Foundation for Offshore Structure
Professor S. Nallayarasu
Department of Ocean Engineering
Indian Institute of Technology Madras
Module 1
Lecture No 27
Pile load test 3

So we will continue with the alternative test methods, I think we have discussed enough about pile testing both in terms of horizontal and vertical and static and dynamic. Basically those involve either pile or kentledge which requires considerable effort and time.

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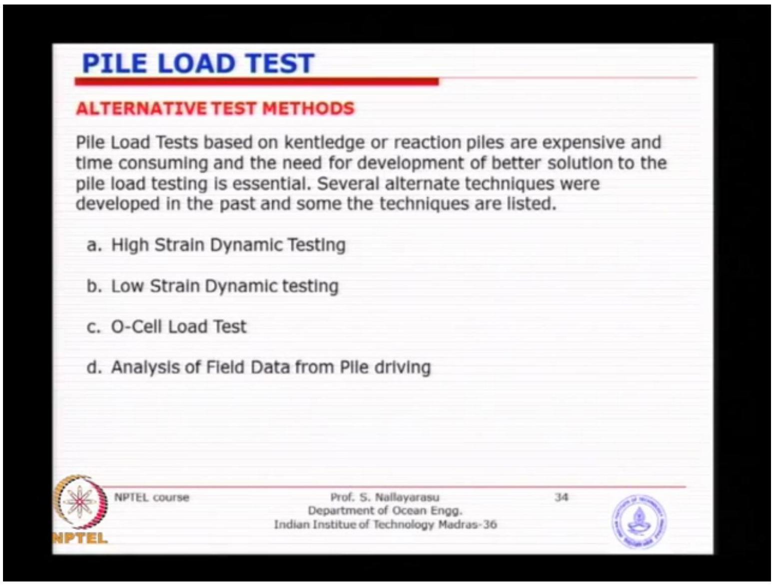

So in this alternative test methods what we are trying to look at is getting some parameters either during driving or post driving, for example you can drive the pile and then do the testing in using this alternative is methods or during driving itself you collect the data and uses that to back calculate what would be the capacity achieved by the pile during driving and then you extrapolate to long-term capacity, so it is some of the indirect methods wherein you know it is quick number 1 and also the inexpensive, so this has been in use for several years and one of them…we will try to use for concrete piles which is High Strain Dynamic Testing in fact it is almost you know most of the projects will go for 90 percent of the piles using this method because it is only just 3 to 4 hours exercise and very inexpensive and preparatory activities are quite small.

Similarly Low Strain Dynamic Testing is only matter of you know the weight of hammer differs otherwise the mythology is almost similar. Then the load cell test using O-cell methods which is little bit expensive and it can offer you the real data with regards to the skin friction and end bearing separately. Then the last one is exercised by offshore industry for pile testing, we do not use all 3 of them basically this is because of the constrained that we have on offshore that we will not look at post driving testing, so during driving the collect the data like blow counts, maybe stresses and the penetration per so many blows, so those information are available. Then feedback into wave equation analyser, reverse calculation we obtain to arrive at the capacity that might actually be available from the soil either during driving and also to extrapolate. So these are some of the methods which are used which we will just quickly look at one by one.

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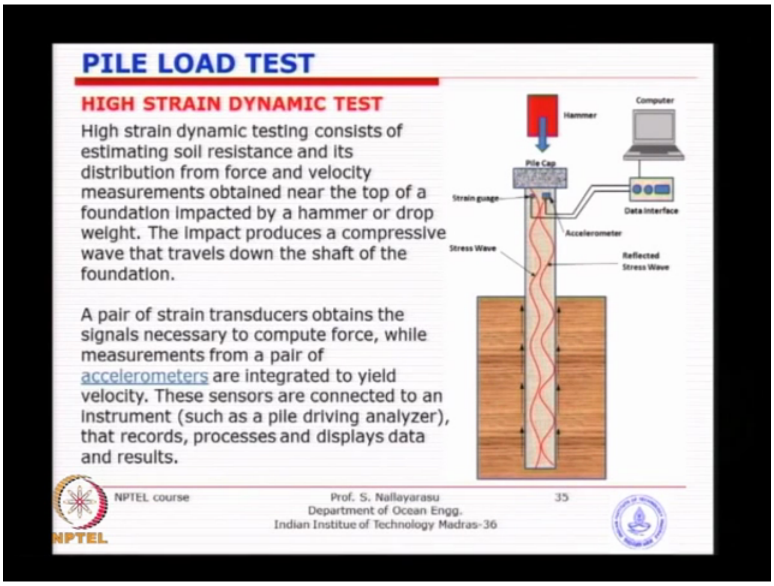

So the high strain dynamic testing is commonly used for concrete piles especially the coastal area as well as some land-based projects, basically what we do is after the installation of the pile, we trim up the pile to a good amount 1 to 1 and half meter and reconstruct with a very good material, so that during hammering you know the surface of the pile head does not get damaged, so that it could be used for your permanent constructions. So you do a recap of the pile constructions and attach strain gauges and accelerometers.

Basically what we are looking at is measurement of velocity at the top and also the strain corresponding to that we can measure the stresses, so basically convert it based on the simple idea and then you can connected to a computer a sufficient hardware and software in such a way that you can actually display instantaneously the impact forces as well as the back calculated velocity which is what is going to be give you an indirect measure of the dynamic force which is I think when we were looking at pile drivability, we had component of resistance one is the static residence coming from the soil displacement, the other one is a velocity which is the dynamic residents, so sum of these 2 will give you the total resistance, so if you know how to separate them in you can actually find out what could be the static residence because it is what we are interested as a long-term capacity.

So you need to measure the total resistance by means of displacement as well as the velocity and then calculate back. The only difficulty in here displacement is directly measured whereas the damping associated with the velocity is not measured directly, so again we will go back to some kind of empirical means to estimate the damping. Once you know the damping you can calculate the dynamic component but the static component itself is very easy because you all do have the displacement of the pile as you drive.

So in this particular case high strain dynamic testing, we are going to just blow one hammer of particular weight and basically it is not the actual hammer that you used because this is being a concrete pile you may not actually use a hammer because it is a constructed pile at site, so designated hammer size will be derived based on what is the amount of energy required depending on depth of penetration. For example if this concrete pile is 15 metre long penetrating into the ground you may require larger effort to transmit the stress wave downwards and then bring it back, whereas if it is a smaller pile you can…

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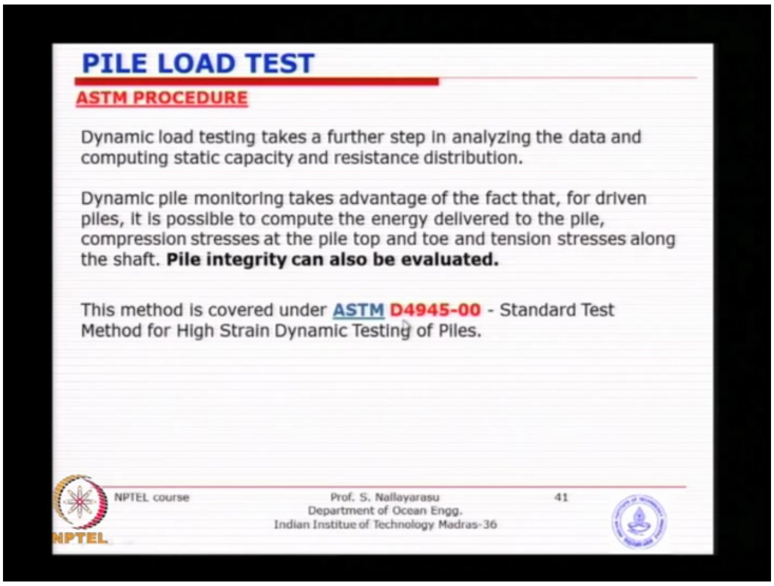

But to avoid confusion there is a code which is basically describing what should be the…of course the similar code is also I think available in Indian standards which I did not look at it but basically our ASTM A4945 give you D4945 gives you a procedure, weight of the hammer, drop and the other requirements, so we could follow easily, so basically a hammer will be dropped from the top with a particular height which transmit the impact energy through the pile and you measure the strain as well as the acceleration at the top of the pile and then basically the system will reflect depending on the type of soil and the type of material if the soil is good then you will get the reflection backwards and you measure that, so the methodology is to derive the representation of the soil means of stress value as well as a reflected or the velocity of the stress wave.

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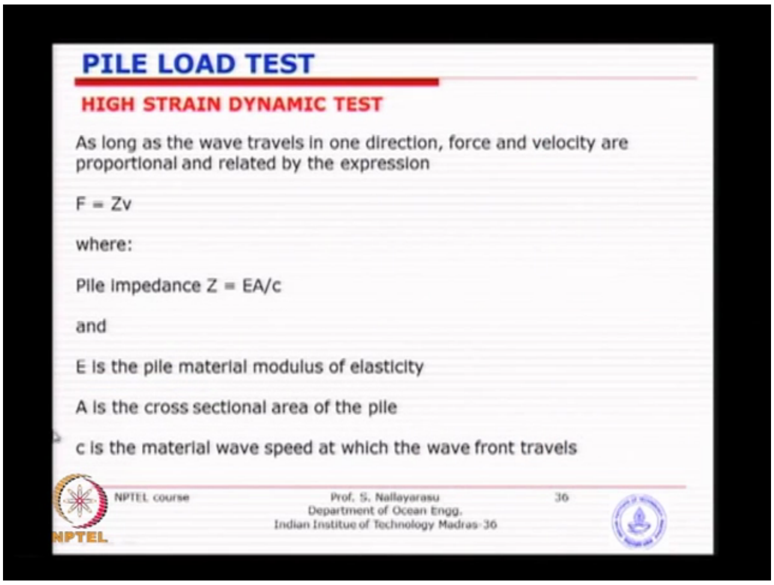

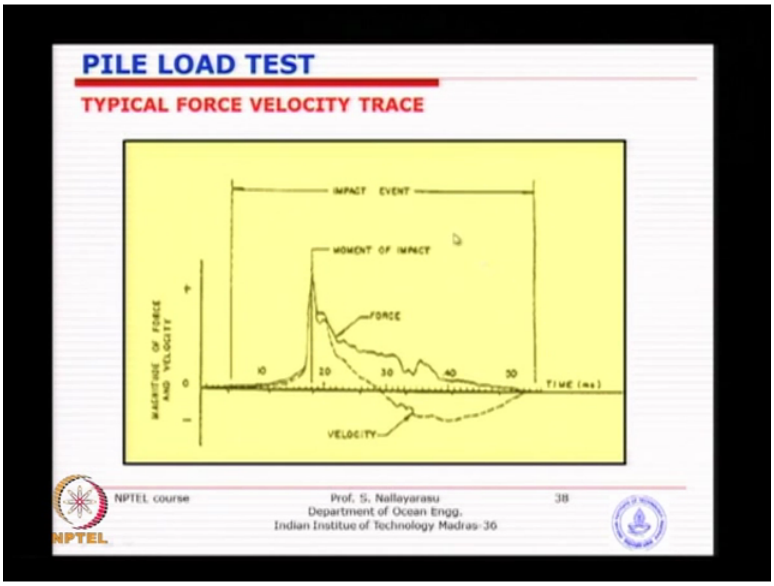

And the force can be calculated using this simple formula once you have the measured velocity then the impedances is the area times modulus of elasticity of material by the velocity of the stress wave transmitting towards the soil through the pile material. So you can estimate this as soon as you have the acceleration you can double integrate and then we can get the a velocity, once the velocity is available can calculate the force back and instantaneously you can display something like this. This is one of the test in the recent time, so you can display this at any time and during the impact process and at the time the wave is reflecting.

