of deeper penetration not shallow not unlike coastal waters they suggest a minimum factor safety of course nobody is going to argue if you give a factor safety of 2 and a half or 3 of course is going to cost you more effort and money but as a minimum for after structures in loaded piles in compression so we have a minimum factor safety of 2.

So you have a ultimate capacity divided by this factor safety, so the factor safety is to account for uncertainty as well as the loading is working loads whereas the capacity what we have evaluated are failure, remember we started from a bearing capacity of a shallow foundation we had upper bound, lower bound all of them where evaluated at failure we cannot allow the foundation to fail, is it?

So we need to reduce the loads such that the foundation will be in a safe state when a working loads are applied.

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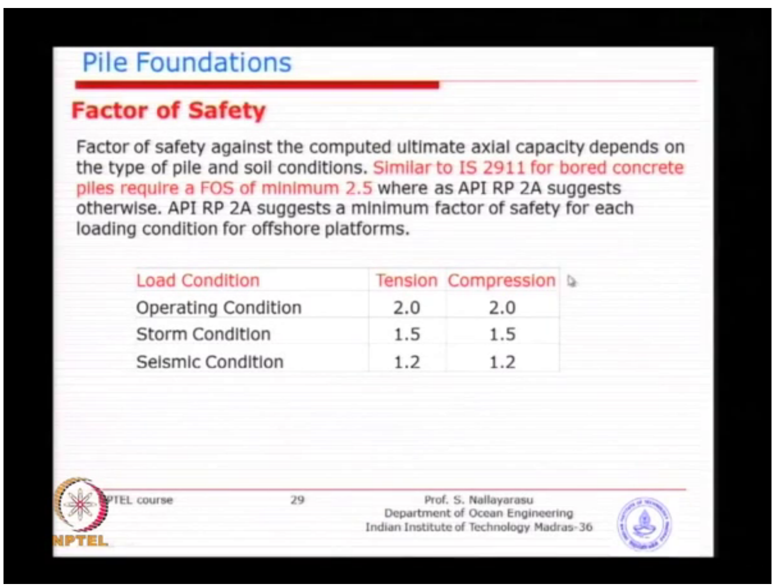

So that is why factor safeties are required and you can see here this table some six numbers in fact two columns tension compression both are having similar capacity when it is operating conditions I think we have defined this in the design course the operating versus storm you know conventionally occurring you know frequent interval which is one year written period storm conditions is called operating, actually storm conditions is the 100 years storm condition.

So basically you have a reduced factor safety very similar to what we were discussing about in the design is basic idea is higher risk can be taken, that means you allow higher loads to be taken by the foundation that means reduced factor safety. Similarly for seismic condition we have further reduced factor safety of 1$2 because it is going to be a rare occurrence. So minimum 2$0 and if you have (())(9:12) further you can as a designer can increase a factor safety but nobody wants to do it unless you have clear indication from the soil reports that the reports suggests the strength could not be evaluated correctly.

In such cases you may not actually proceed with actually the project itself because the risk with the after foundation is very high you go there you cannot drive then you have to come back. So factor safety is essential to find out what is the working. So the relationship between working capacity versus ultimate capacity is called factor safety so the ratio is ultimate capacity by the allowable capacity you can call it.

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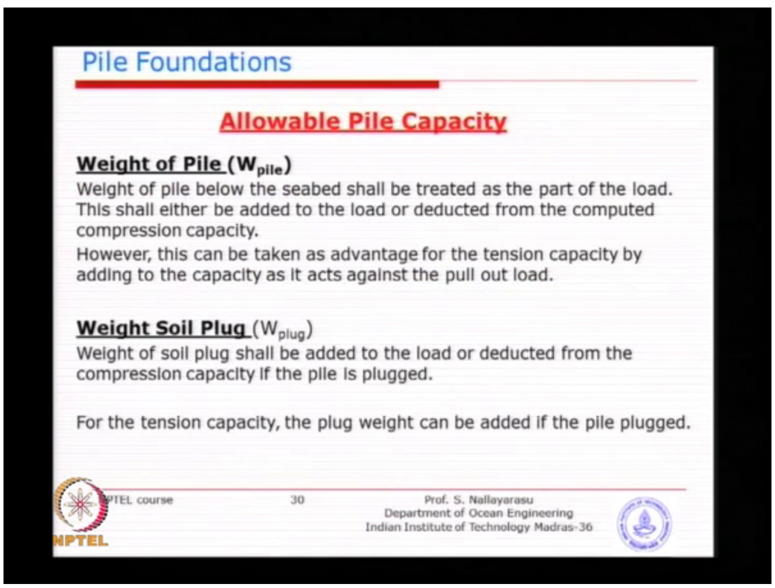

Now how do we find out allowable capacity is just a simple matter of taking the ultimate capacity divided by factor safety but then the added information that we need to remember is the weight of pile and weight of the soil plug remember we were talking about when you drive the pile inside and just pull out the pile if the pile is plugged one, what will happen the soil will come out together with the pile itself.

So vice versa when you are applying a load to the pile above the sea bed when it is applied say compression load the pile weight plus the soil weight must be added to the load itself because it is the part of the system.

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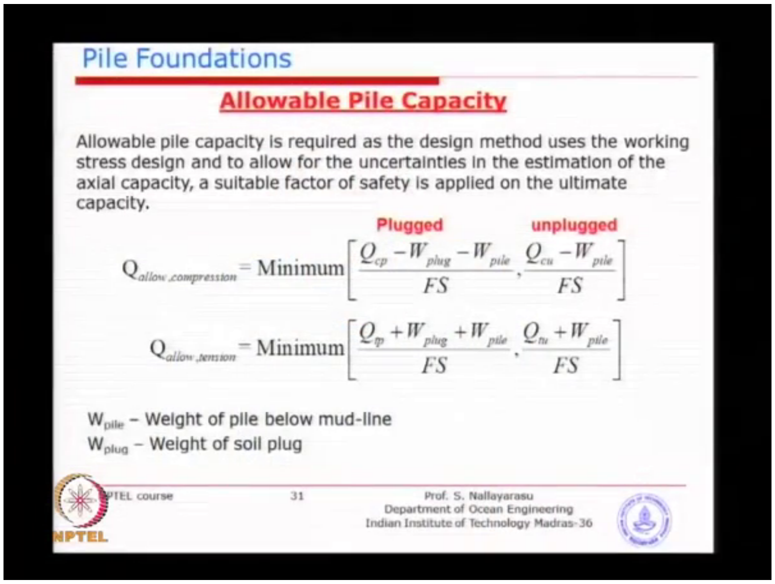

So that is there we need to make sure use this you know basically the information. In the plugged case you will remove the pile weight and the soil weight from the capacity divided by the factor safety because it is part of the load.

