Foundation of Offshore Structures
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Module 1
Lecture 10
Pile Foundations 1

So today we will evaluate the capacity of the pile plug so that we can determine what is the N bearing capacity we can limit as proposed by Randolph we can see here.

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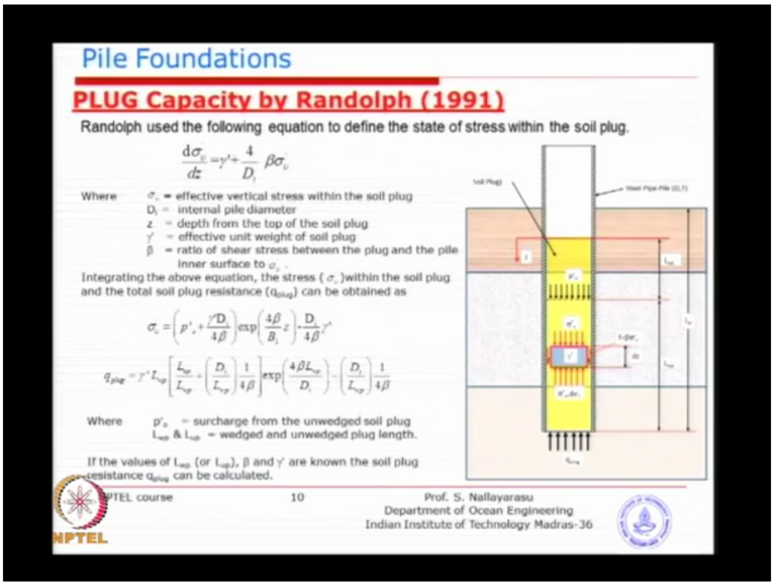

He has integrated the internal you know the vertical pressure and arrived at the limiting capacity which will be either the frictional capacity plus the rate of the soil or the plug capacity determined here is depending on the soil at the base.

So that is why not only just because of the type of soil but also depends on the soil within the plug and the frictional resistance within the pile inside also will determine what amount of N bearing that we can allow. So basically that is the starting point from where they started.

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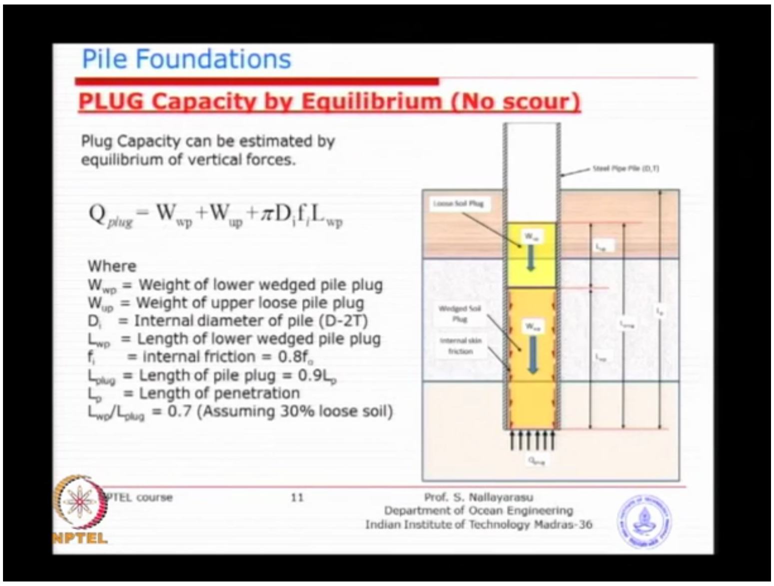

Now if you look at the simplified approach when the plug the soil inside is lower than the actual level of soil outside due to several reasons one of the reason is the course grind material get densify and you get slightly lower but off course the depth by which it goes down is not substantial sometime you get a plug ratio of 0.9, 0.95 like that it is not going to be completely not there. So many times we get a 90 percent plug ration means 10 percent of the depth inside soil in not there. So you can calculate the plug weight by using density and height of layers.

So you can see here one important approach taken by Randolph also is to assume slightly less denser soil a loose soil plug and a densified soil plug so they called it density ratio of the soil plug within the pile plug itself. So you can see here the weight of the lower wedge and weight of the upper wedge slightly different because of the different type of density assuming that the soil outside is same.

But here he got multilayer soil so you need to proportionate, proportional to the depth of the soil layers outside and correspondingly reduce the height. So it is a little bit geometric exercise plus the inner friction capacity basically taken only on the denser soil the friction capacity and upper soil is ignored because it is anyway loose and it is not going to offer that much basically so that's why we can see the frictional capacity is only taken in the insides and only on the lower soil.

So when you add all of them together and that will be the the plug capacity for the bottom so if you have higher plug capacity because the soil is very good at the bottom does not mean that you can take it because anyway when you have a N bearing of higher capacity the soil plug will start move that means the plug will fail before the pile files. So this is the limiting capacity basically when there is no scour, scour I think we will discuss about it in the later part of the course where we will talk about the causes and type of scour and the nature of scour.

Scour is nothing but removal of soil in vicinity of the, the structures or the pile that you constructed on sea floor basically because of the obstruction the increased flow circulation will remove the particles away and forming a small crater around which is called scour and is very-very serious when you have a granular type of material it takes away very easily and except the if the granular material is heavier then it may not be possible.

So the scour means the soil is removed in the vicinity in this particular case there is no scour so is the inner plug is smaller than or height is lower than the outer. When you go to the same thing if you look at this picture

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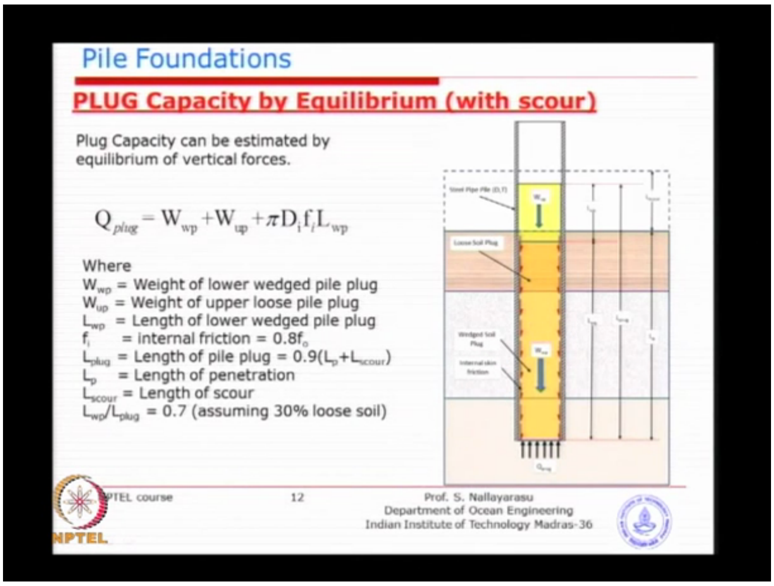

The soil original soil floor is somewhere and the soil have been removed because of the scour so that is the difference otherwise the calculation is same but the inner soil within the soil plug has not been removed because it contained within the soil.

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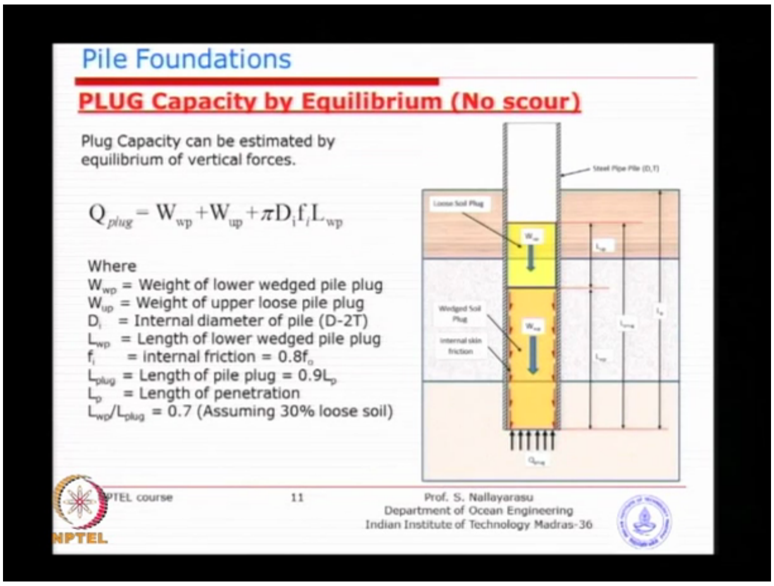

So that is the a simple geometry so in here we have to understand two things, one is the internal friction, the external friction so the internal friction is taken as 80 percent of the external friction as you can see here the pile the soil within the pile is confined so the development of 100 percent friction is somewhat questionable. So generally we assume lower friction capacity of the internal pile surface to soil to the external surface to soil.