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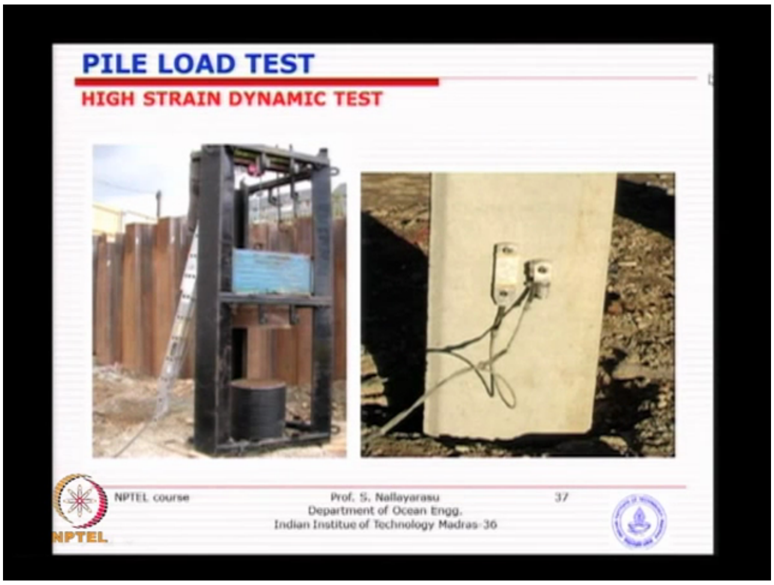

Typical picture, this is of course this is one of the concrete pile testing, this is the pile head this is the hammer in controlled manner. It is going to allow you to fall down and that is the acceleration measurement device and the strain gauges attached to a concrete pile but of course for steel pipe the attachment will be slightly different.

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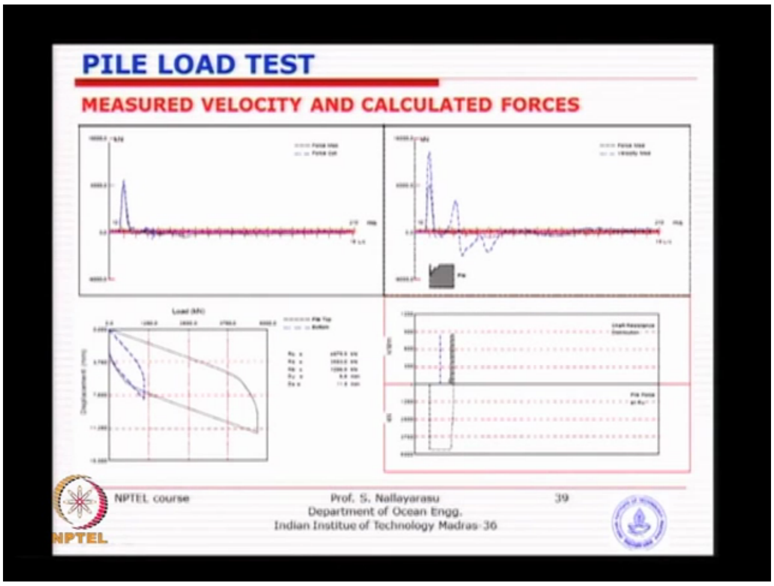

So once you have this, this is the actual display coming from the we call it pile dynamic analyser, so you can have instantaneous display of resistance offered at that time as well as the measured velocity and the integrated measured acceleration and integrated velocity and together.

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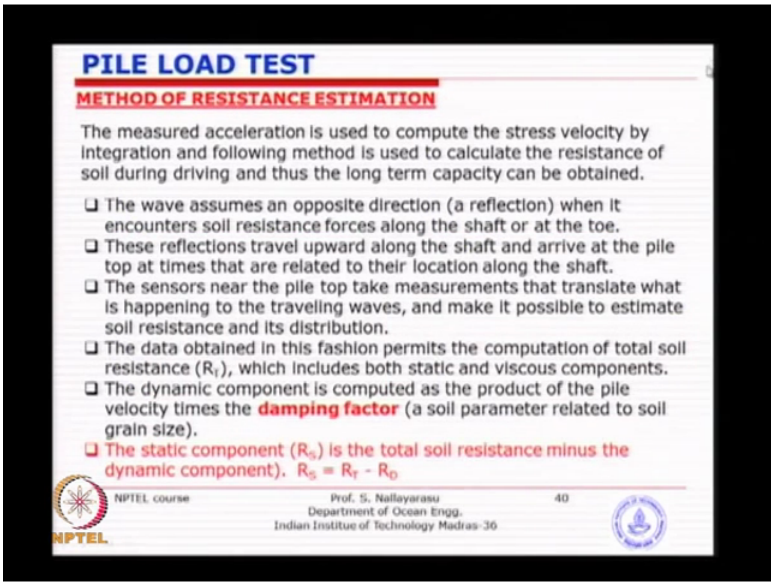

So the idea is…calculation of static resistance is possible only when you have the total resistance which is coming from that calculated force and minus the dynamic resistance if you take the assumed value of damping, some value of damping has to be taken depending on the representative size base. Many a times we do actually a weight average, if you have a multi-layered soil for example clay, sand and you know the damping value theoretically could be potentially this much and you do a weight average and then calculate back the dynamic resistance, so total resistance minus the dynamic resistance will give you a static resistance. At the time of driving and you actually need to re-establish the long-term capacity based on certain assumptions of remodelling or setup.

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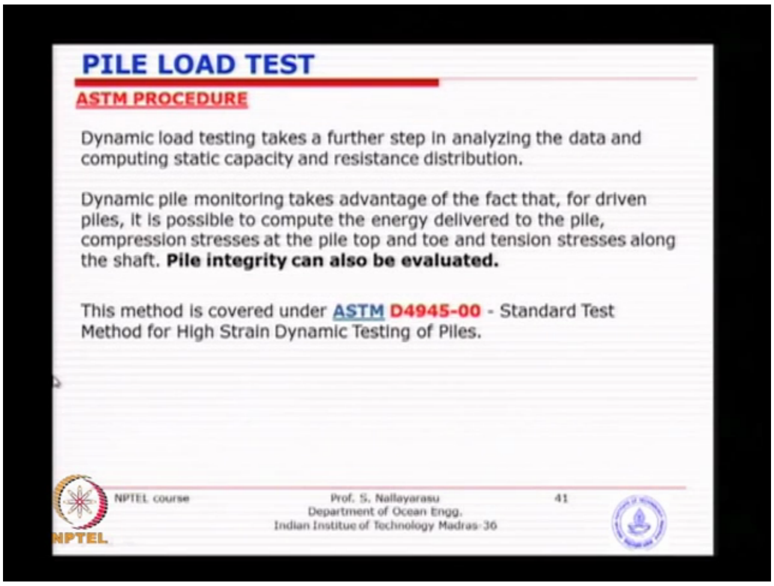

So as I mentioned earlier this also can be used for pile integrity testing, normally we do not use the high strain dynamic testing or pile integrity means suppose you construct a concrete pile, you have a hollow (())(8:20) you know due to inefficient concreting or kind of wide space, so the transmission of stress wave will be interrupted, so the reflection will happen from there only.

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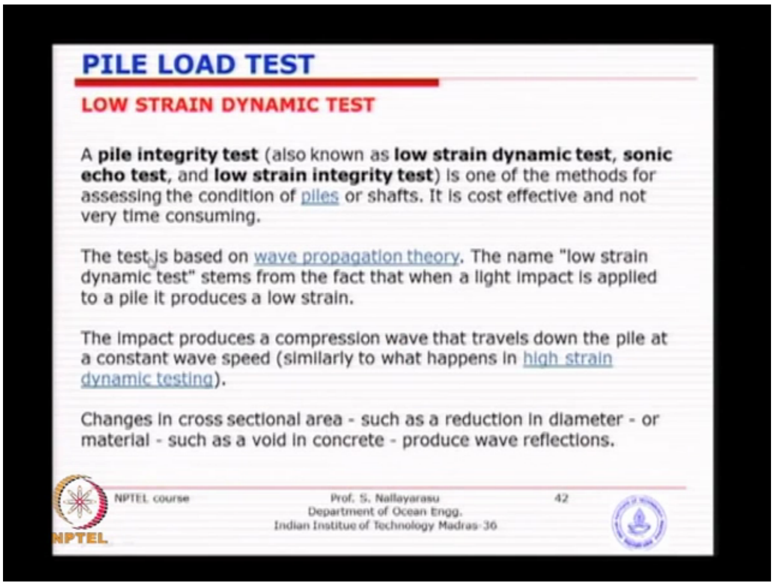

So this method can also be used at commonly we use low strain dynamic testing not for soil resistance because it may not reach the soil, so many times we use this low strain dynamic testing only to test the pile integrity itself. It can also be used for steel piles where the pile is broken example at middle, if you have a welded connection, if the pile is broken can also be used to find out whether this stress wave is transmitting further or is it reflecting from that interface at that location. The procedure is almost similar like high strain dynamic testing, only the energy of impact is smaller, so that means you can use a hammer instead of real hammer just maybe few kgs weight not actually a bigger driving hammer.

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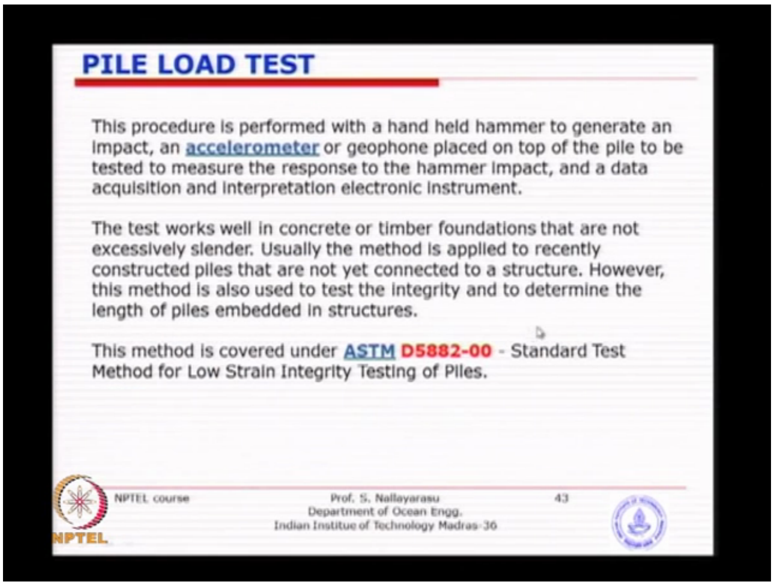

And procedure for this method is given in 5882 which is again another ASTM course which you will find an equivalent in Indian course also.