And whereas for unplugged case that means the soil is supported by soil itself because it is soil is not becoming part of the pile very similar to solid pile for example instead of a tubular pile if you have a solid concrete pile what happens the material of the concrete in the pile itself is becoming part of the load so that is what your.

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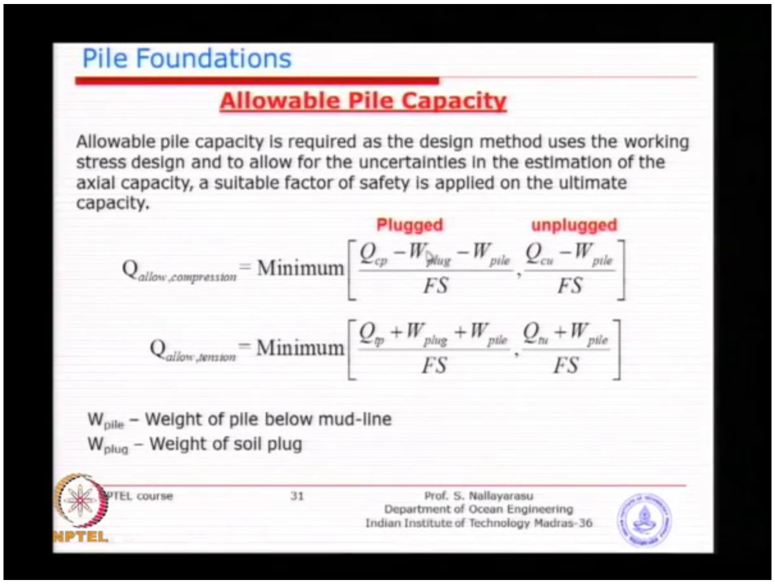

So that is exactly when it is plugged case weight of the pile plus weight of the soil must be taken out of the capacity for the buried portion, of course the portion above the sea bed is anyway part of the load because you are analyzing the jacket structure.

Similarly for tension you take advantage of it you know when the load is applied upwards it has to overcome the weight of the pile and weight of the soil within the pile itself. So you can add when you are talking about the tension capacity is a capacity coming from friction and add the weight of the plug plus the pile which is going to give you. So the more weight you are going to gain more tension capacity divided the factor safety.

For unplugged case is only going to be the pile weight, so this needs to be taken into account because this can be substantially imagine if you are talking about a 100 meter pile it can give easily 200 tons of weight 200 ton is nothing but 2 mega newton after all if you look at the pile capacity maybe 10 mega newton, 15 mega newton out of 15 mega newton if you get 2 mega newton either for compression or for tension you are going to deduct it here so it is almost 10 percent of the soil capacity itself, so if you ignore it for compression you will be over predicting the capacity for tension you will be under predicting capacity.

So that is why 10 percent is not a small amount that you can simply ignore it so allowable capacity needs to be taken in to account the weight of the pile and the weight of the soil plugged inside.

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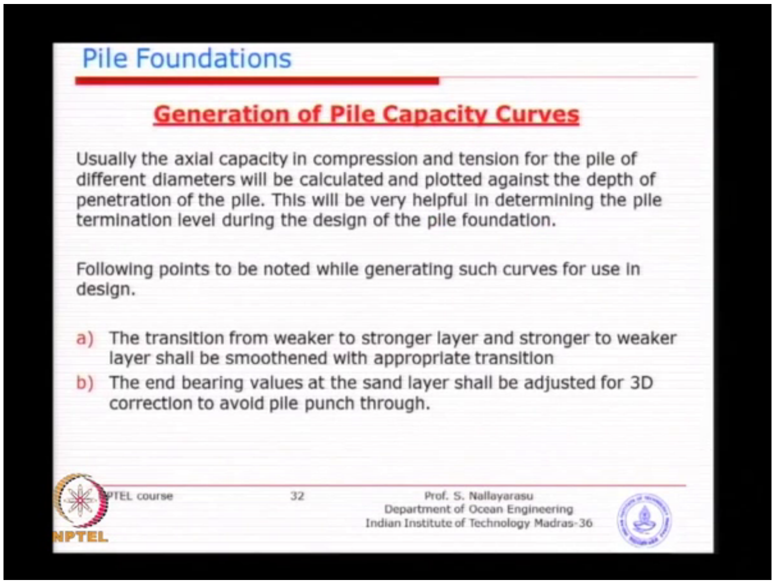

Now normally we do not know the pile penetration in a design work which we will have to calculate for several iterations when you are designing a jacket you do this analysis and find out what is a pile loads. To determine what penetration is required you are not going to do everyday calculation separately.

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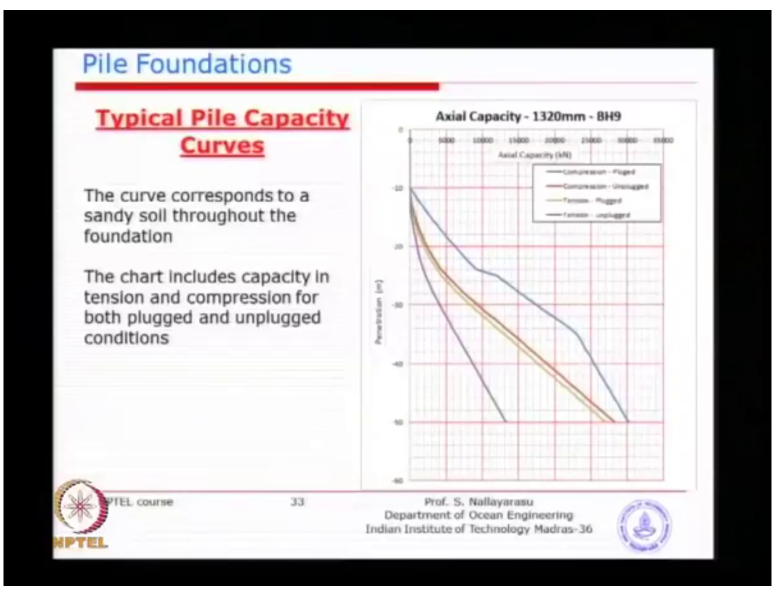

So normally we do a something like this pile capacity relationship with the depth of penetration. So you see this chart you can see here are 4 you know graphs or relationship showing the capacity versus the pile penetration below the seabed level one for compression plugged and unplugged and the other for tension plugged and unplugged like what we did just now for you know the relationship. So you can see here once you have the loads calculated from your structural analysis for super structure and you take the loads come back here if you need a specifically for example 10,000 kilo newton is your compression load and maybe 8000 kilo newton is your tension load and the piles are plugged.