So normally we take about 80 percent and you can see here the length of the pile plug which is typically about 90 percent that means penetration is say LP 90 percent of that is basically the height of the plug inside so that is the meaning of point nine LP is the plug ratio and you can see here the ratio of the denser to loose soil is also around 70, 80 typically last (20) 30 percent of the soil is going to be slightly loose.

Unless otherwise any information is given you can by default you can use the values of the numbers I have given here and especially this friction though API does not actually differentiate between the internal friction and the external friction you know the give the engineers choice to decide a value of internal friction but generally we use 80 percent.

So 80 percent means when you calculate the frictional capacity of the outer surface to soil is 100 percent the inner surface to soil is 80 percent because is well confined and unable to mobilize that much shear between the soil and the pile so that is some information you have to keep in mind which you will not find in the course. Course does not necessarily limit point 8 they just allow you to use 100 percent.

So the same thing which we can do a calculation for the scour case

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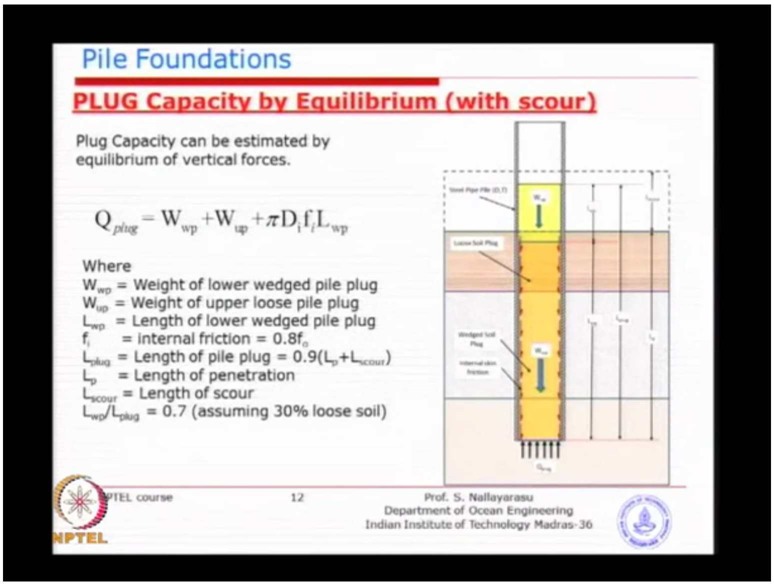

Where the soil in this outer vicinity has been removed exactly same except that the plug ratio to the final form of penetration will be higher because you just have to take into account the scour also because that is the only difference otherwise calculation method is exactly same there is no difference. The reason why we do this I think hope you have understood is basically because the pile plug matters in determining the capacity of the N bearing.

It is not that only the N bearing is determined only by the soil by which you are actually resting on it so that's the thing that you need to remember. Whenever you have a soil here based on the soil you calculate the N bearing very similar to the bearing capacity that we have determined for clay type of soil we have used the lower bound solution for four CU and upper bound solution of 6.28

So in between you can take a value which will be your bearing value but if you take that value and find out the capacity limitation based on the plug and whichever is lower you have to use that. So that's why the limiting plug capacity has to be calculated before you proceed further. Next one basically computation of ultimate capacity,

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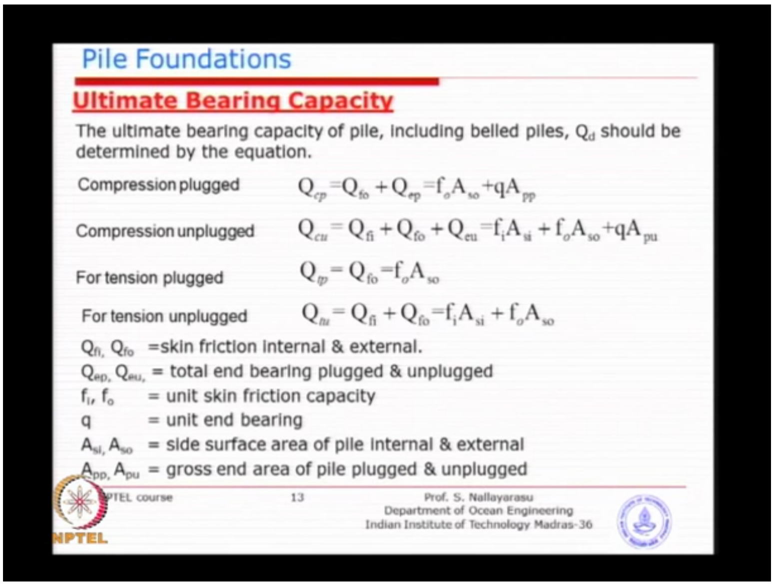

I think the first in fact yesterday we were talking about how the summation of capacity is arising from the skin friction and the N bearing. Two cases we have seen plugged case, unplugged case plugged case is basically the full N bearing with external friction and unplugged case internal friction external friction plus the annular N bearing. So that is the thing that I have written here in a basic idea is compression plugged compression unplugged.

Let us only look at this two so you can see here this is a external friction and the N bearing and this is internal friction external friction and the N bearing on the wall of the pile. So you have a two cases whichever goes lower automatically you will have to assign. As I mentioned you know basically you don't need to do this if, you don't need to really do both of them as long as you are able to determine whether the pile is plugged or unplugged.

If you are able to calculate the plugging is going to form by means of summation of the weight of the pile plus the internal friction and then compare with the weight of the soil. So you can determine whether the pile is plugged or not then you don't need to really do this automatically this will govern. So that's where you know you are not able to determine whether the pile is plugged or not plugged then you can find out the capacities of the external plus the full N bearing internal external and then annular N bearing and whichever comes lower you can assign that means the pile has plugged or not plugged accordingly.

For tension capacity is only the skin friction can be taken because the load is applied upwards so you cannot take the N bearing so in this case external friction multiplied by the surface area of the pile which is A means is the surface area of the pile O means whether outside or I means is inside.

So you can just calculate that wall thickness of detecting the wall thickness. For tension unplugged and the only difference you can see here unplugged means you here the internal friction plus external friction. That means you have a friction inside friction outside. Whereas when the pile is plugged you only have a the skin friction outside. So these four cases basically just to calculate the capacity and compression capacity in tension when the pile is applied with a downward load its compression load is applied again the gravity is basically tension.

So the parameters involved is the surface area, internal external and the end area either the annular the steel wall area or the total area depending on whether is plugging unplugging and F knot and F phi which is the skin friction capacity in terms of say unit values per square meter per square feet or per square inch which we need to find out this are geometric values which is not a problem because is as long as the pile diameter is given we can calculate.

Whereas the F knot, F phi and then the unit N bearing which is very similar to the bearing capacity of shallow foundation which we saw the other day so Q. So these are the three parameters which we require to calculate depending on the type of soil that is what we are going to see today. So if you know three parameters then you can find out what is the capacity then accordingly you can decide what is the total capacity available.