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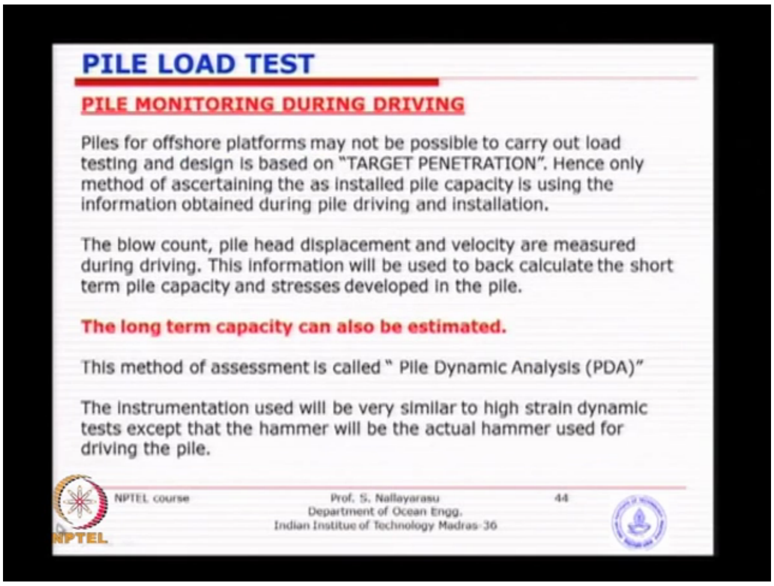

So pile monitoring during driving what we are looking at is trying to gather as much information, only difference is instead of using a specialised hammer, you will be using the actual hammer which drives the pile and that means every time you can measure the exactly the same data what you are doing in the high straining dynamic testing that means stresses, acceleration as well as you know the blow count for driving the pile to certain particular depth every time, so you will have a continuous record of the information and nowadays we have an instrument which is fitted with the GRLB program which we saw the other day which calculates forward given the assistance, dynamic parameters, static parameters, it gives you the blow, number of blows required to achieve the final penetration at every depth.

Now the same programmer is available in this including data acquisition from the live driving of the piles, so you can feedback this information you can get back the estimated capacity at instantaneously every time you drive, so that is one of the company the same company is giving you this program together with the hardware and the software and the interface. So only thing is they will be on-board to access the capacity, so you can call them during driving I would like to know what the estimated capacity could be, so they will come with all the prepared instruments like accelerometers, strain gauges and then the software and the hardware interface to measure all these data online and then they will give you at the end of driving this much capacity has been achieved.

So this is one of the methods commonly adapted nowadays in offshore industry, this is an alternative to actual testing any special testing required because that will also occupy more time. In this case you are not giving any extra time for doing this testing, it is during driving you collect information and this process of analysis will be done and the capacity will be known. The reason why we actually do this is sometimes what happened when you are planning for a driving of say certain penetration, you go there you drive and then you are unable to drive say maybe three-quarter of length is only possible because he blow counts have increased substantially and you stop driving.

Now one of the biggest questionnaires, your target penetration you have decided that based on your calculations I need hundred metres, now we are able to only drive 60 - 70 metres, so what happens? You have concluded that theoretically possible you drive and then you are unable to drive in the real practice, whether the pile has achieved its capacity because you are going to install the superstructure and then you are going to plan to operate the platform. Now this decision has to be taken when can we accept the premature refusal of piles? Is it an indication that high blow count means pile has achieved full capacity or is it something else?

So that is why this pile monitoring is nowadays almost mandatory, every project we employ them but one of the biggest worry is many times it becomes a hurdle in real practice because even if the piles achieving hundred percent penetration sometime it shows does not have sufficient capacity because what happens is again there is a manipulation of parameters like dynamic factors, the damping factors and that makes the capacity prediction reasonably difficult to make decisions, so that is why this results from pile monitoring is very carefully reviewed before arriving at…whether the pile has achieved capacity or has not achieved capacity but in any case you know it is nowadays commonly used for offshore projects to make sure that we get some sense of pile capacity at the end of driving.

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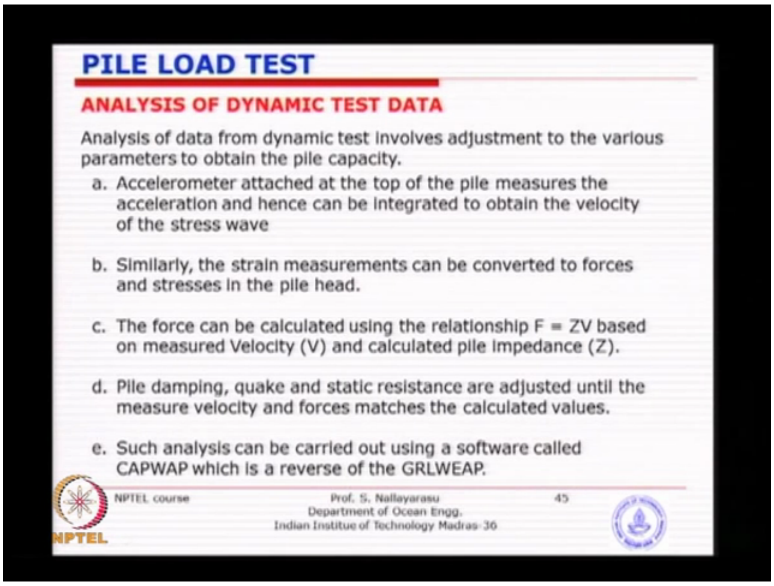

and I think that is the summary that acceleration is measured using accelerometer. Strain measurement to find out the stresses. Force is calculated using the impedance and velocity. It is exactly same thing is done in pile monitoring system also as well as the high strain dynamic testing, the only thing this pile damping and quake values have to be adjusted until the static resistance are you get these matching whatever values that you have actually got and what is being measured and this is called the program instead of this program what we were looking at the other day GRLWEAP is the forward program to calculate the stresses and blow counts using wave equation analysis. The reverse program is called CAPWAP is basically reverse means you trying to get the capacity or so-called resistance by giving input as number of blows and stresses induced an acceleration measured value will go back into the program you will get the results as, the resistance at the time of driving and then you have a pro rating long-term capacity.

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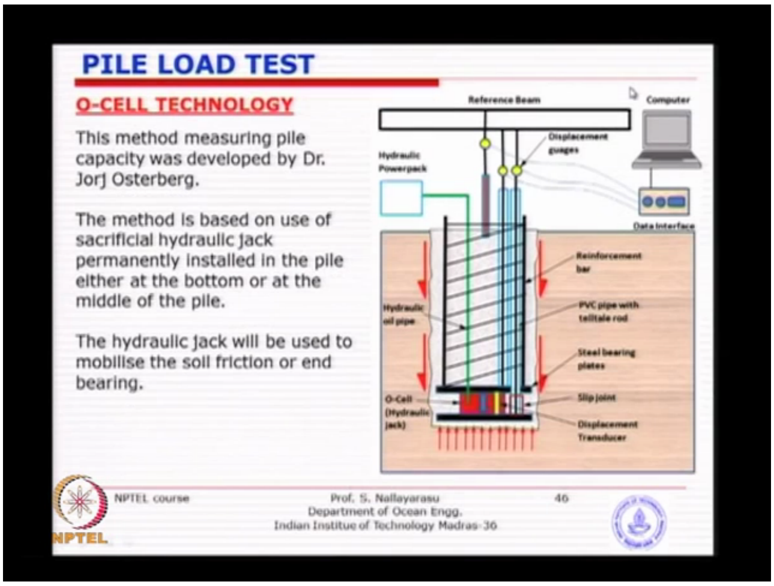

The last method that we want to discuss today is the O-cell technology which you can see it as simple device, so this is basically commonly used for concrete piles, I have used for one of the projects for steel piles in in the case where we had a very hard rock and we could not install concrete piles then we had to go for steel piles in that particular case and the client insisted that we do 2 test, one using the kentledge test the other one using this O-cell, so that few other piles can be done using O-cell method.

So for calibration purpose we did do one of the kentledge test, so you see here the picture is simple at the end of the pile…this is just the one case where we have installed hydraulic device which is basically a load cell with a bottom plate attached and the top plate attached an bottom plate attached to the reinforcement bars whereas you plays the jack in between, both the jaws of the jack are welded to this plate and this plate and basically the reinforcement is not connected to the bottom a job plate, so when this hydraulic jack is pushing the whole of the pile will be pushed upward reacting against the endearing of the pile itself or the soil there, so basic idea is how do we measure the moment of the jaws.

See you see here one blue color and you got telltale rods that means physically you have a rod attached to the top jaw as well as to the bottom jaw and separating them from concrete is a PVC pipe that means they are free to move, so you should not have you know if you cause this telltale rod also with the concrete then you will not be able to measure differential moment of the bottom and the top jaws, so basically that is the idea behind, so and then you have a dial gauge attached to the bottoms the jaw plate as well as the that top plate, so that can find out how much is the bottom is moving because you do not know whether the soil of this bottom is 100 percent like no moment means the bearing capacity is so large, so that also will move and this also will move.

So the difference in moment will tell you the moment of (())(16:50) fiction so that is the idea behind and the amount of load that impose on the or the hydraulic pressure that you apply on the jacks will give you the capacity to overcome the friction between the concrete and the soil, so that is the that is the methodology. This is their one by one Osterberg, Prof Osterberg in US. They have used this one for several large diameter concrete piles for bridge structure across river, across sea and basically where the testing involves because of the size of the pierce 3 meter diameter pierce the capacity requires may be few thousand tonnes. (())(17:30) kentledge test became almost impossible and that is the time they were trying to do this kind of idea and of course is a permanently implanted inside the pile which we cannot remove it, so that is one of the difficulty but not very expensive item because (())(17:48) sorry the load cells are quite cheap you can fabricate or you can buy from the market. So this power pack, hope you all understand what is power pack, power pack is nothing but a pressurised fluid pumped into the load cell to increase or decrease the jaw length.