So you will come here so I need 10,000 this is being actual capacity in ultimate so you just come here you read this is the capacity minimum I require 24 meters of penetration so you can decide I need 24 meters. So like so that means before you start the design work you need to generate this graph by simply doing the integration of the resistances coming from friction and the end bearing. So every level you will add the end bearing at that level only the friction will be cumulatively added one end bearing can be taken at the level at which you are going to consider so that is how you plot the.

So you need to learn to generate this, in fact this will be one of the test or an assignment paper or tutorial we can do so that you can understand how this can be generated, is nothing but you do a layer wise evaluation of the friction and for that locality you add the friction above plus the end bearing at that point you move to a next point you will add the skin friction all above up to seabed plus the end bearing at that particular level.

So you just keep on doing it and you will get a relationship between the horizontal axis and the vertical axis which is capacity versus depth. So you can divide the total soil layers into say every 2 meters or every 1 meter each level you will do this evaluation of combined capacity.

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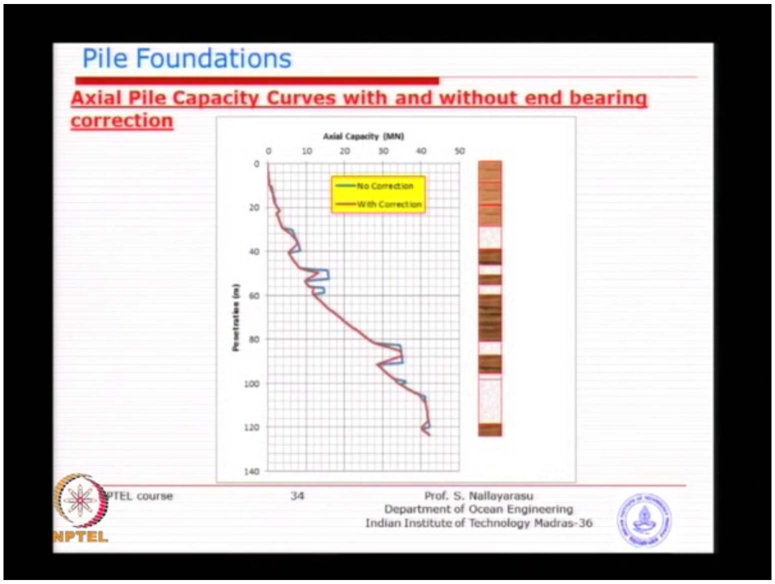

We will now look at a capacity generation for interface layers for example I have a only single layer soil of clay or sand then there is no issues, whereas when you are talking about offshore pile systems, for example if you see here multiple layers of alternating types sand and clay.

So you can see here predominantly clay material except that several locations at intermediated depths of sand material, now you see here this is slightly deeper sand layer and then you have slightly bigger layer. Now we want to go to this point because I want to get certain capacity that is what you are trying to decide when you drive this pile all the way from 0 to 100 meters for example or 110 meter you will get a end bearing capacity of that particular layer because that is going to be very large so let me (())(16:06) drive that.

But while doing so you are going to puncture through layer 1, layer 2, layer 3, layer 4 of smaller sand layer as long as you have sufficient effort to drive through you can drive if not, what will happen the pile will stop at that layer because you have taken a smaller hammer to offshore you did not evaluate properly. So what will happen you are at the starting of this layer or maybe slightly gone but you are unable to drive either the hammer will break or the pile will fail because you are trying to overdrive.

So if you stop the pile here what happen to the capacity, now you have a lesser penetration number 1 and this layer is not too large for you to take the capacity because there is only a small say 3 meter or 4 meter. Now there is eventually there is uncertainty whether that layer is there or slightly lower whether the thickness is 3 meter whether the thickness is 2 meter. Now if that happens whether can we take the capacity of that layer full or can we take the capacity reduced because there is an uncertainty.

So that is where several rules and regulations have been there for last several years basically idea is when can you take the capacity of a increased layer like sand layer or a rock layer when can you consider that layer as effective in giving you the resistance whenever the layer is sufficient enough depth to avoid punch through, for example you design in such a way that the pile is resting on this and if the layer is only 2 meter and or 3 meters whatever and you apply the load in reality and if the layer has supposed to be 3 meter happen to be 2 meter and during the slight overloading of the structures punch through and the pile fail.

Now that to avoid that we need to have a minimum layer depth minimum pile must have gone inside the layer itself, so that is the reason why you put the smaller layer we cannot consider full capacity we need to downgrade the capacity of that so that we are in a safer side. So that is the rules we want to do so that means we need to downgrade the capacity something like this you can see here in blue color is no correction the red color is correction that means if you stop the pile at the start of the layer you cannot consider full capacity you can only consider a path capacity and if you go by slightly increasing you can consider slightly more.

So linear interpolation between the resistance of this layer to this layer because otherwise there will be a certain increase no you can see there the blue color the same layer gives you a lower capacity because you are using the capacity of the clay and the same location if you go to this using the property of the sand you get a higher capacity which you want to take that is where the biggest problem.

So we will normally do a linear interpolation with acceptable penetration depth into the sand layer, so that is where we are going to see 3 cases.

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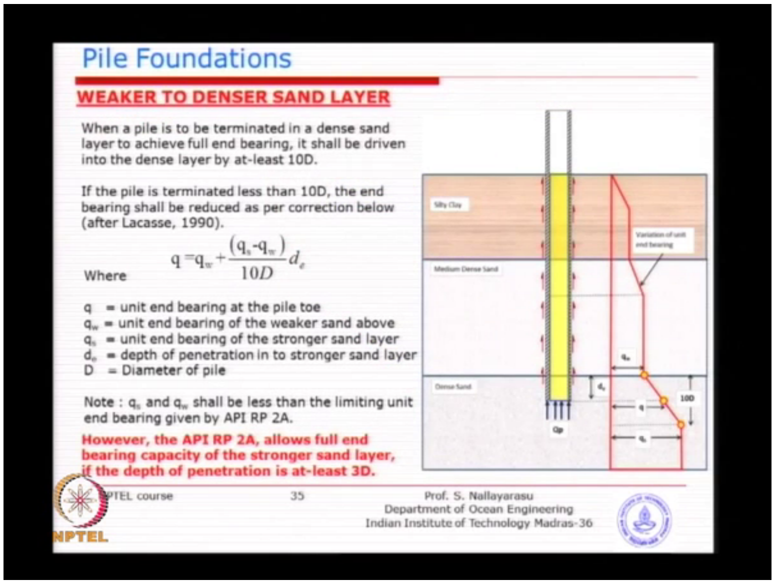

The first case if you see the this picture you have a medium sand to a dense sand transition from sand to sand but you have a slightly less dense on our first layer and a denser sand on the last layer where I have decided to penetrate into the denser layer and then bound to take advantage of the capacity.