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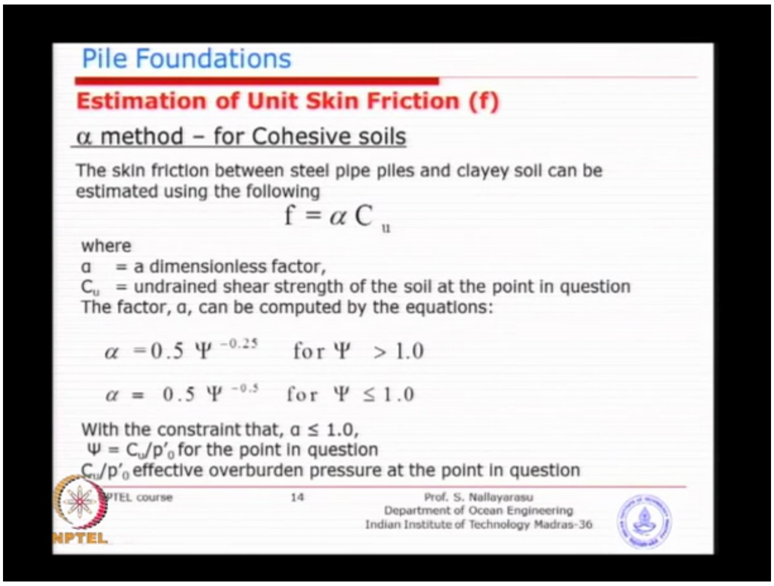

So the first one lets introduce one method simple method for you know cohesive type of soils where the strength is given in terms of undrain shear strength for clay type of soil and it is a fraction of that will be taken as the frictional resistance or frictional capacity between the pile and the soil. So alpha is basically a dimensionless parameter this alpha and that parameter needs to be calculated depending on what type of soil and where it is located.

So can see here numerical formula of this type is given here is alpha is proportional to the overburden pressure so basic idea is soil value is nothing but CU divided by P knot, P knot is nothing but the height of this the layer in which you are calculating from the surface of the seabed so basically multiplied by the density. P knot is nothing but height times density.

So only thing is because undrain condition in underwater we have to take the effective unit weight rather than the total, so basic this is just gamma H so as you can see P knot will keep on increasing as you go down so if it you if it is under surface of the soil its zero because the height is zero as you go down it will increase as p knot increases the value differs.

So there are two criteria given here if the soil value is greater than one used this 0.5 and soil value is less than one use this limiting value of to the power minus 0.5. So this is the difference that we have to adopt so basically whatever you do the calculation alpha value can up cannot be greater than 1. So that means the frictional resistance can only be as much as the undrain shear strength and not more than that.

The soil cannot actually give a friction resistance more than the undrain shear strength that's the thing that you need to make sure that remember to limit as soon as you calculate the alpha value you check whether it is less than one or greater than one, if it is greater than one limit the value to one and value depends on the strength plus your location of the layer from the seabed.

The more that you go down you can easily understand now for example the (())(13:07)layer near the surface and clay layer say 100 meters down you could easily see that the 100 meters down the layer is having so much of overburden effect which will allow will not allow the soil to move away from the pile so that means that you have to take into account the effect of overburden which is going to cost the (())(13:27)of soil to the pile.

So that is why in think that the few days back we were talking about overburden pressure is going to be very important parameter in the deciding what is the capacity of pile foundation because is going there we are going deeper, the deeper you go the soil in this vicinity of the pile is going to help in keeping the soil together with the pile and frictional resistance will definitely increase.

But there is the limit as you can see here for example if you don't have this limit alpha is less than or equal to one this P knot is going to keep increasing and I you can see here the alpha value is as you go down maybe more than one which is not going to be the case. Why did they do this, is basically to limit and based on experiments you know several times experiments on frictional resistance have been carried out and basically in cannot be more than the strength of the soil itself.

Even though the depth of the soil or the depth of the pile is very large like few 100 meters like you know offshore foundation if you go as much as 150 meters so that's where this limitation is there. So you have to remember to limit the alpha value to less than 1. What it means is undrain shear strength this is the limit by which the friction capacity can be mobilized. So this is typically called alpha method of for only clay type of soil it cannot be used for sandy material so will just quickly look at the alternative

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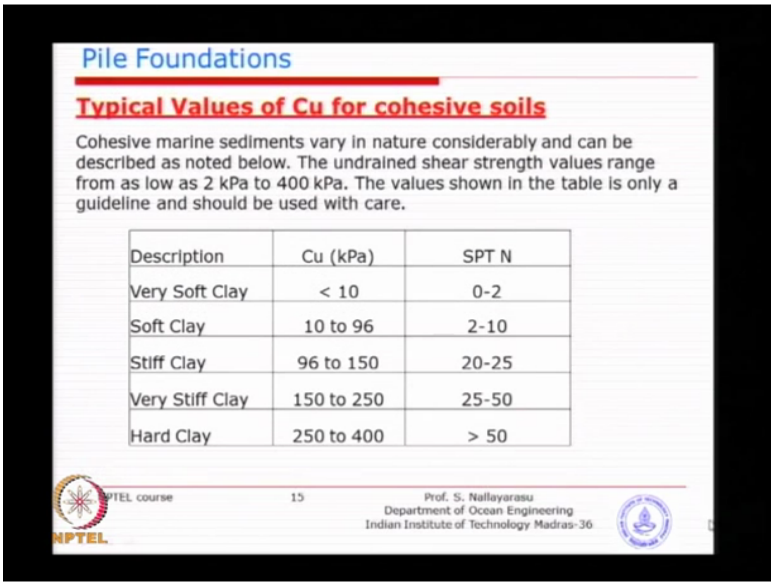

Or in fact before that we can just quickly spend some time on typical values of CU I think we have already seen this table from the interpretation from SPT results is similar. You could see here very low SPT is of something around less than 10 and the values increasing.

So as long as you can find out alpha typically you know 0.5, 0.6, 0.7 very rare cases you will go into 0.8 and 1, so you will see that there frictional resistance is in the order of 50 to 60 percent of the CU values you will get reasonably and as long as you can get into SPT value of greater than 50, you will see that the soil is going to get a good amount of frictional resistance.

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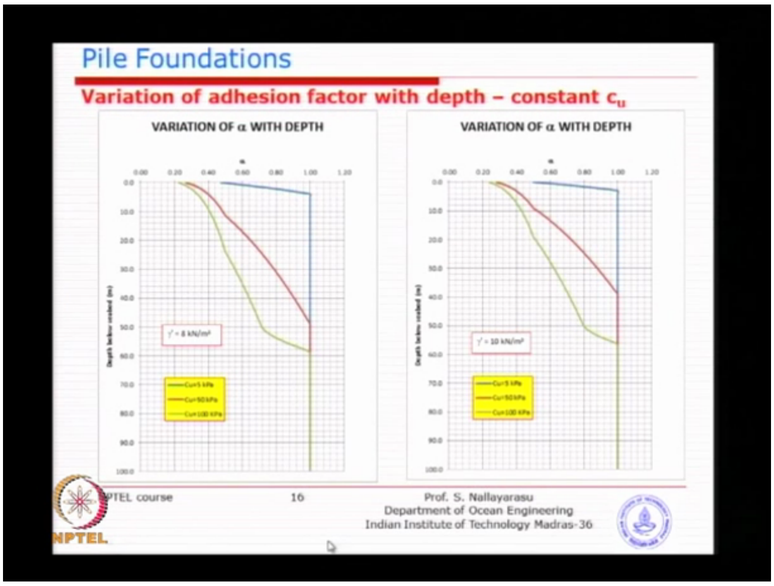

Just to show you that variation of alpha you know we were this is what we were looking at you know the alpha value is going to limited by one, even though when you go deeper so you can see here three different graphs are given one for 5KPA to 50 KPA, 100KPA, 100KPA is basically the green one you know it took almost 58 meters before it becomes one. Because it is basically the density value is 8 kilo-newton per is submerged density.

Whereas for at slightly increased density you can see here it is alpha value becomes one slightly earlier and it depends on the strength because that equation if you look at numerical formula you know the Si is the ratio of the Cu divided by the overburden pressure. So you can see here for lower strength soil like 5 kpa it becomes 1 as early as near the surface. So that is the so depending on the type of soil where it becomes one the limiting plug is achieved can be calculated and then accordingly applied.