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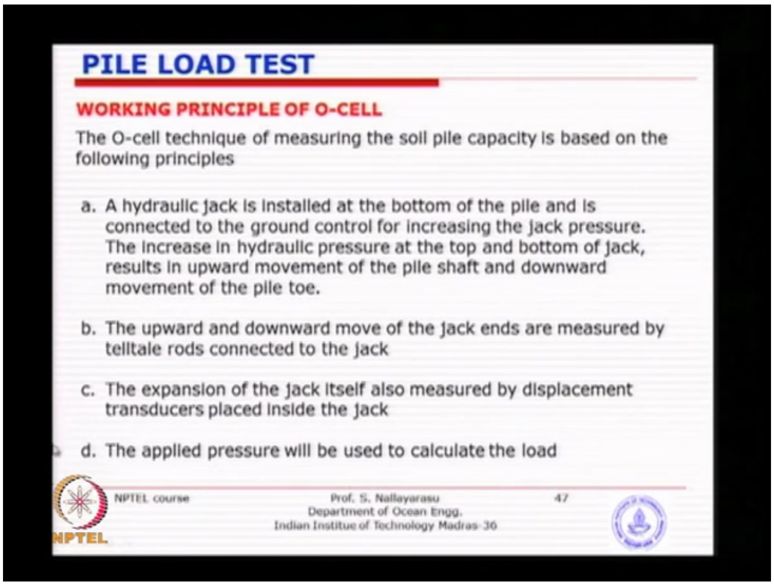

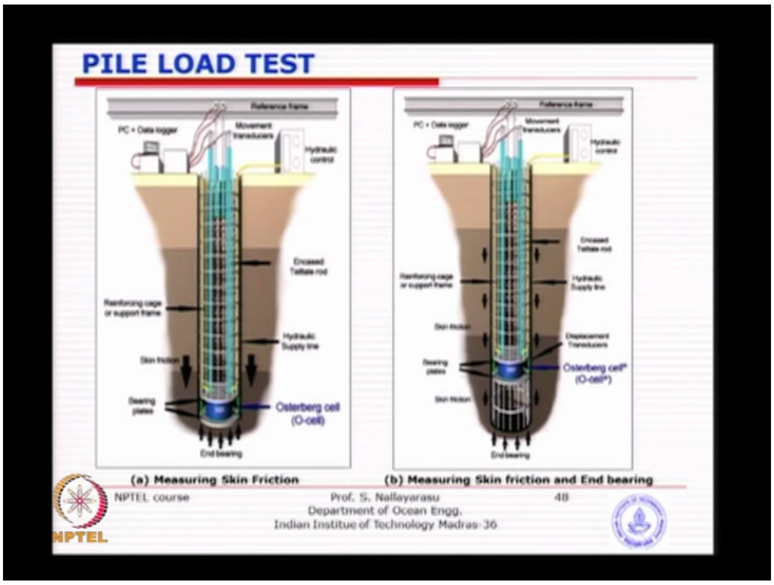

This can be used for both compression and tension testing. I think the diagram is on the something like this, you have an option either to attach the load cell at the bottom of the pile which will only be able to react against the end bearing and the skin friction will be measured, so that means you trying to move the whole thing by shearing the frictional resistance between the soil and the pile whereas if you actually put it somewhere in between then it will take some amount of an bearing because there is a fiction also at the bottom side of the load cell.

Now the one of the difficulties is which is the best place to put it, that is that is exactly the problem with this particular method, if you put it at the bottom you are going to use the end bearing as the reaction point whereas you are going to use the measure the skin friction, whereas if you put exactly at the middle then you will measure 50 percent skin friction and 50 percent end bearing but in reality we really do not know how much will be end bearing, how much will be skin friction? There is one of the disadvantage is using this method and most of the cases no basically we use to only measurement of skin friction because implanting such a discontinuity in between the pile is also potential danger.

Imagine you have a 50 metre pile and middle of the pile you go and break the pile structurally because you cannot have connection structural connection here and basically what happens is transmission of any bending or shear becomes a major problem, so that is why the methodology to measure both skin friction and end bearing is little bit weak in this method whereas and be easily used for putting this load cell at the bottom and then just measure, so for full 100 percent skin friction type of piles this method is quite useful.

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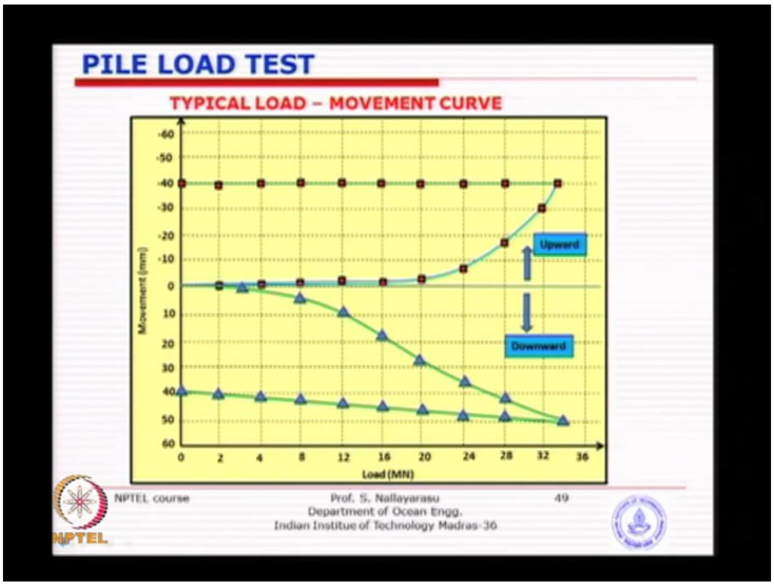

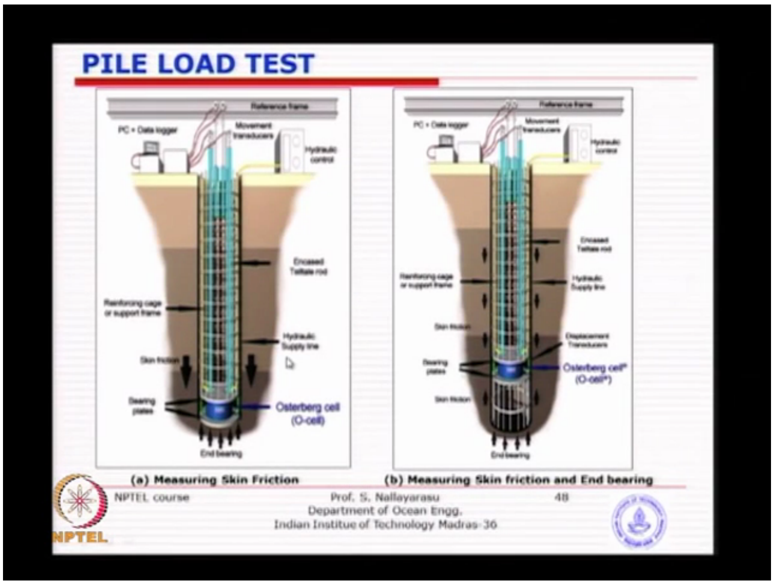

And that is the graph that you will see that at the load versus the moment of upper and lower jaw, the larger the difference you will find out the displacements can be larger and that differential moment will be taken as the final settlement of the pile. Corresponding load can be taken in terms of the jack hydraulic pressure multiple by your the cylinder area. So typically this method is used for concrete piles and also to skin friction not for combined because it is very hard to estimate even by theoretical means you cannot estimate that accurately.

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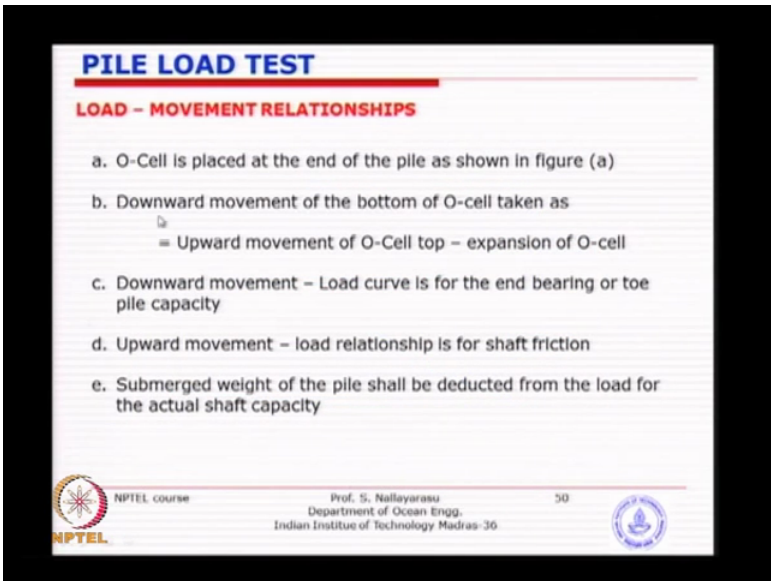

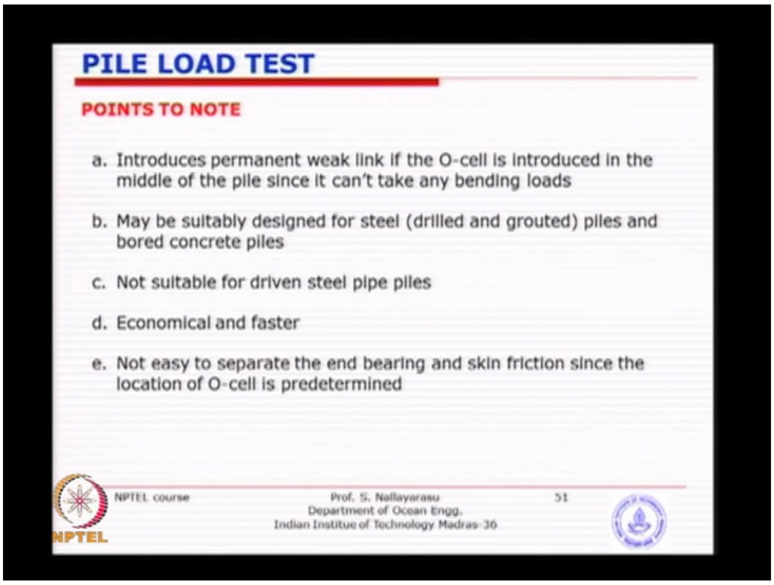

That is the procedure given here, I think that I have already explained. Drilled and grouted piles sometimes used but again with caution was breaking up the structural continuity is a problem. Driven steel pipe piles not suitable because you cannot attach his load cells while driving it actually will get damaged, so only when you have a steel pile but steel cannot be driven because it is very hard soil, so you do a drilling very similar to both the concrete piles, then you place the steel pile inside and that is what we did in in that particular project where you drill it and place the pile and before placing the pile you may place this O-cell and grout the whole thing and together with the plastic or PVC pipe to bring that telltale rods to the surface and then measure the displacements and I think this is one of the limitations that even the Professor Osterberg himself has explained that use of you know this methodology measure in case if you have both end bearing as well as the skin friction may be misleading.