So you can see from this picture it has got slightly reduced end bearing capacity this has got a higher end bearing capacity but theoretically speaking when I put the pile on exactly at the interface I should consider the full capacity of this dense sand layer but it may not be true for several reasons one is the variation in the layer thicknesses from what you have learnt from the geotechnical investigation to actual situation plus the distribution of the pressure the bulb will actually have some effect on the previous layer.

So that is why this minimum 10 diameter if you have penetration of the pile into the denser layer by 10 diameter then you can consider that layer capacity as full. So you can see here when you penetrated the pile into 10 diameter you take the capacity of the denser layer. Whereas anything less than this you cannot take the less denser one you can do a linear interpolation between the denser layer to the less denser layer.

So that is the idea behind you see here the qw is the end bearing capacity of the weaker layer we call it slightly weaker whereas qs is the stronger layer in between if you penetrate for example if you try to penetrate you think you want to achieve but you can only drive say 2 diameter, 3 diameter because the denser layer is having so much of resistance.

Then you do a linear interpolation that means simply qs minus qw divided by 10 diameter multiplied by the (())(21:14) the depth of penetration what you have achieved and that will be your capacity which will be including the capacity of the weaker later. So something like this has been proposed several years back but imagine if you have a 2 meter diameter pile and 10 diameter is 20 meter if you have to drive 20 meter into a very dense sand as well becoming impossible.

So API has been collecting lot of information over several decades finally they have come to a conclusion that 3 diameter is good enough to achieve a full capacity, so hope you understand the idea behind why from 10 diameter we have come down to. So normally when you try to install a pile foundation whether it is a concrete pile or a steel pile if you are able to achieve at least 3 diameter then you can take the capacity of that layer, if not you have to use the weaker layer or interface or interpolate between the weaker layer to the stronger layer.

So that is the message that proposed by Lacasse in one of the geotechnical general which has been followed you know in fact everybody is doing this nowadays except that API has reduced that idea to 10 D to 3 diameter.

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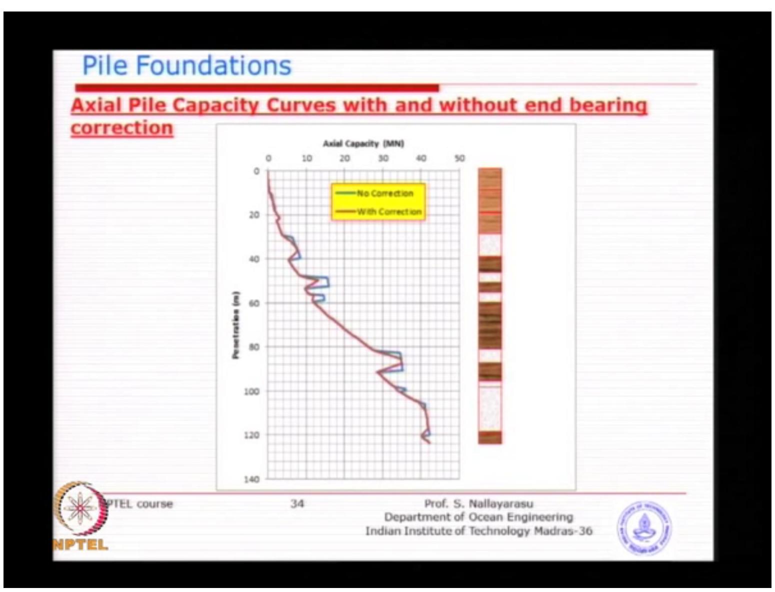

So when you are actually going back to this picture now you can see here what has happened if you just concentrate on this layer the starting of the layer capacity is calculated based on the previous layer basically based on the weaker the clay material and then when you are gone down to 3 diameter below it has achieved full end bearing capacity of sand layer but in between you see the red color is just linearly interpolating, comparing the blue one the blue color is basically with no correction that means I will have lower capacity and higher capacity like a steps which is not correct which is not going to be achievable.

So that is the idea behind the corrections for the interface of layers to layers which needs to be definitely done. So that is one from weaker to denser like this we have two three cases which we will go through quickly.

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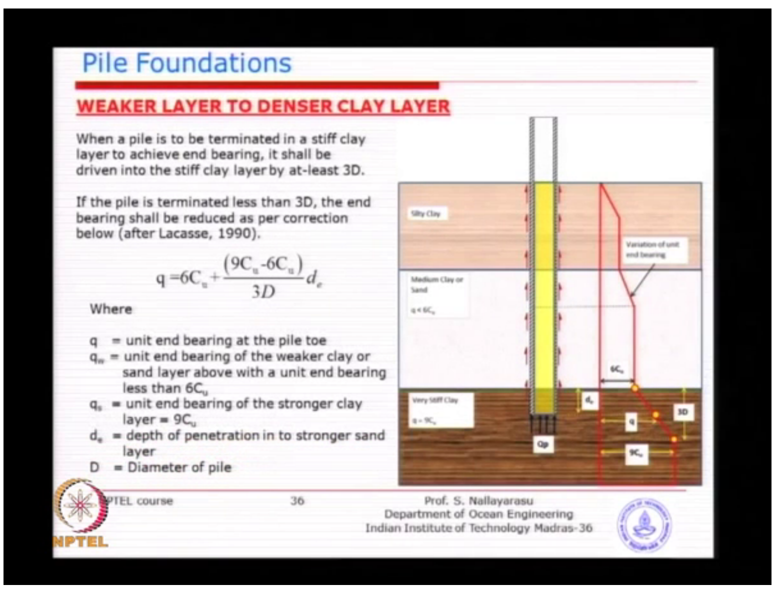

The next one is you have sand layer and a stiff clay of course arguably clay is not going to offer so much of end bearing capacity as you can see from the equation you know is undrained shear strength is the only parameter which is contributing to your end bearing which is not going to offer two grade unlike sand layer where the over burden pressure is going to present good amount of you know the end bearing resistance.