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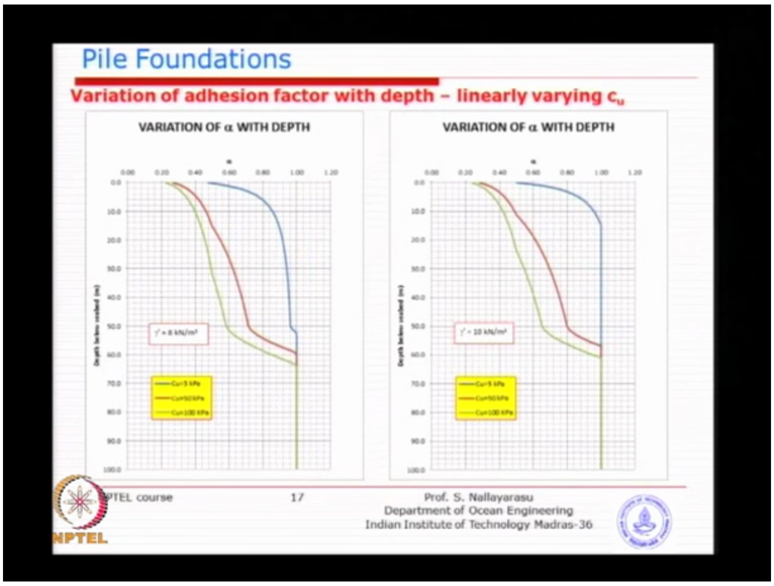

Another chart showing different in fact is the same or different, is different. That is the variation of alpha I think is the same or its quadratic. This is linearly varying CU

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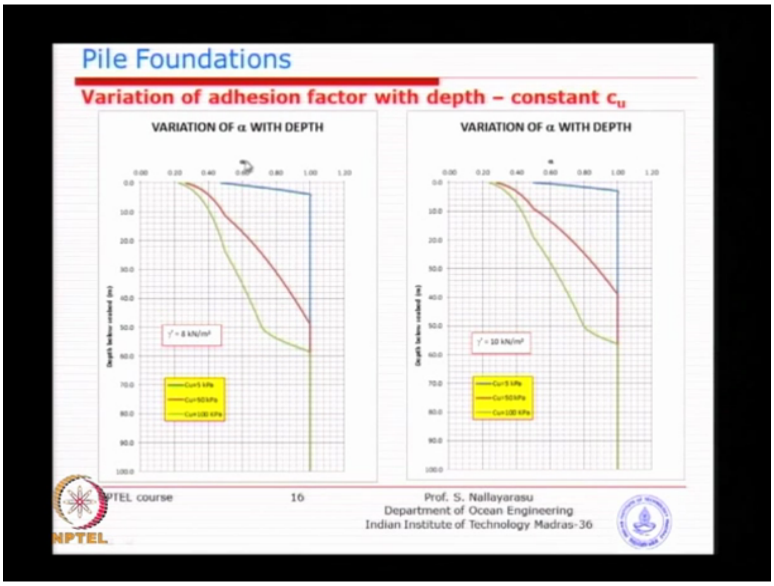

This is basically the constant CU, CU is constant throughout the layer whereas we were seeing that the previous bearing capacity calculation with CU is varying from surface to some depth below. So you can see here is is just basically a curvilinear versus linear just because the CU value is constant here and the CU value is changing all the way from the surface to a down.

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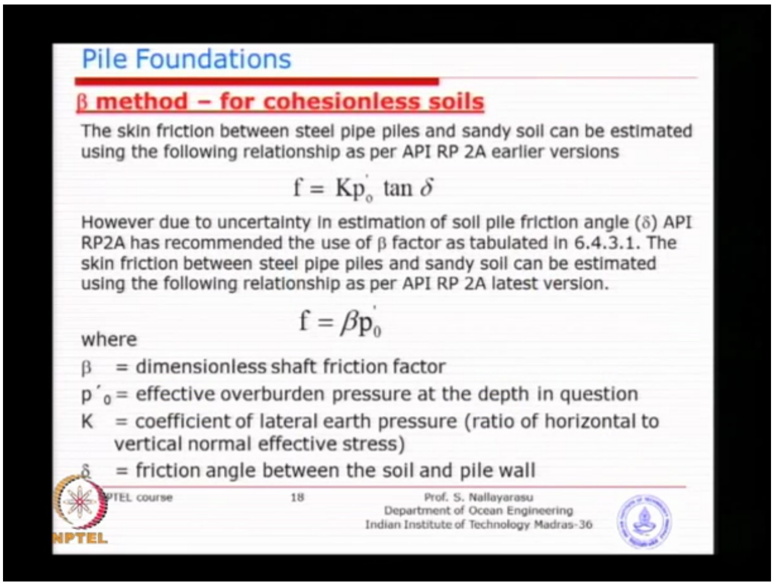

The second method which we called it beta method is applicable for you know the sandy material or cohesionless soils and it's a similar idea only thing is the parameters involved is different. You can see here the tan delta is the parameter which we discussed the other day with respect to angle of internal friction is internal failure angle of the material.

Whereas the delta is the angle that actually forms between the foundation and the soil which h we called it the friction angle and that needs to be determined it is not exactly same as phi and in the past in several literature you can find some relationship between phi and delta which I have given you a table

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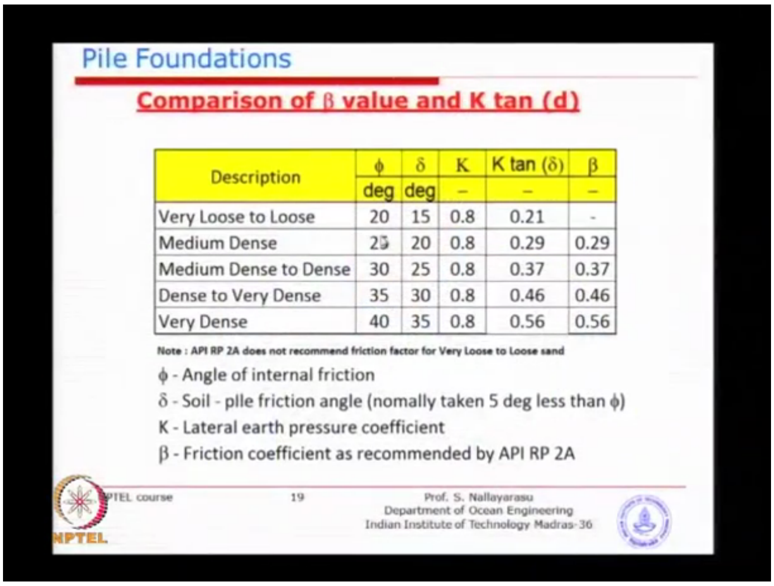

So if have a phi value of 20 degrees delta is approximately by about 15 degrees. Many times we take two third or sometimes some literature you will see delta will be phi minus you like API code they recommend something like this but if you look at some of the literature you will find you can take two third of phi value as delta but in many case when you are using API code they have given you this table nicely so you don't need to really do an approximation. You can remember is 5 degrees less than the phi value so that's something that you can remember.

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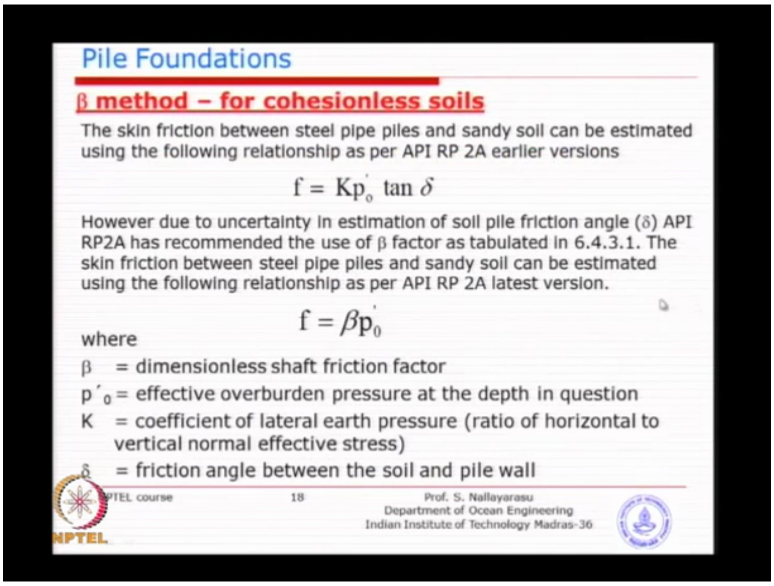

So you see here the frictional resistant depends on three parameters one is the frictional angle between the pile and the soil and the overburden pressure which is nothing but as you go deeper and deeper this overburden pressure is going to increase and K is the, k is the earth pressure coefficient which we I think we calculated active passive earth pressure.