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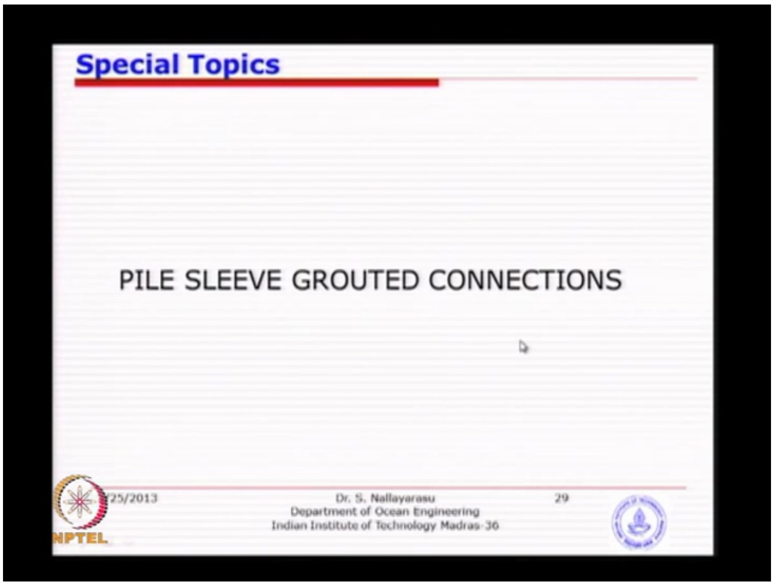

Okay we will quickly go one to another quick topic as wherein the design of connection between the pile and this soil and basically pile to sleeve or pile to leg when we used the grouted connections to transfer load, so far I think what we have been looking at is the skin friction between steel material to soil but when it comes to grouted piles example just now we were talking about you do a boring and place the pile inside and then you do the grouting of the annulus between the pile and the soil.

Now the interface become grout and the soil and also grout to steel or grout to whichever the pile material, so we have 2 interfaces to check, so that is exactly the idea behind the grouted connections you know many cases I think I have also shown some videos the other day whenever you encounter hard striatum after certain depth instead of going for alternate foundation you still proceeded with steel pipe piles you could drive the piles to certain depth and then do a drilling inside, we call it relieve drilling which we will talk about the remedial measures later on and then you grout it either with and without the enforcements. Some projects you know still wanted to go for jackets do not want to go to gravity platform where you wanted to change the concept because of the soils which you are talking about the other day in the tutorial, so we can use this strength of grouts interface between soil and to the steel material. How to improve? What are the methods available? So we are going to just quickly look at that methodology.

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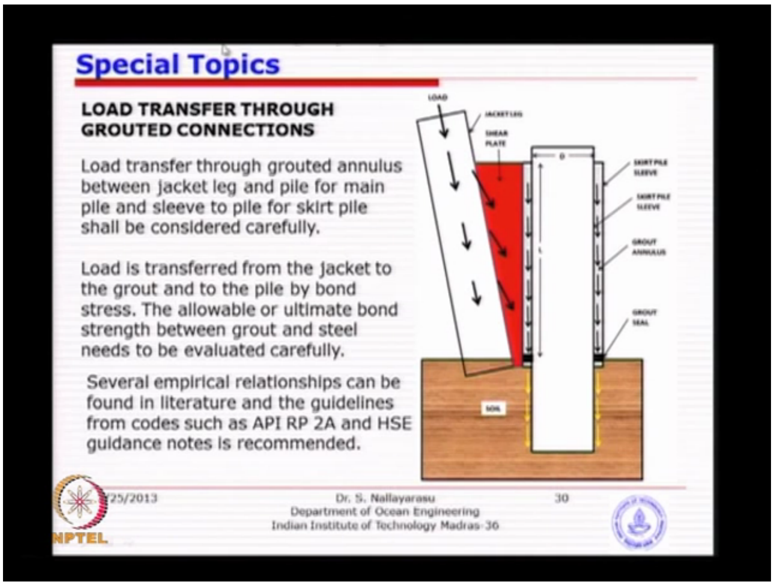

Let us just only look at the connection between pile to sleeve through the grout today that means when the load is coming from the jacket, it is going to be transmitted to the outer sleeve which is your large diameter pipe through which you are driving the pile into the ground, so when you are doing this the load has to transmit through the grout from steel to grout interface then grout to again steel interface. Once the load is transmitted to the pile then the load goes through the soil, so we do just look at the interface shear strength or we call it bond strength. In fact if you have studied concrete design, we normally have bond strength of concrete of certain grade with respect to the small diameter bars, so imagine you have a mass of concrete, very huge mass and you have reinforcement inside.

When you try to pull the reinforcement out, so there is an interface bond between the reinforcement bar and the concrete. Now it is exactly opposite here, the grout is very small the structure is very big, now we can we use that concept of bond strength available from concrete design or should we recalculate with a slightly different approach because when you actually have a mass concrete and try to pull the reinforcement bar there is a the conical surface of flow transfer will happen you know I think you might have studied in your applied mechanics is here the grout is only very small but the steel is quite big, so when you trying to do mostly here you will see a surface transfer by friction or by shear.

So that is where you will have a reduced bond strength compared to mass concrete with small reinforcement bar you will have a considerable if you remember, bond strength between M30 concrete to reinforcement bar, plain bar could be as much as 1 to 1 and half newton per mm square, so you may not get that much here because the grouts space available and the load transfer is going to be slightly different, so we need to find out what is that and how much? So normally we do some projects, we do actually reduce the scale test in the laboratory with this type of connections as early as 1990s quite a few projects involve testing but in the recent times several codes have suggested after doing considerable amount of laboratory as well as full-scale testing.

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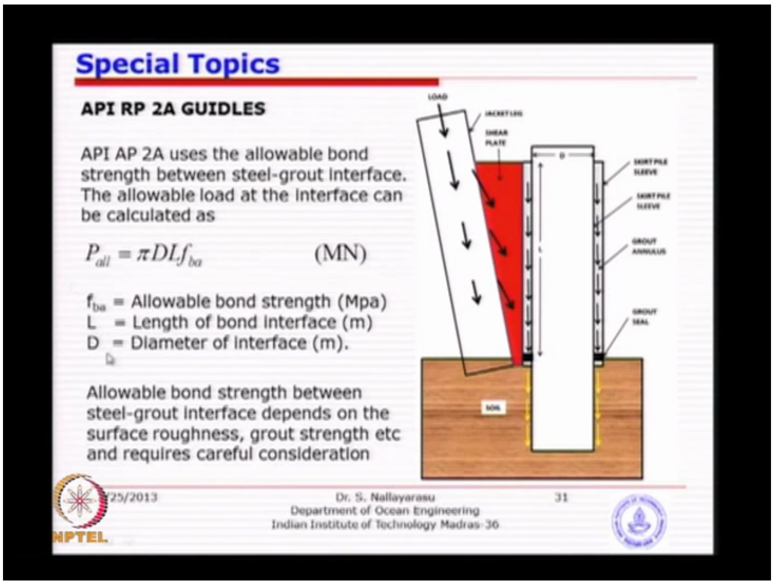

They are provided with a simple formula, so basically the capacity can be calculated using pi D time L. L is the length of low transfer from this point to this point, pi D is the surface of interface between the grout and the steel multiplied by allowable bond strength. Now we need to determine this value and if it is not sufficient we have 2 choices either to increase the length or to increase the bond itself, so how do we increase the bond? So there are several methods available to do that we will just look at that one by one, so this is this is basically given by API using allowable bond strength.

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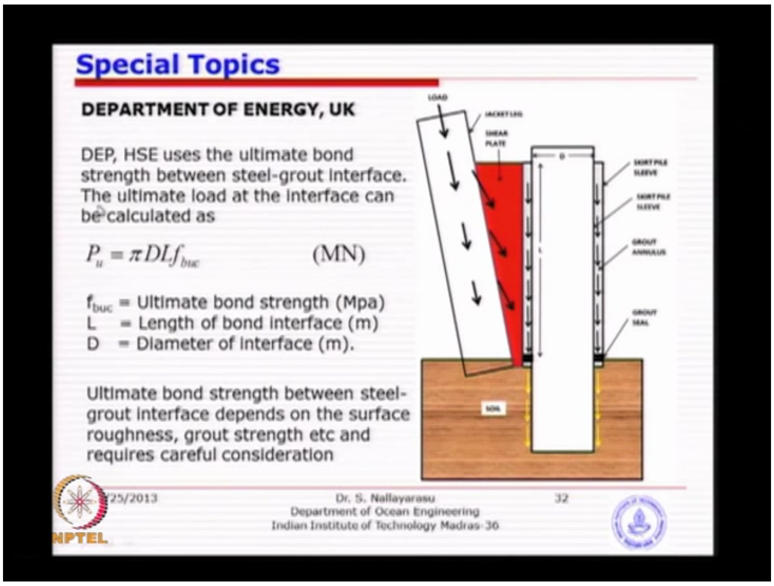

Whereas the one other code where we have is the Department of energy, UK which is a British code but it is not specified in the code it is only a guidance basically the ultimate bond strength instead of allowable bond strength they have given the formula for, so you can apply factor (())(27:37) over ultimate bond strength, so then you get ultimate load then you can compare with your working load to for arrive at whatever the factor safety required.

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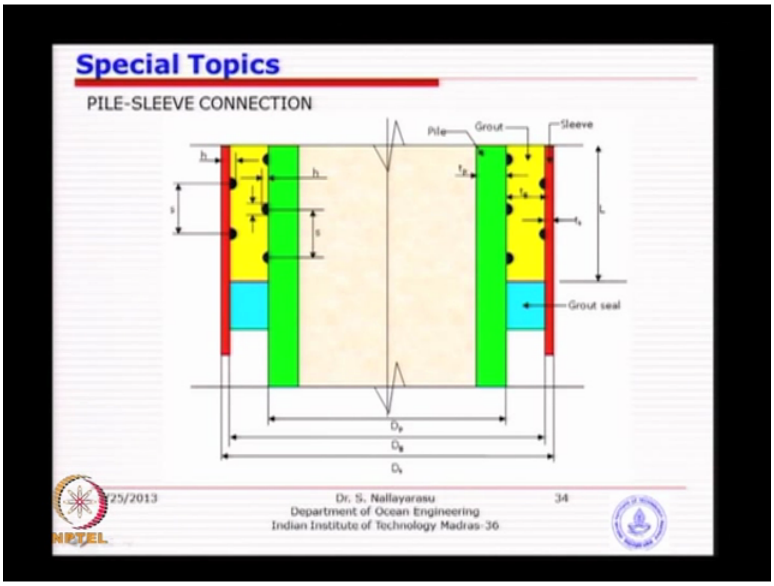

So if you look at just an enlarged picture of the pile and the outer sleeve can see this yellow color is the grout the annulus space will with grout, so what we have done here you can see some black spots is nothing but a welded steer case by means of you can actually take the reinforcement bar just bend it into a shape of a pile and fit in and do the welding, so when the pile is trying to shear off these projected steel rods will actually make it slightly increased bond strength is what the method normally used you roughen the surface, in this case you roughen the surface, so what we are doing is at periodical intervals you have a circular bar or circular plate welded all-round the pile as well as the inner surface of the sleeve itself, so what happens is, this increases the bond strength between the grout and the…

Now if you if you come up with an idea that you weld this one to close, what happens? This is of no use because the shear will not be produced if you have every you know just one diameter you put one more one more then the shearing surface becomes the surface of the rod itself so which is of no use, so there is a definite requirement of which will work, which will not work? So we need to have a spacing ratio, this much spacing or this much diameter of the rod and what will be the annulus space required, so if you make this grout space very small then it cannot actually mobilise the interface, it will fail by shear.