So in here we have medium clay or it could be sand either way and you have a very stiff and what we are looking at is similar formula I we know very well that 9Cu is the maximum capacity that you can achieve for clay and 9Cu minus 6Cu divided by 3 diameter straight away I have put the API requirement instead of 10 diameter because we are not practicing 10 diameter so we will just use 3 diameter multiplied by. So is again a similar linear interpolation from weaker clay layer to a stronger clay layer only the equation or the resistance is changing from sand to clay.

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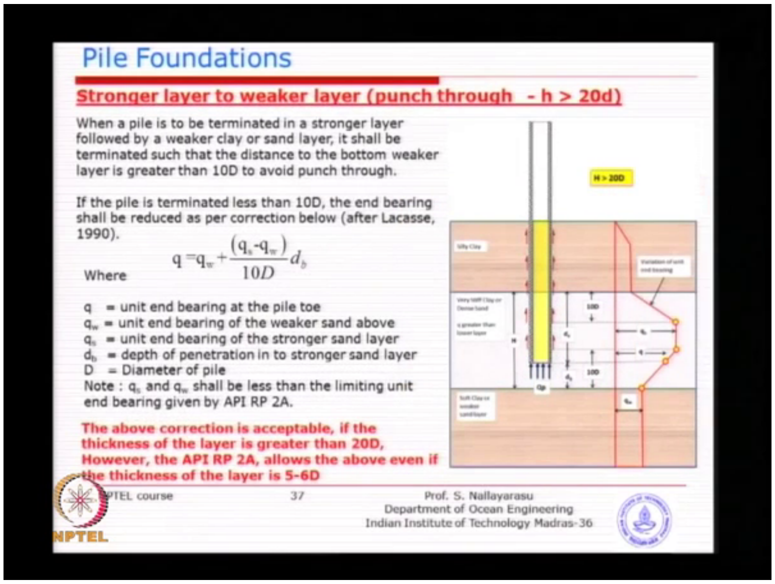

The last one we will be looking at something difficult one we have a softer or less denser material on top and we have a slightly different material but also not very strong but we have a intermediate layer very similar to the one that we saw here something like this we have a sand layer and preceded by clay or less denser sand and also followed by either a clay or a sand which is less stronger than the layer in (())(25:19). So what we need to do is we just need to apply and compile both the things one is forward and the other one is backward.

So both reduction has to be done and that is what you see from this picture if you just go back here we have done a forward reduction we have done a backward reduction you come from bottom to and come and join. So what will happen if the layer is too small? If the layer is say only 3 meter, 4 meter so you may not actually achieve full capacity, is it? Because we need to come forward reduction by 3 diameter backward reduction by 3 diameter and at least you need to have 6 diameter to get the full capacity one place.

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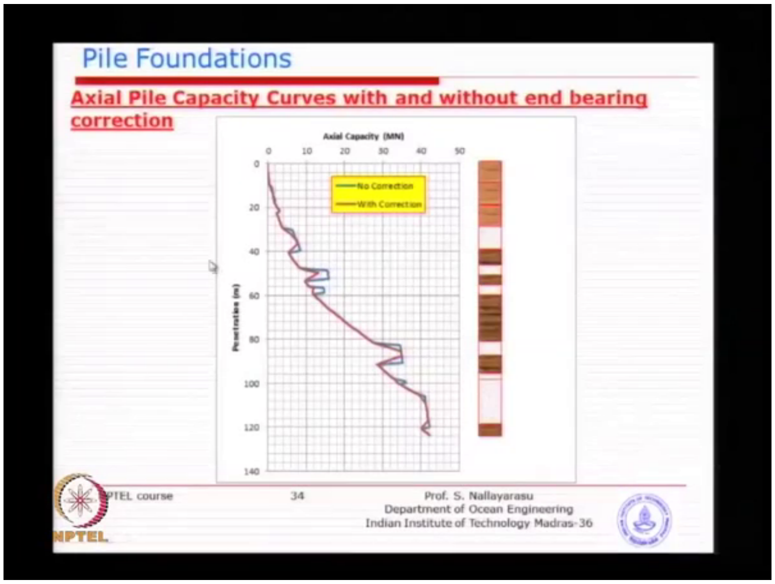

But if you have only say 3 diameters only you will see that you will not be able to achieve that has happened in some places if you go back to this picture you can see here the full capacity is this much whereas the capacity achieved is less because when we are doing when you are meeting the forward and backward reduction lines you will come and only just get 50 percent or 40 percent you will get full capacity only when you have the depth of the layer bigger than the twice the requirements of 3D or 10D whichever is.

So that you need to understand that you are not going to get full capacity unless that is what has happened so you have not actually come to the maximum the maximum is somewhere here you see when you are looking at the backward reduction maximum is some here. Whereas the forward reduction comes to meet here you cannot achieve both the capacities either the capacity of the stronger layer, so that will be a typical task when you actually do a computer program or calculation by yourself.

And originally we were looking at 10 diameter but now most of the time we use 3 diameter forward 3 diameter backward and wherever the meeting point and suppose if you have for example 10 diameter what will happen the graph will be something like this, so you will see that, is it?

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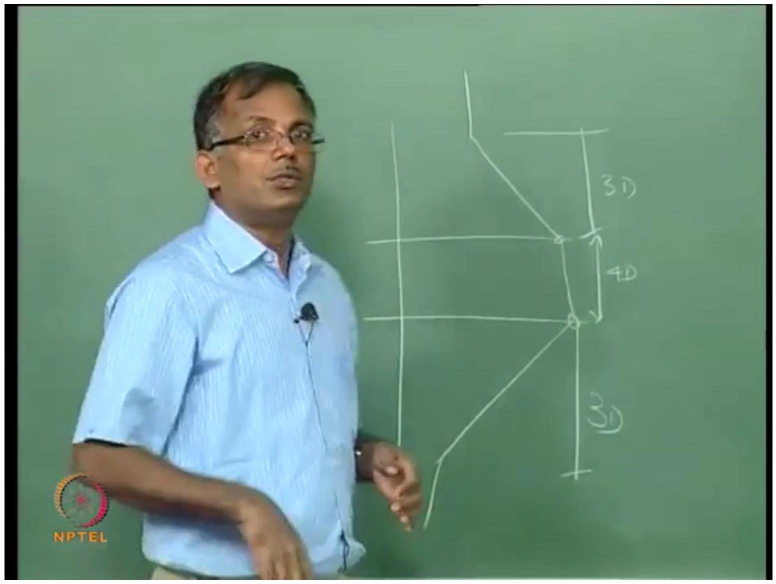

So for this will be your 3D and that will be your 3D reminding 4D will be full capacity as long as you get that much of depth.