So when you drive the pile inside a granular soil the soil is getting squeezed away so there will be a soil pressure coming towards so basically this coefficient of lateral earth pressure can be calculated as long as you know where is the depth it is the ratio of the horizontal to normal and this because it is a 100 percent displacement pile it will be more, but in this case is open ended steel pipe pile when you drive amount of soil displaced is very limited.

So that is why we will see lower value will be used delta I think not a problem you can calculate as per the relationship between phi and you know the delta. Beta is replaced by the earlier we were having this type of relationship K times P knot into 10 delta in the later part of the code they have replaced this value P knot is kept here and K into 10 delta is replaced by a direct parameter called beta.

Which if you go to this table if you look at this if you calculate k times Tan delta is this and beta is this value. In fact originally the previous version of the code they used to give this delta value and k value and we calculated ourselves. Instead of that the revised version of code directly give because one of the reason is people were trying to use or many of the projects got into issues because even though when the delta value is say 20 degrees its very loose to loose a basically the soil is so loose that the material is not going to offer any frictional resistance.

But because we have a phi value and delta value people used to use this for capacity equation. So new code says if it the material is identified as a very loose sandy granular material you can’t use it for any a strength inclusion so you have to exclude them from calculation that’s why specifically for attempting to make sure that the people are misusing the code is the values of beta is given but not the K and delta. So if you if, we just look at the table

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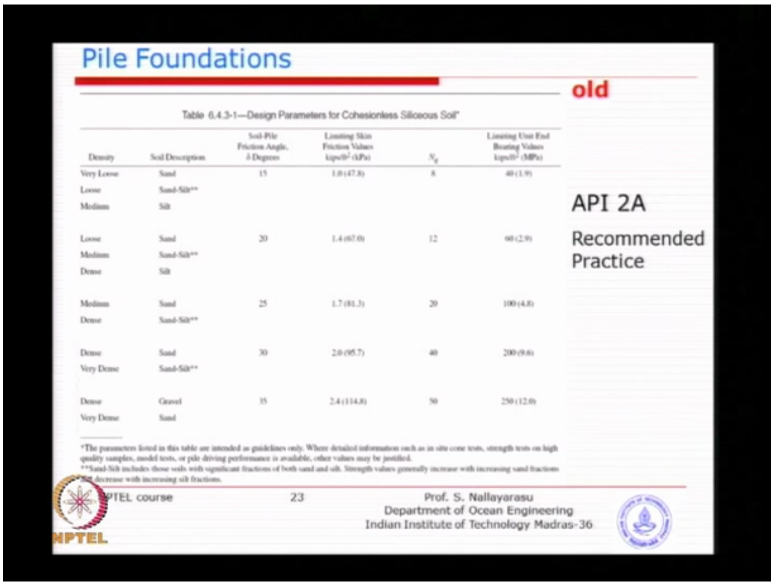

Two table the previous table and the new table that you can see here specifically the value of beta is given rather than the earlier code we used to have a delta angle and you can calculate yourself and then misuse it. The idea is to avoid the use of loose material into foundation capacity calculation. So that makes slightly comfortable. So you can see here in this table as much as angle of friction is 40 degrees you could achieve reasonable frictional ratio 56 percent of the 10 overburden pressure.

So overburden pressure more you will be having the frictional resistance higher, isn't it? but here also we need to have a similar limitation to what we are doing here, in here we limited the alpha value to 1, similarly API recommends to limit the total value that you get from beta times P knot to a limiting value so if you go the table you will see that the new table limiting soft friction value, though you can calculate using beta times p knot.

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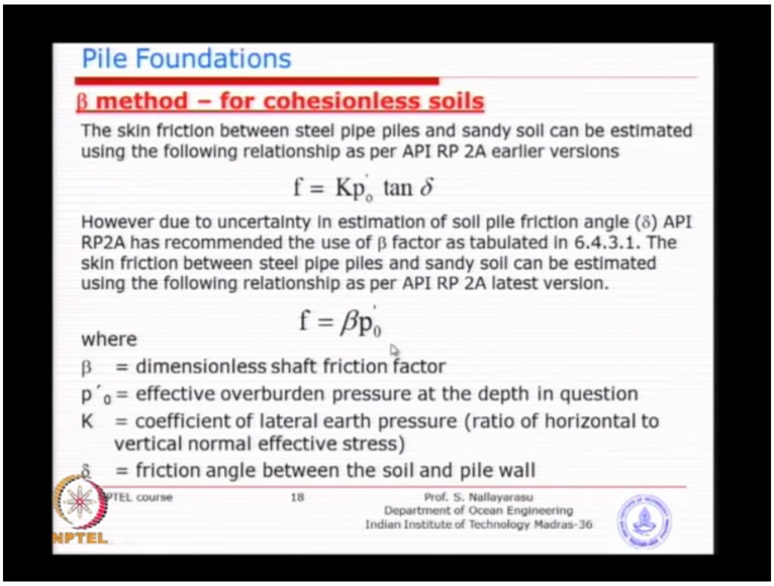

If the value exceeds whatever is specified here you have to limit to the limiting value, you need to remember this. For example there are two units given one is in kips feet square the second one is in kilo Pascal, so you have to use if you are using metric units take the values given in the brackets. So that the limiting value that you have to

So after calculating beta times p knot and find out whether the value is exceeds because you see here beta times P knot means is basically a linear increase with the depth. The more that you go knot is going to be substantially higher if it is 100 meters K knot will be very large value multiplied by this beta you will see that the frictional resistance is going to be, so you can ask a question why we are limiting, again the similar idea the larger depth does not mean that all the soil going to offer the overburden effect to squeeze the pile soil interface intact.

Because after certain depth what happens is soil is going to be self self sustaining and it is not going to give you the so much of effect on the frictional resistance that is why you have to limit this after a certain depth you will not be taking into account this limiting value. So basic idea is two methods one is alpha method the other one is beta method. Alpha method you have alpha times CU, beta method is P beta times p knot.

Both of them involve overburden pressure calculation, overburden pressure is nothing but height times the density of the soil above. Suppose you have three layers how do you calculate? basically layer one times density plus layer two times the density plus the layer three times the density will be the overburden pressure at the place where your , so you should know how to calculate and all that.

The next thing is the N bearing, so think skin frictional is very simple after all the simple algebraic calculations and easy to find out.

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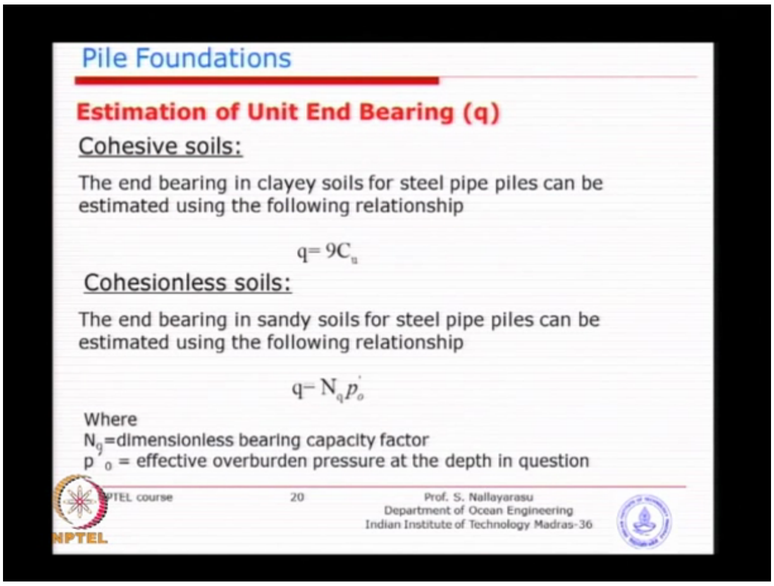

Only thing is you need to remember to limit the values if it is clay you limit the value to alpha equal to 1, if it is sand you have to limit the multiplied value beta times p knot to the code specified limits and that limits are given here for different types of material.