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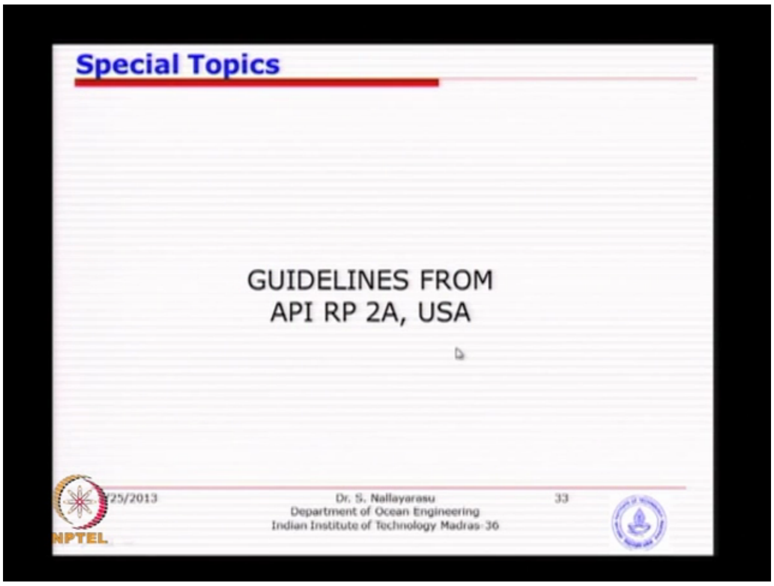

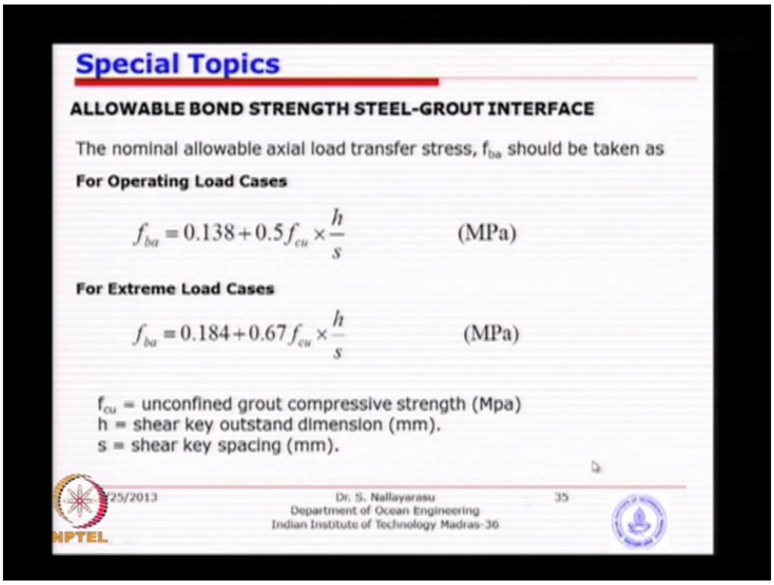

So that is one of the reasons why specifying these requirements APS given certain limitations, you could only work with that region of you know parameters which we will quickly look at. First, in fact we can go one by one, the allowable bond strength in in concrete grade of f cu of some value is given by this but directly proportional to the height and the spacing of the shear key that you are welding on to that surface of the pile.

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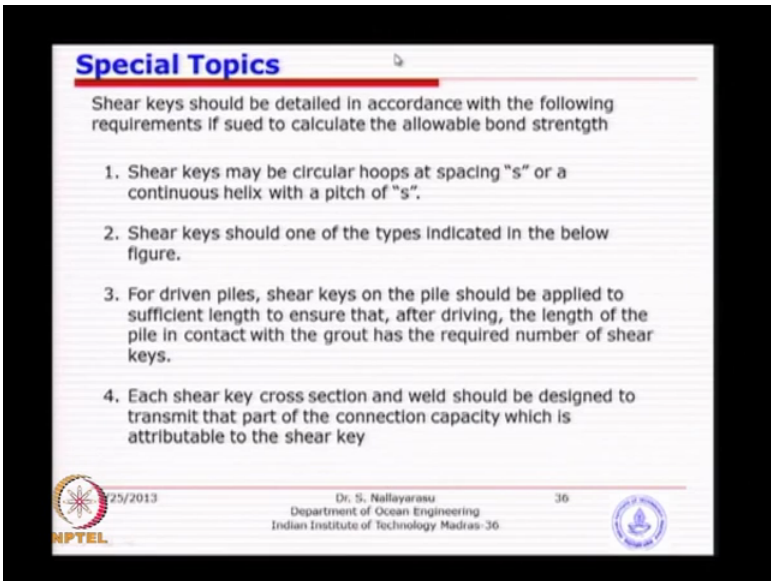

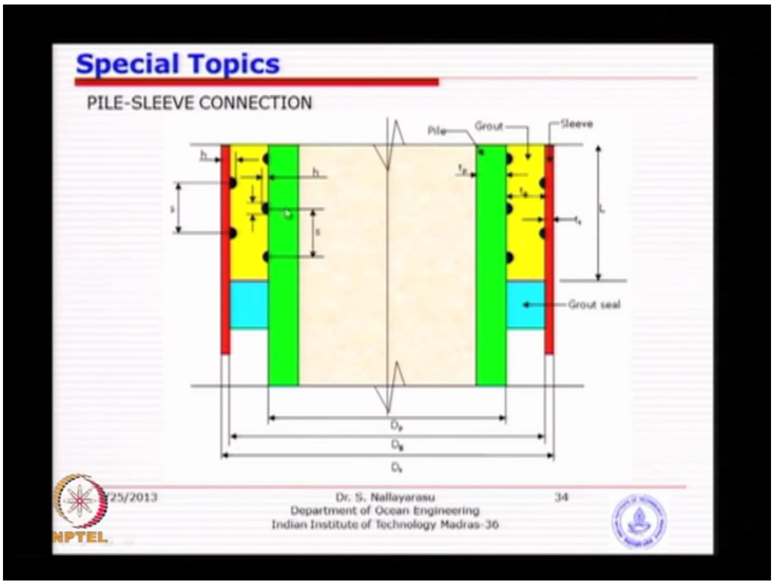

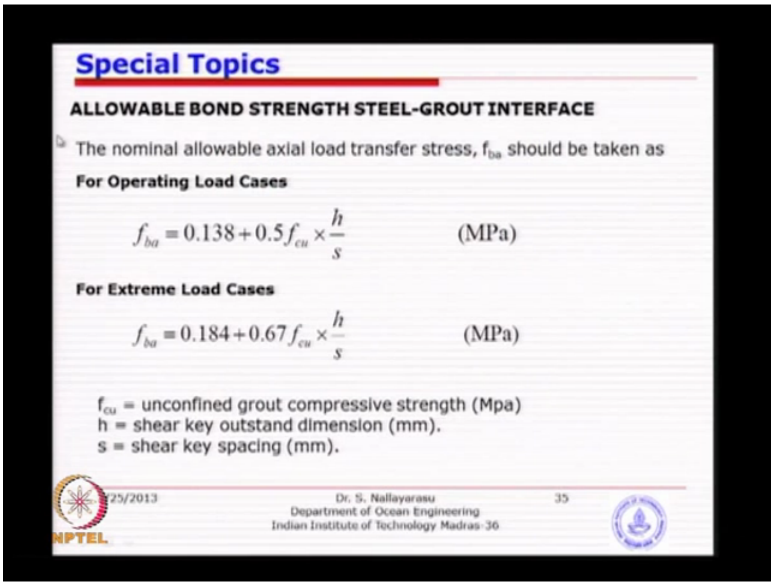

So this is basically the height means, if you go back to this picture is the protrusion from the surface of the pile outward so that is h. It could be a semi-circular bar or rectangular bar welded in this way or circular rod welded in this fashion which produces some height I think this supposed to be to the surface, the drawing. So this height is the protrusion outside here and the spacing is center to center this is between (())(30:43) to the next one which gives you an idea that this formula what you have seen here the basic bond strength is 0.138 newton per mm square quite small compared to we have learned I think last time if you remember the plain bar with (())(30:58) concrete it could go easily to 1 to 1 and half mega pascal.

So that is there the difference because of the methodology as well as the relative size of the structure and the grout 0.5 times f cu, f cu is a unconfined grout compressive strength, in this case it is not great strength, it is only grout, so it is only sand and cement paste whereas for extreme load cases that means the factor safety here is 2 factor safety has 1 and half so slightly higher. 0.184 plus 0.67 times f cu into h by s, so now if you have the height and spacing ratio within certain range this formula is applicable that is the idea behind because this is being empirical you cannot violate the…

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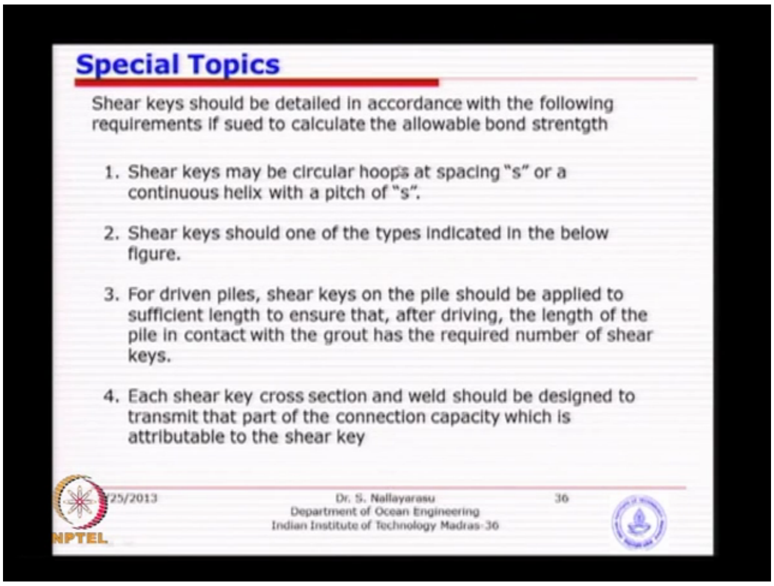

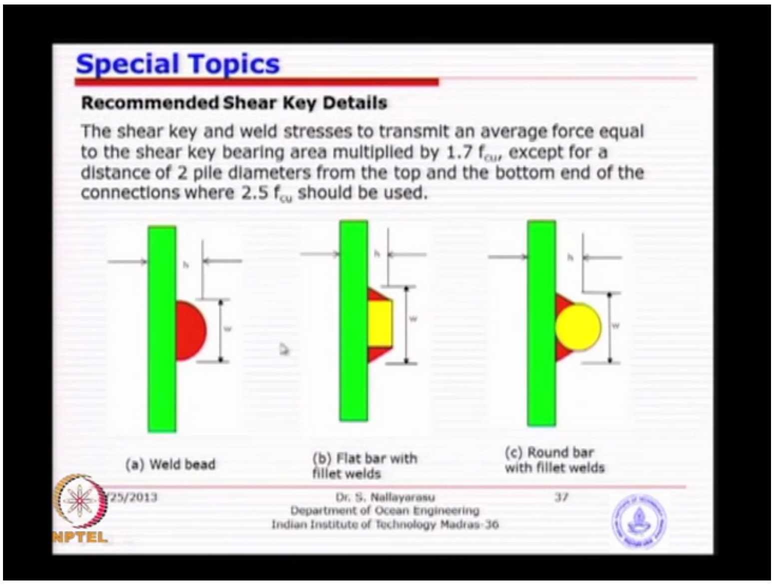

Shear keys may be circular or rectangular but it needs to be around the pile surface and inner side of the sleeves. Shear keys should be one types indicated below and these drawings anyone of them. For driven piles Shear keys should be applied to sufficient length, this is one of the biggest problems even today we face. For example you have hundred metres of penetration and then plus maybe another 50 metres of jacket length or the sleeve length is say 10 metres, where do you want to put this Shear keys?