So this stronger layer to weaker layer is predominantly for the purpose of punch through you know if this layer is lesser and lesser we should not consider the end bearing that is the message that you are trying to get we call it punch through effect because many times what happen you try to locate it there but slight overloading of the structures will punch through and end up in during operation of the structure and then you will fail foundation that is many times happened so that is why you have to be very careful there.

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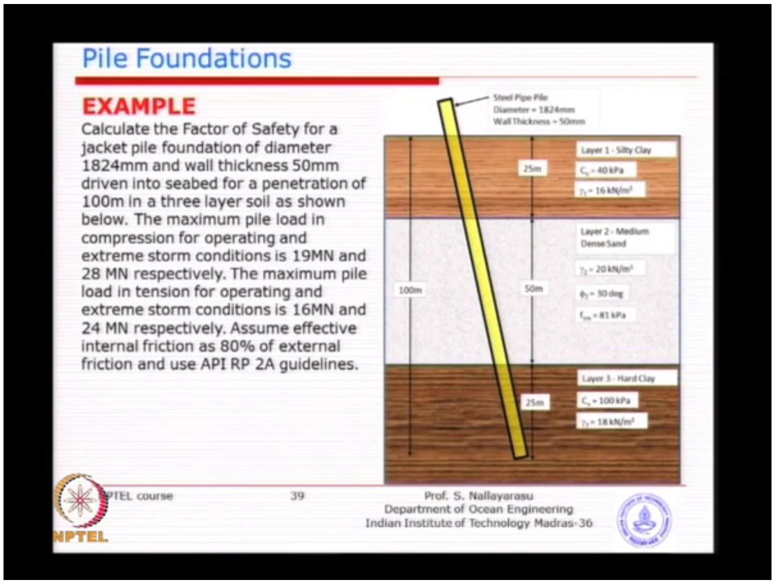

We will see a quick example I think the recap of the whole calculation is very simple mostly geometric I would say you know surface area multiplied by the length what you are looking at is the skin friction resistance end bearing resistance and skin friction we have two methods alpha and beta method very simple and then end bearing empirical formulas are given in relationship with either Cu or with the overburden pressure and you see here there are 3 layers given to you 100 meter penetration and the first layer is predominantly clay and the second layer is sand third layer is also clay but of slightly higher strength.

So you could see the typical pile diameter wall thickness just for practical purposes I have given one of the recent project. So basically 100 meter penetration is a typical number you should remember most of the optional pile systems will be something like this not very small not too big 100 to 100 50 meters maybe 1 to 3 meter diameter any diameter that can occur. And the type of load you can see here 19 mega newton so you should get some kind of practical sense of the magnitude 19 mega newton is almost 200 tons you understand idea no 200 tons 28 mega newton is approximately about 3000 tons.

So that is the magnitude of foundation loading if you just recollect most of the foundation design in onshore structures you know something like 100 tons 200 tons you will be talking about 300 tons but not more than that you know handling and such type of numbers using remember what is a magnitude or order of magnitude when you are designing foundations. So you can see it is

10 fold increase from onshore to offshore we normally design foundation onshore maybe not more than 300, 400, 500 even if you look at a multi-story building several story building you put so many foundations or so many piles in such a way that loads are distributed that is the idea.

Whereas we do the exactly opposite in offshore we cannot put as many piles as we think because of the difficulty we face in offshore installation. So we actually combine every one of them together with 4 piles or 6 piles which carry multiple times of the same type of pile that carried by onshore foundations that is the difference you are looking at. So you can see here 2000 tons versus 3000 tons is basically for 2 different type of conditions why it is given there because you are going to evaluate the ultimate capacity now remember 19 mega newton is operating 28 mega newton is storm now you have a different factor safeties.

So when you multiply 19 multiplied by 2 the ultimate capacity required is 38, whereas 28 multiplied by 1$5 will take you to 28 plus 14 will be 42. So now you see there are two different numbers one is 42 the other one is 38 now you can conclude that it is governed by the storm condition. So you need to go and look for this 42 mega newton of ultimate capacity as a minimum so that is the idea behind why these numbers are given so you should look at evaluate what is factor safety is remember and then find out.

Similarly for tension 16 mega newton and 24 mega newton, so that is where so required tension capacity is 32 based on 16 mega newton operating and 24 you will or 36. So you see here 42 mega newton compression is required and 36 mega newton tension is required based on this information you go here so you could actually get the variety of problems here you could be asked to find out what is the factor safety you know in this case I have asked you to find out the factor safety or you can actually go vice versa find out what should be the minimum penetration required to achieve a factor safety as per the code, is it?

So now you need to do a iterative procedure because is going to be a problem the overburden process depends on the depth of penetration but depth of penetration is not known to you, you understand the idea no? So that is where the slight twist to the if it is the forward question like this is very easy because anybody can do it simply do 2 minutes of calculation so you need to learn to practice unless you practice you will not be able to get things right.

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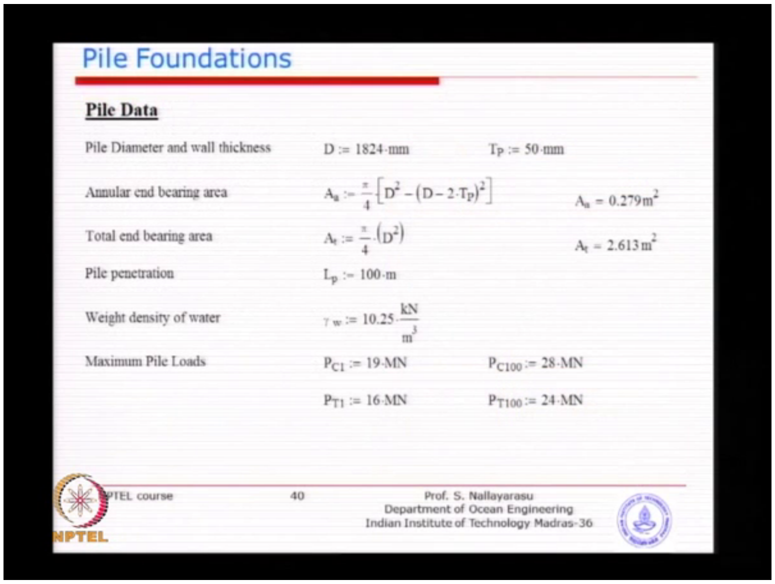

So now let us go to quickly review of this particular problem all the data is given you should know how to calculate the areas and geometries and modular (())(33:20) you should not ask for formulas so you should remember all those information.