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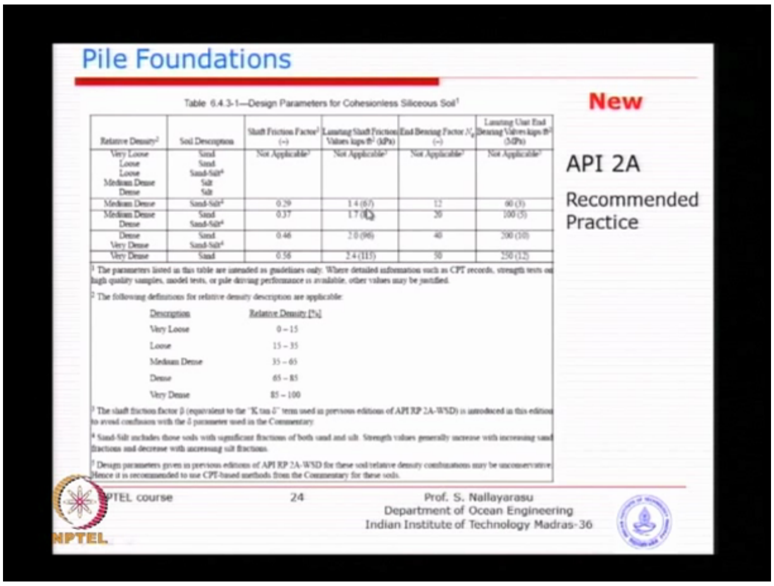

Medium dense is 67kpa, very dense 115kpa so if you if you calculate and find that your values are higher you should limit that so that's the idea behind it.

The next thing is the bearing at the bottom. Now you can see and recollect what we derived over the last few classes about the bearing capacity of shallow foundation in clay type of soil when phi is equal to 0 we derived a lower bound as four times CU and we derived 6.28 CU when the foundation is at the surface of the seabed, isn't it? Not below.

Now you can imagine this pile is going to be installed 100 meters, 50 meters, 60 meters down into the earth that means is overburden effect will come. If you go back and recollect the formula for the footing bearing capacity is four times CU plus Q knot. You know the effect of overburden will come the deeper you go the bearing capacity is going to substantial increase and that exactly the idea here.

You can see here instead of four times CU or six times CU we have 9 times Cu because the pile foundations are going to be definitely installed on the top of the soil, soil surface. No point of installing a pile which is going to touch down the surface only. So it is going to be several meters deep and overburden effect will be taken into account .So that because of that you can see here the increased bearing capacity because we are going to install the pile and the effect of overburden.

Instead of directly calculating they taken as 9 times CU base on several test so that is why the bearing capacity of pile foundation terminated in a clay layer is 9 times CU as a numerical number, we sometime called it this nine replaced by NC very similar to our Terzaghi bearing capacity equation.

You have the C times NC so here also similar and cohesionless soils similar idea P knot times NQ again NQ is the bearing capacity factor similar to the bearing capacity factor we were having in shallow foundations only thing is this number will be slightly different, different from the one that you chop a chart indicating the various values of NQ, N gamma, NC so N bearing capacity is very easy to calculate this is 9 times CU no limit.

As long as C value is larger you can use it but as we know very well clay means N bearing is going to be very-very limited.

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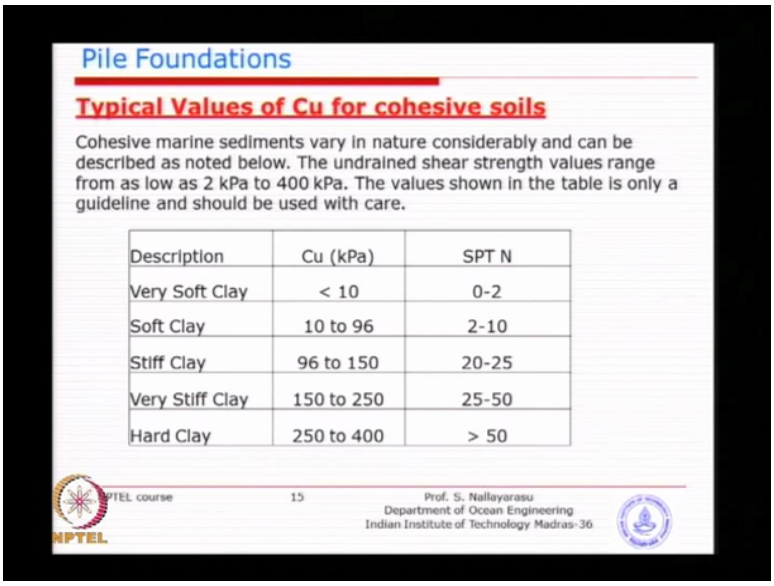

Description	Cu (kPa)	SPT N
Very Soft Clay	< 10	0-2
Soft Clay	10 to 96	2-10
Stiff Clay	96 to 150	20-25
Very Stiff Clay	150 to 250	25-50
Hard Clay	250 to 400	> 50

We saw the values of strength, you see here C values is going to somewhere around even if you hit a very strong clay you are going to hit 400kpa, 400kpa is nothing compared to if you look at a granite or granular material you can get as much as ten thousand.

So that's where the difference clay is not going to offer you a bigger capacity but clay can offer a bigger frictional capacity because the length is more whereas here if you multiply this 400 with whatever the pile surface area at the bottom , you will not get any capacity. So that is why there is no limiting value for bearing capacity of the pile foundation at the terminated at this clay type of layer.

So you can use as much value doesn't matter. Whereas when you look at cohesionless soil P knot is going to be substantially larger if you drive the pile to one hundred meters and p knot will be very large. Even if you take a typical value of say for example 100 meters penetration density of soil is say 2 ton per cubic meter. I think typical sandy material will be something like this and because is underwater you get minus one.

So you get 1 ton per cubic meter, if you take one hundred meters times one you get nearly one hundred ton per square meter, is the overburden pressure which is applied surrounding the pile material the pile itself. Multiplied by a numerical coefficient depending on you know type of soil you can calculate or find out from this table see basically you can see here N bearing factor given by API .

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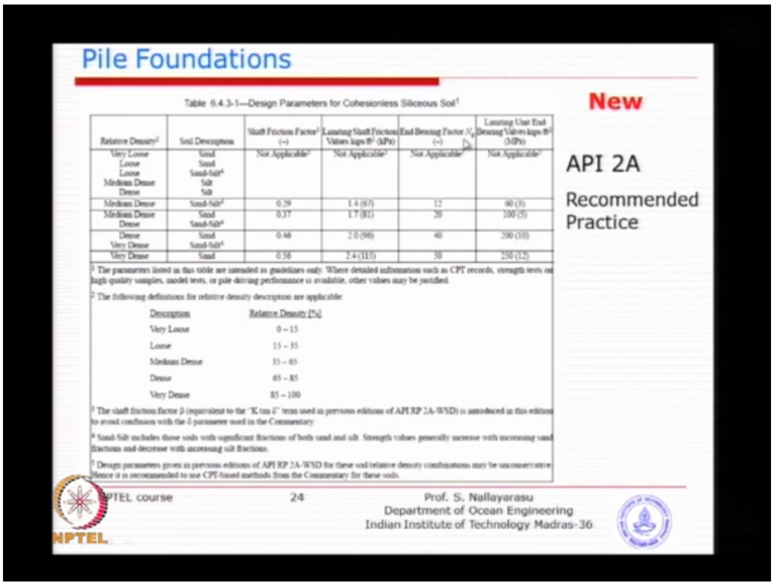

Very similar to the numbers that we look for shallow footing and you can pick up say for example if it is a very dense sand is 50 so 50 times hundred ton. So you can see here the numbers becomes very large 500, 500 in fact 5000 ton per square meter. So it is a large value capacity even if you have a pile of 1 square meter you are going to get a huge capacity coming from there and that’s why you want to terminate the pile in a sandy material rather than clay material even if you have the best form of clay you are not going to achieve any N bearing capacity.