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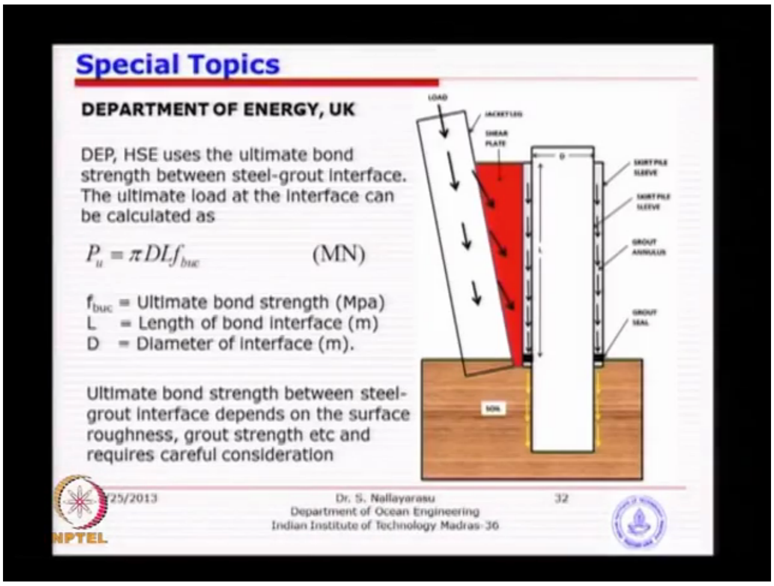

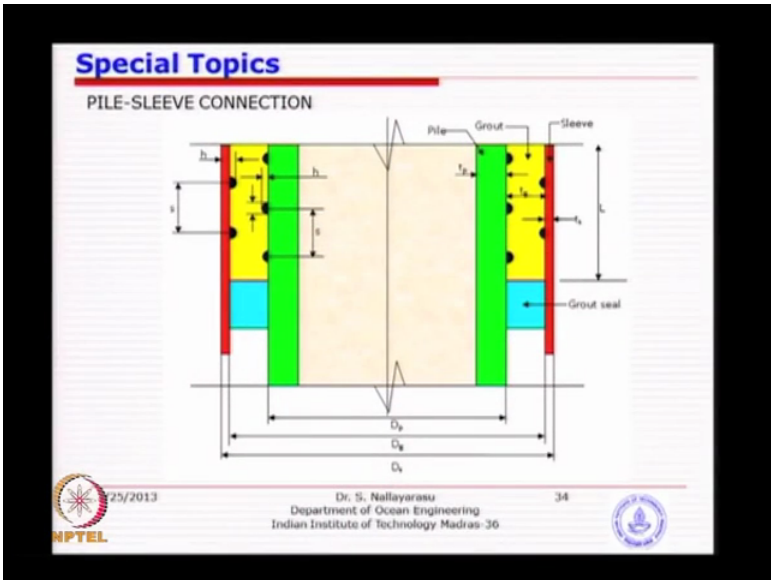

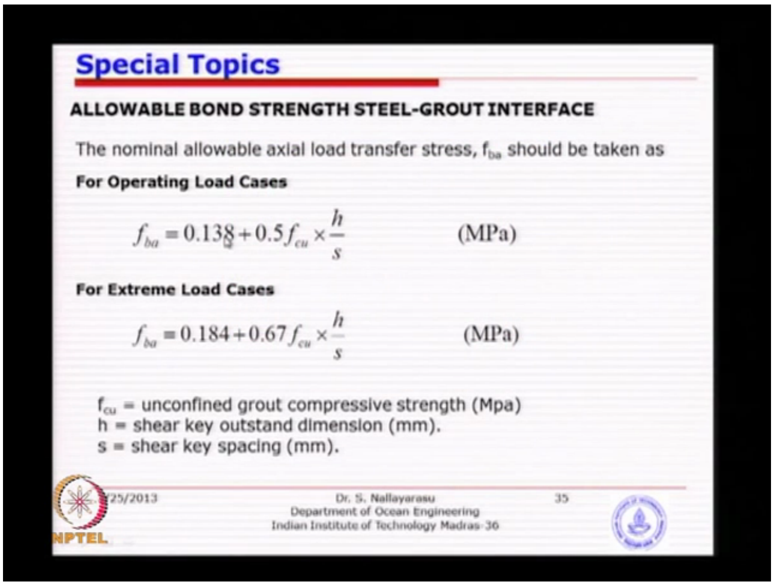

You only want the Shear keys to be placed only where this connections are happening, only from here to here, is not it? Now if you plan for certain location and you start driving the pile you could either have premature refusal the pile is unable to go or the pile is going faster than or more penetration then what you expect overdrive, sometimes happen you give a simple few blows, the pile goes for overdrive that means unexpected soft soil is coming there. Now when you do this, what happens is? The location where you have a welded this shear keys either it will be too below or too high and your connection becomes problem because you relied upon these your keys to get the strength as much as you want but then the position of them is not in the sleeve location.

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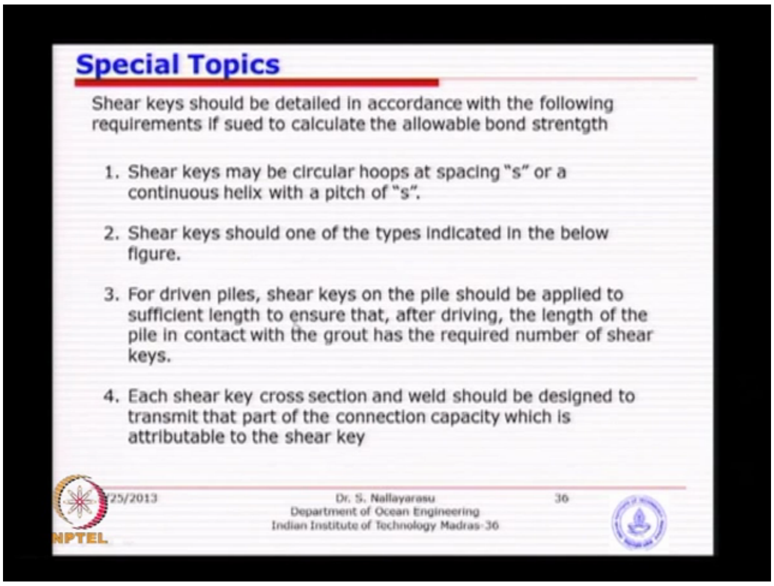

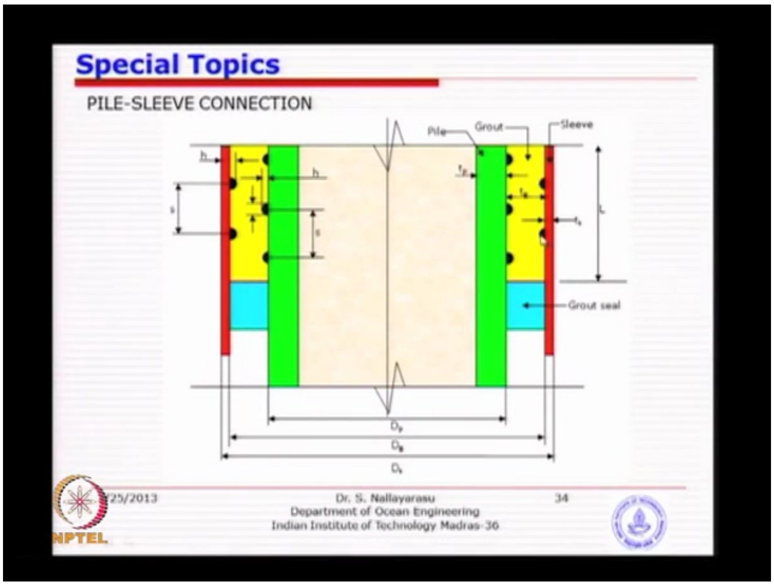

So that is why we normally give sufficient length that means you can give tolerance of plus 5 meters minus 5 metres, so you weld these shear keys sufficient length even if there is uncertain in soil and driving you still can accommodate this type of availability, so that is one of the problem but despite we still have problem, somehow one of the projects last year we had a similar pro exercise of the premature refusal then the pile is completely in fact it was 20 meter up, so what happened is? The connection between the pile and the sleeve became… only one side is this this surface you have the Shear keys whereas there is no Shear keys and there is not enough capacity so what happened is? We have to decide to pump in high-strength grout.