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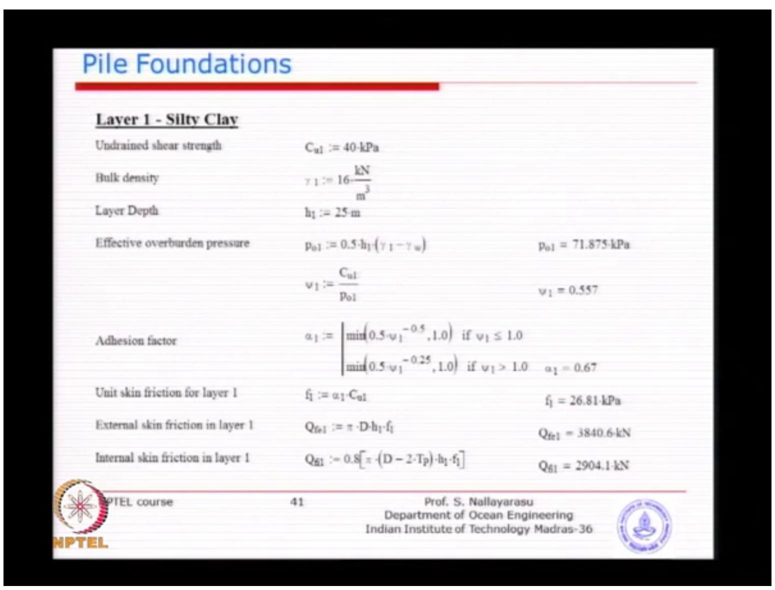

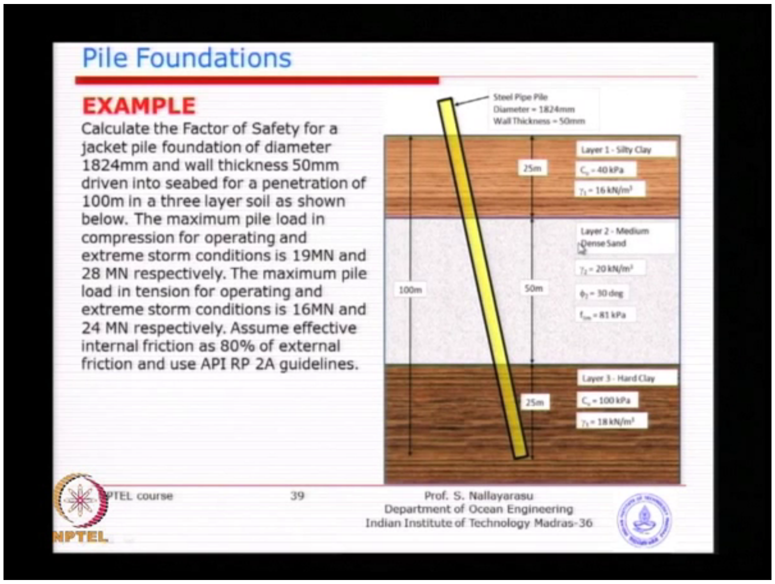

So let us look layer number 1, layer number 1 is the depth of the layer is 25 meters density is given bulk density which is basically will be provided to you as similar to this sketch will be given to you and then we have undrained shear strength of 40 kPa. So three information layer depth and then you have got density you have got undrained shear strength. Now we know the procedure for clay this is basically once you have been given with undrained shear strength straight away you should understand it is a clay type of layer hopefully if you remember and then use the method which is relevant, so you should go for alpha method and alpha method is very simple you need to find out undrained shear strength for that layer plus the overburden pressure at the point of interest.

Now you have 25 meter but if you look at the equation how it varies alpha is varying with C as well as overburden pressure. Now if you look at that equation it is to the power minus 0$25, is it? And strictly speaking you should do divide the total layer into say every 5 meters every 2 meters depending on the time you have if it is examination we can divide cores but then normally if you plot the variation of alpha with respect to if you see that picture I have shown earlier on it varies non linearly is not a very straight line but most of the time we accept the approximation of a linear relationship between depth versus alpha.

So for this particular problem what I have done is I have taken at the center of the layer and calculated the alpha value you could do that for starting of the layer end of the layer and between several points and then you can plot the capacity depending on the time. For examination point of view we will do a center of the layer, so in this particular case if you look at this formula for overburden pressure is half h 1 multiplied by effective density, effective density is your bulk density minus water density.

All of them I am working on the basis of weight density not the mass density, so basically you can see why I have put half because I am evaluating at the center of that layer you could do so you can actually do starting of the layer and ending of the layer and do an average we know very well that it is nonlinear but still approximation is acceptable. And basic once you get the p not and find out the ratio of c by p not and you find out what is the value of alpha using the empirical formula given to you depending on whether the value of the ratio is less than 1 or greater than 1 which we have already explained the other day and must be limited to 1 if this value comes out higher than 1 that is the you need to remember.

So once you get 0$67 multiplied by c value you get a the skin friction so I think this at least this much you should remember. Then calculation of the capacity within the layer is you know pi D times h pi D will give you the circumference and h will give you the surface area multiplied by the surface skin friction will give you the skin friction capacity I think very simple. So basic idea is this is external and I have already explained to you we will normally take reduced capacity of 80 percent, 70 percent for internal because the (())(37:10) soil.

So you calculate the internal surface by detecting the wall thickness and you get the internal skin friction. So when you add internal plus external you have got the capacity of the soil at the inner surface and the outer surface of the steel soil interface. What we have represented is f 1 is representing full layer depth, you understand the idea no because we have calculated the center. If you do not want to do so you can actually do it at the surface which is at the seabed you can do it at the end of the layer you can do an average or you can do a every 1 meter if you have enough time but the difference is going to be very small I think I have shown you the plot of alpha with respect to depth.