So that is why many times when you are designing a pile we want to look for where the good material is whether its rock or sand of good capacity you terminate the pile there you don’t even need to worry about the skin friction because is N bearing capacity is going to be surely a very high. So because of that we need to definitely find out the limiting value so the API gives you limiting N bearing value not simply because you cannot infinitely increase N bearing.

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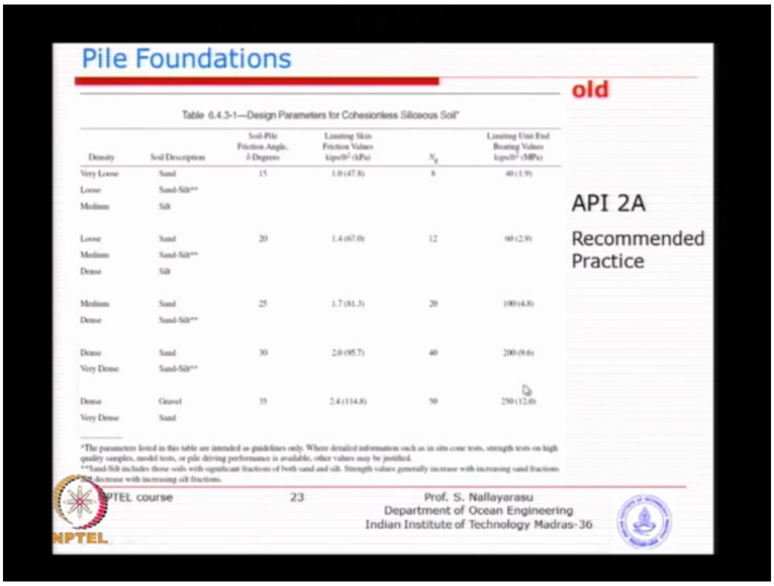

So if you go for very dense granular sand even after you calculate the N bearing by NQ times P knot you have to limit the value to the values given here in think you will you have to be little bit careful here also. The values given here kips feet square and in bracket is mega Pascal. So you can see here 12 mega Pascal, which is nothing but you know 12 mega Pascal concrete, you know if you look at the M30 concrete what is the capacity? Or what is the unconfined compressive strength ?

Is 30 mega Pascal, so you can see here 12 mega Pascal means as good as lean concrete of somewhere around 10 to 15 mega Pascal. So it is going to be a good material so that's the limit you have to use for different material like dense , medium or slightly loose medium so can go as much as 2.9 mega Pascal. So that's the limiting value so can see this table is very useful you are going to infact you have to use this new table.

You have to use is a similar value so basically this giving you limiting N bearing value this gives the limiting soft friction value it also gives you the bearing capacity factor which we need to take and multiply and the friction factor. The only thing this what you have is the density or so called relative density. Now you remember when we were doing the first few classes when you are doing the testing.

The first thing you want do is the classification once you know the right classification like this you will have a several literatures to take out the strength values so once the classification is correct and you can go into whether the pure sand or sand with silt or silty sand you can use this table if you are not falling within this range you will have to find out reasonable relationship with other parameters.

That is when you will actually go into finding out the delta value from literature and come back here. Many times you will you will not find direct classification lie this if you fall outside this for example you have a instead of silt you may have a clay fifty-fifty . You may not be able to come here because is not classified under this group so have to go somewhere in the literature find out the equivalent strength form and then come back here either with this value comparison, or you can use the old value of delta and calculate.

So you will have to do according to the situation. So basically the four parameters we have now calculated, the skin friction for sand clay I think very simple clay and sand you should be able to determine based on which strength parameter is given. Even if it is not specifically given to you if a phi value is given its going to be a sandy material if it's a C value is given it is a clay type of material and you can.

One of the disadvantage of this API method is when you have a sandy clay C phi soil you will not be able to do this so you will you will find that difficulty you know in assigning frictional resistance or N bearing value. So you have to see which is predominant you know if you are finding some places in you will find sandy clay, you know you will you will have a mixture you will have a C value of some lower amount phi value.

In such cases you can ignore the minor component and used it. That is one of the weakness of this API method which makes this simplified but there is little bit complication but if you into the literature you will find there are several other forms of equations where C phi soil cab be represented so the N bearing is also very simple 9 times CU and NQ times p knot and this is limited by the limiting value this is not limited by limiting value. Whereas the skin friction both of them are limited and we should know how to approach.

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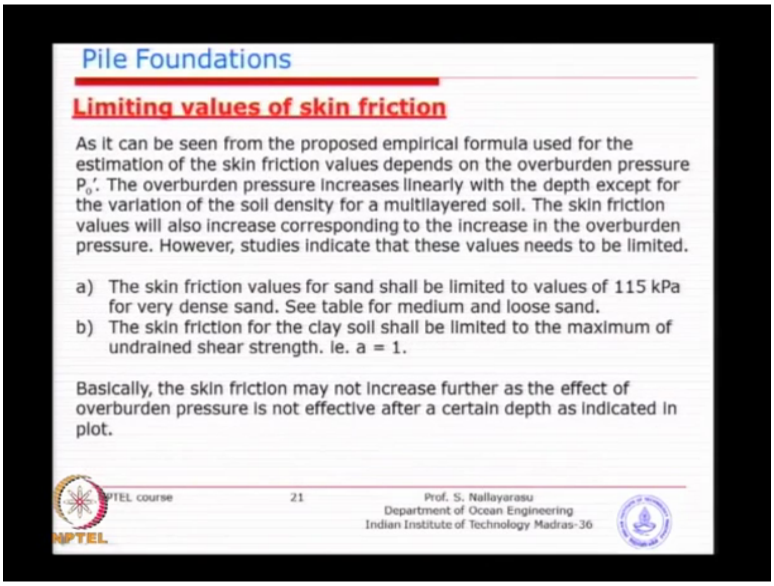

This we have discussed just now

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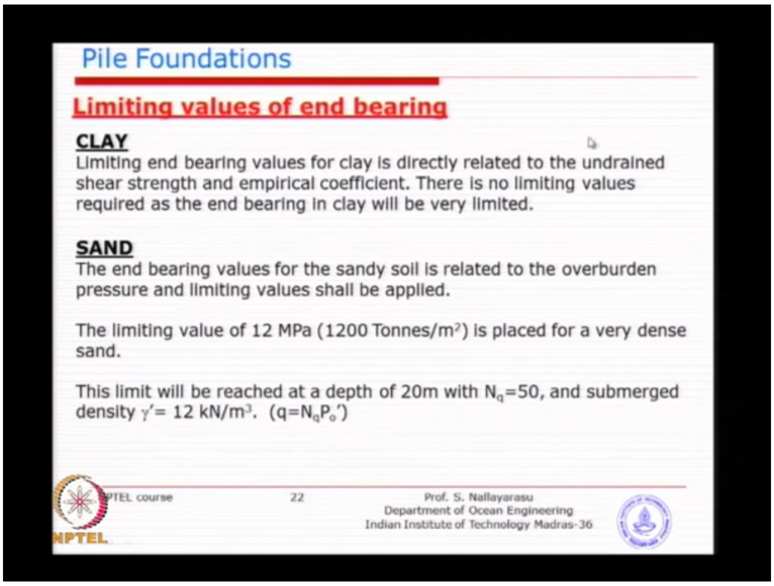

This is also discussed basically clay no limitation sand is limited by 12 mega Pascal old API table which is no more in existence so will not be will not be giving in any examination or testing

We will use this table so this numbers you don't need to really memorize in case if it is required for examination point I will print it and give it to you so that you can use it.