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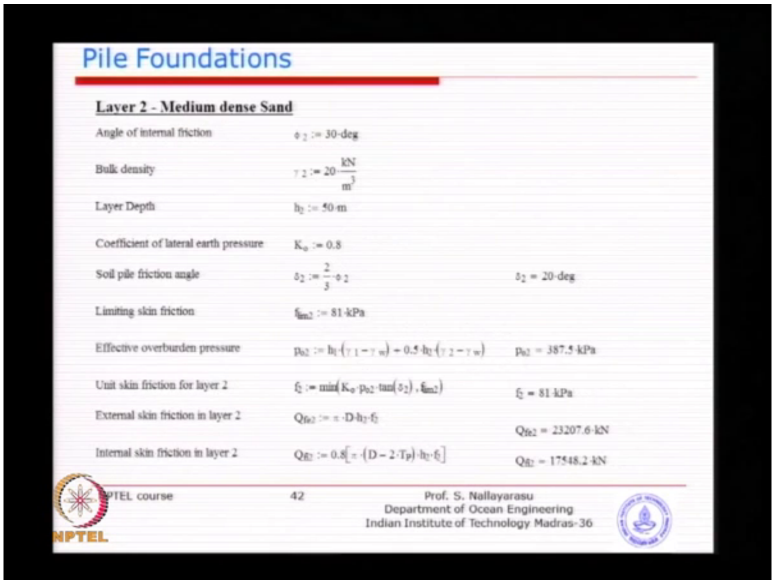

So that gives you an idea how you calculate for one single layer when you go to the second layer we will just quickly look at second layer the only difference is this is being sand method become beta method instead of alpha method but the overburden pressure you can see here overburden pressure for the second layer I have taken half the depth but cumulatively add with the weight of that first layer that is very very important you forgotten then all the results will be wrong remaining is all just putting together numbers.

In this particular problem we have used direct calculations of beta based on 5 value because that is given to you here if you go to the problem its phi value is given you have not been given with beta directly if you use a new API code you will be given directly beta but in this particular case phi 2 is given so you calculate this delta value and then correspondingly you calculate the beta value is k, p not and (())(38:57) delta which I think you should remember. So all this formulas will not be given the formula that is supposed to be given I have already given information only the table will be given if require.

Then you calculate this internal external by simple means of pi D h internal pi D h external and then we got the last layer exactly do the same thing only thing is add the layer one 1 and 2 full bed layer 3 you take the middle of the layer for skin friction and this is being a clay layer you do repeat the procedure. In this particular case what has happened now alpha becomes 1 because overburden is so much that we should not take the values of higher than 1 so limit it.

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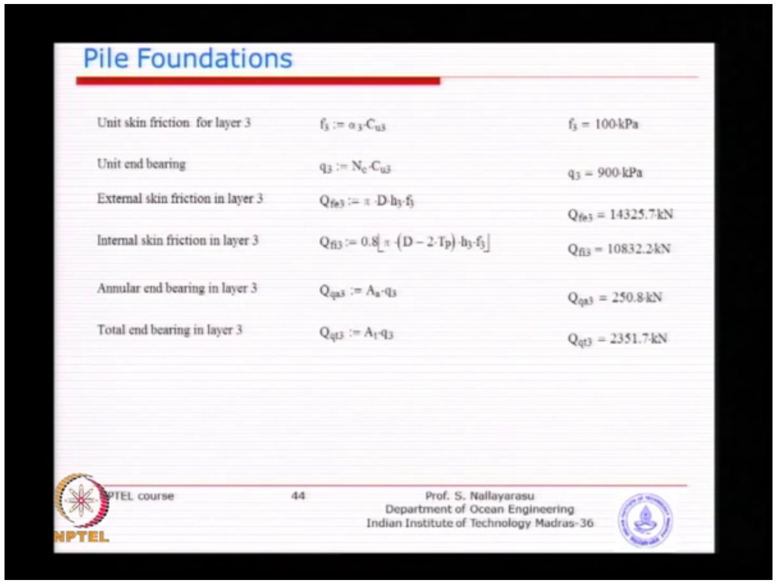

Then come to the end bearing, end bearing we need to do is we go back here when you are evaluating the end bearing at this point you cannot use the previously calculated p not value at the middle of the third layer we have to recalculate the p not at the end of the pile it is sometimes people make mistake because take that half value and then you cannot do it because for skin friction representative is the middle of the third layer for end bearing you have to recalculate the p not value or overburden pressure at the tip of the pile you need to recalculate I think it is done somewhere here or it is not done, yeah it is not done here I think annular end bearing Q values this is done it is clear but this is only for skin friction but for end bearing I think it is not require for clay type of soil but if it is a sandy type of material then nq times p not will come.

In this particular case you have nc is empirical value given as 9 so we do not need to worry, but if when it is a sand layer you have to recalculate this p not by replacing this 0$5 with 1 and then use that p not for but in this particular case it has become no problem because we have c times nc nc is 9. So once you do this then you have got the two types of end bearing annular end bearing and total end bearing.

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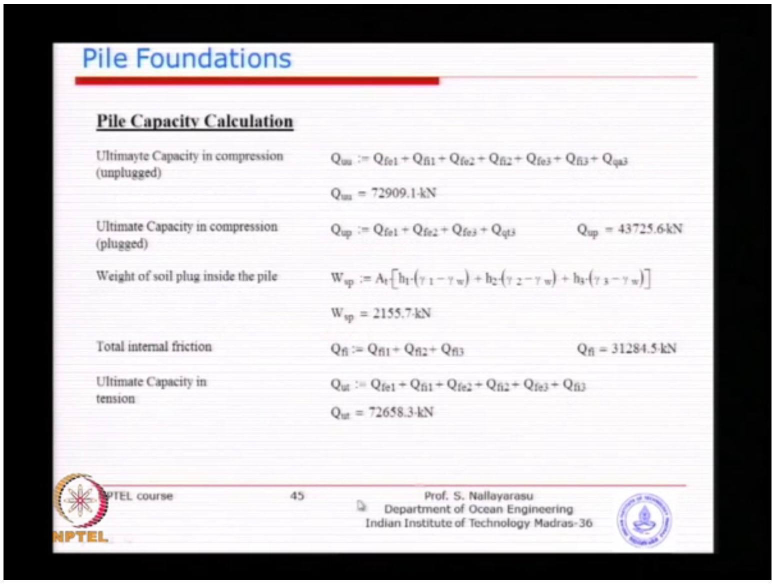

Then the corresponding calculations whatever I was trying to explain determine whether the pile is plugged not plugged summation of internal friction all those things can be followed.

And then ultimately ultimate capacity intension, ultimate capacity in compression and then use the formulas to divide by the factor safeties to compare whether you have sufficient capacity or not.