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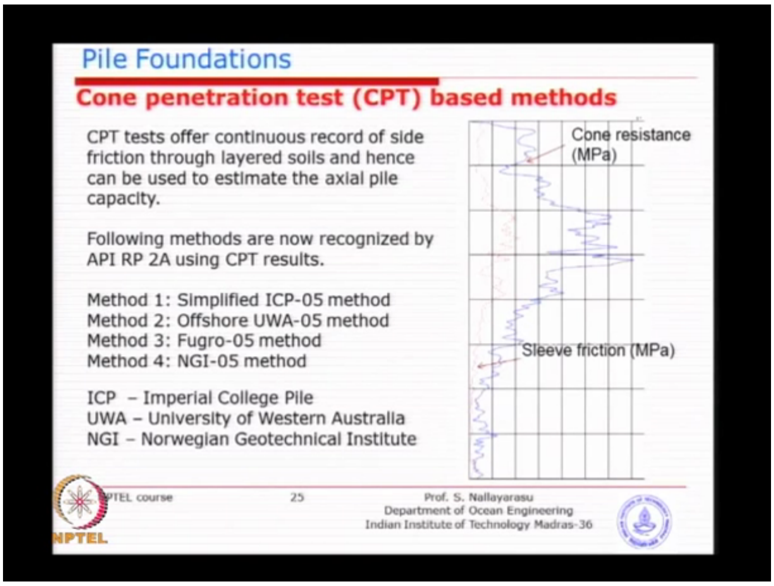

The next method which is also useful in terms of estimating the capacity is the CPT so you can see I think CPT gives you a continuous form of resistance as you drive a cone I think this was introduced soil investigation time. CPT is nothing but a cone fitted with instruments like strain cages and load cells so when you drive this cone into the soil the strain cages gives you lot of information skin friction resistance as well as the N bearing and the total load taken to push the cone into the soil.

So if you can get gather this information and a its one of the advantages it is continuously available unlike other forms of testing where you have to excavate the boring stop and do the testing at that particular location and then further bore and then do the testing. Here the cone is continuous so you will get something like this like an analog signal and if you are able to do a numerical integration of this frictional resistance you will be able to get the capacity very fast.

That's why nowadays you know from the field you get the report within few days like if you talk about 20 years back, you know they take a sample and then bring it to the laboratory. Do all the testing they take about few months before you can see any test parameters. Nowadays most of the modern soil you know investigation companies have this vessels fitted with CPT instruments as soon as they complete that boring or testing within next days you get the report saying that this the capacity you can achieve.

So that's one of the greatest advantage of this CPT and especially electronic CPT with all this strain gauges you can get the results as soon as just you come out you can get the result because everything is based on computer program as soon as you start driving you will get the information so this CPT methods were not recognized because of a complexities involved not everybody is able to do it.

Previous versions of the code they only say we leave it to the geo technical experts to decide depending on the site. But now what they have done in the recent revision of API or other codes infact ISO codes or British codes they have included this methods as part of their evaluation procedure and that's why we will go into details one by one because is very important because many of the (())(37:51)geo technical reports will provide you with this information.

You should know how to integrate and which method to use. There were several ideas in fact that is why I have given you the phi as mentioned by API. API says you can use any one of the method simplified numerical integration or university method or fugro method this are some private companies. So they have given slightly modified procedures based on two things one is the (())(38:20)and at the same side you drive the pile until to the twisting and compare the capacities.

So they have calibrated these methods basically and several locations and API has given you the complete procedure for four methods.

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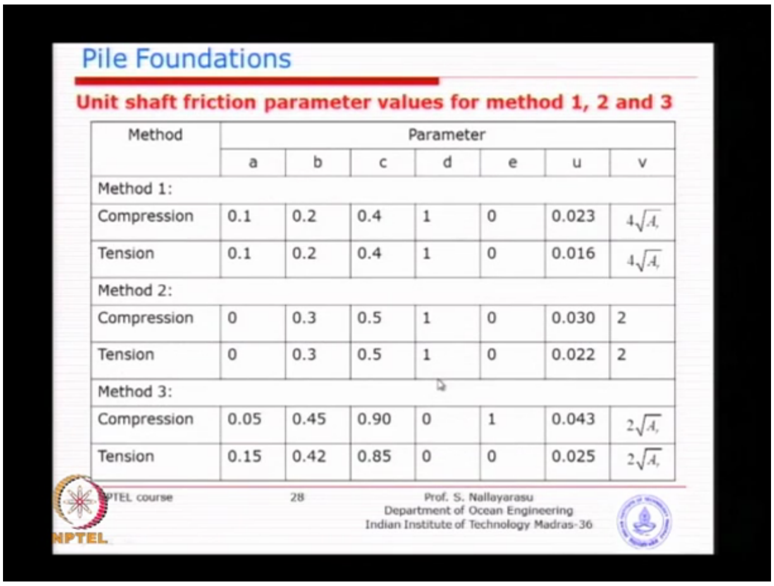

Method	Parameter						
	a	b	c	d	e	u	v
Method 1:							
Compression	0.1	0.2	0.4	1	0	0.023	$4\sqrt{A_r}$
Tension	0.1	0.2	0.4	1	0	0.016	$4\sqrt{A_r}$
Method 2:							
Compression	0	0.3	0.5	1	0	0.030	2
Tension	0	0.3	0.5	1	0	0.022	2
Method 3:							
Compression	0.05	0.45	0.90	0	1	0.043	$2\sqrt{A_r}$
Tension	0.15	0.42	0.85	0	0	0.025	$2\sqrt{A_r}$

One of the important issue with this when you are doing this integration each one method has used adjusting parameter I think I mentioned about this earlier on. You know whenever you do the soil testing and you do the piling and do the load cell and test it and compare the results by theoretical calculation using the results obtained from laboratory test or from the cone and from the pile testing.

If the difference is too large you try do a correction on your method until your results comes closer so that is what you see here a lot of numerical parameters for adjustment because they have done their testing they have also done their laboratory investigation and finally they come up with different-different numbers so each methods

Methods 1, 2, 3 you can see here this methods the last one they don't have this data in API. So you should use whichever the method and ultimately should get a similar result. So this first one is they simplified ICP is a Imperial college as early as 2002 they started working under this procedure,2005 they published one paper on OMIE and from then a lot of people were using but then was not recognized by API but in the recent revision they have included. And then UWA also was early as 2005 the method was implanted but not much useful.

But now we can recognize and can use it. All the methods are based on the integration of the resistance measured by the cone in the form of strain cage readings continuously.

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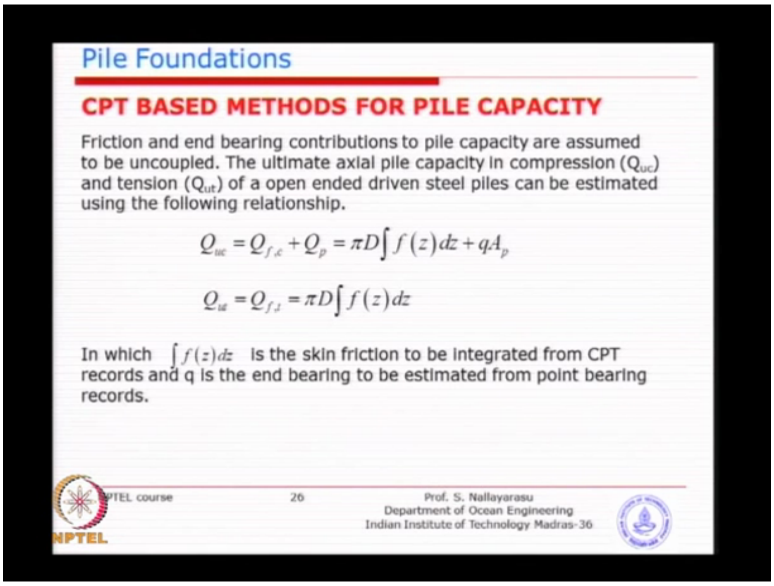

So you can the signal is coming in this fashion and you what you need to do is integrate from whatever the depth. So if you have analytical analog form of reading then you can do a numerical integrator and then get the values or if you can digitize those values depth wise and do a simple numerical integration also can be done.