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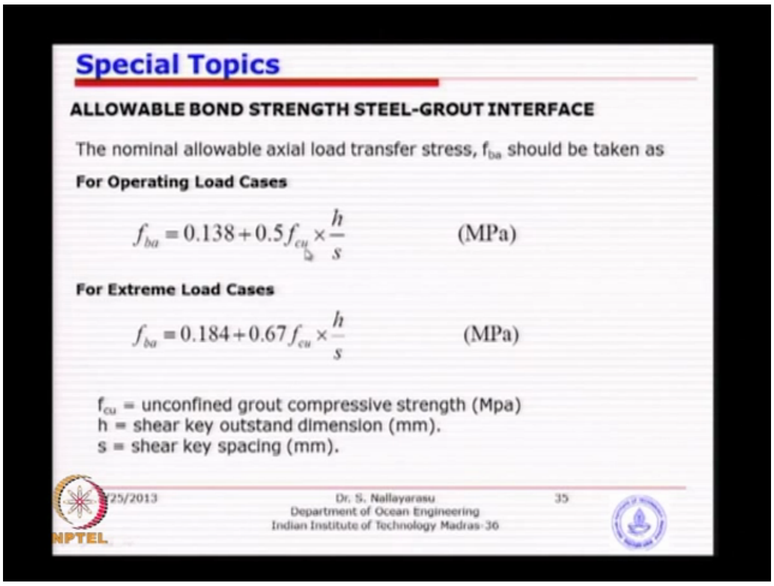

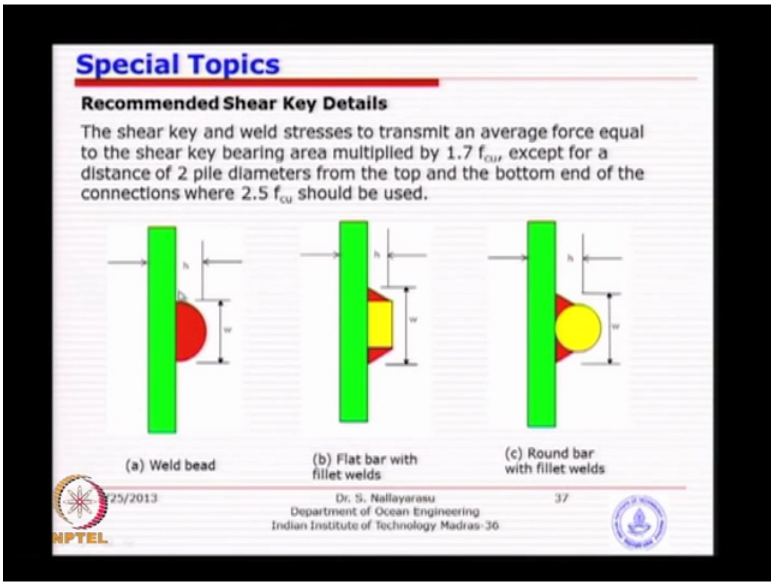

So this is basically f cu of 30 40, so once you have such a situation it has to be decided that we have to bring in different grout may be higher than the expected grout strength and use that as the design value, so and then you have to prove that with this formula they cannot use anymore we have to go for special testing and prove that that is achieving because this formula is applicable only to certain grout strength, up to a I think 60 I think it beyond if we use even higher grout strength this formula is not valid because API has not done testing to all the grout strength, so that is why the welding Shear keys, you should not be restricting exactly to the length by which you require.

Each shear key cross-section should have sufficient strength to transmit the load that means if we go here you take for particular length of spacing, how much load is coming? And you are welding should not fail. In this particular case this is not actually semi-circular rod, it is actually by depositing weld bits, so you just go around keep on welding to get a shape of this kind, you may not get exactly semi-circular, you may get some kind of shape close to semi-circular shape but it takes considerable amount of time when is here to avoid such thing you just take a circular rod and then bend it to the shape of the pile and just do a (())(35:35) all-around, so you will get that shape.

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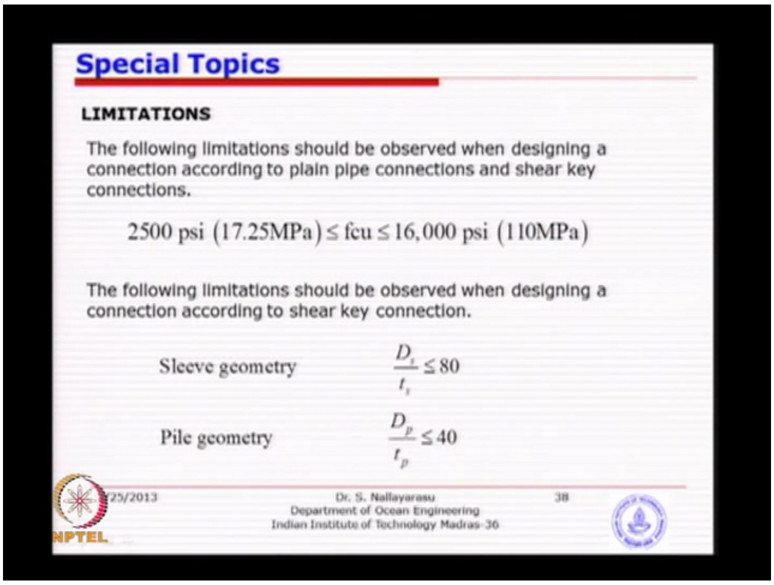

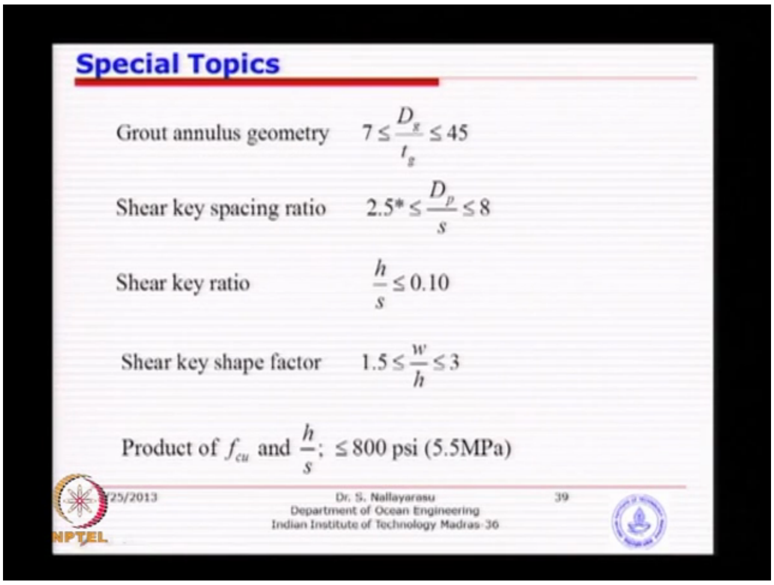

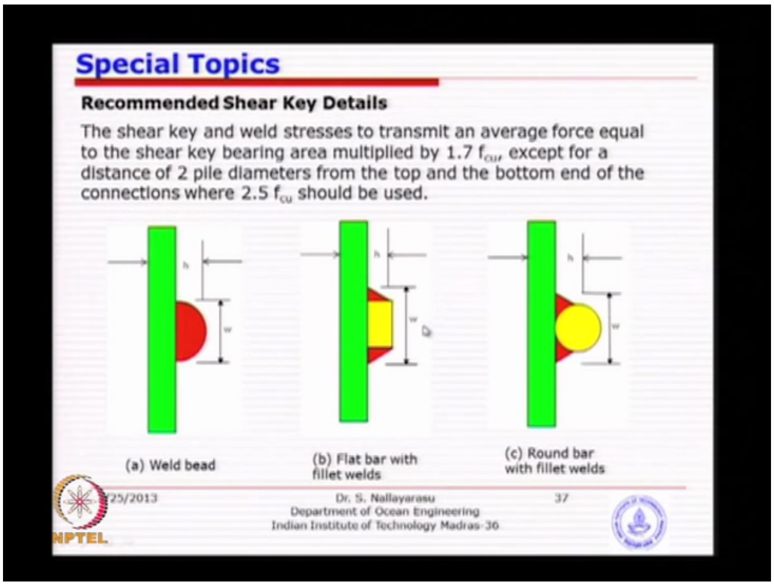

What are the parameters? So this is what I was talking about the f cu values can be from 17.25 to 110, so this is quite high-strength value and sleeve geometry and pile geometry they have tested is D by t ratio should be less than 80 and pile geometry should be less than 40, so when you have a pile outside these parameters that means if your D by t ratio is higher these formulas are not valid, so first thing you have to check these 2 parameters and similarly there are various other parameters for example shear key aspect ratio that protrusion outside to spacing should be less 0.1, so if you have a 10 mm as you are height of the rod or protrusion outside, so you can multiply so 10 divided by 0.1, so it will become at least… Similarly shear key shape parameter the width to height ratio, so if you go back to this picture the width to height ratio supposed to be between 1 and half to 3, it should not have too wider suppose you make it width too much is also not good because then you will not get that effect too much protrusion also not very good, it will become cylinder instead of Shear it becomes a bending, so all those things say very simple idea.

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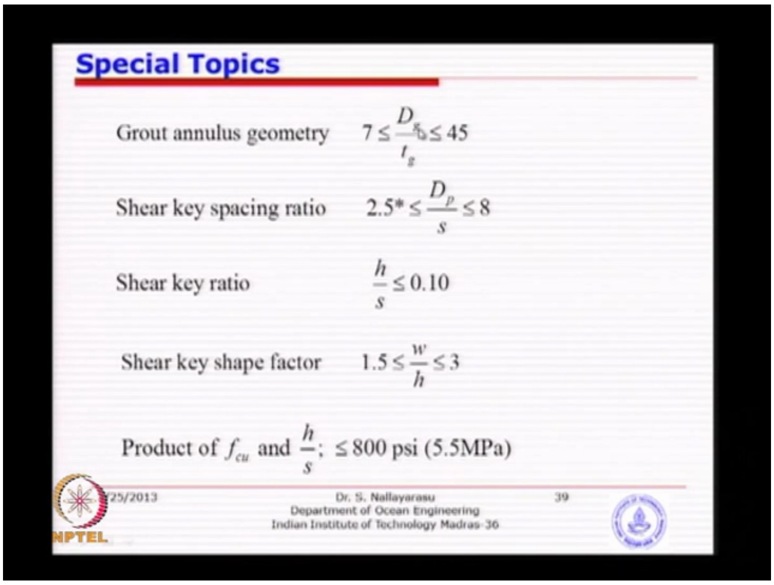

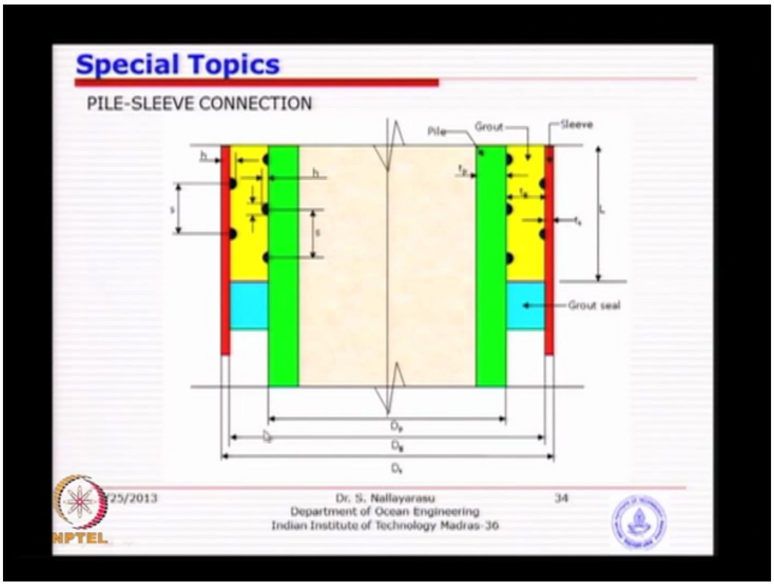

Similarly the grout analysis diameter to the thickness of the grout D g is given here I think D g is basically the inner diameter of the sleeve which is given here D p is the pile diameter D s is the outer diameter of the sleeve, so there is outer pipe, inner pipe and the ground. So these parameters we have to stick to it if you are outside then you cannot use this formula, so when you are configuring a connection like this when you are doing design you must make sure that you are within these limits and also there is the product of this concrete strength with h by s ratio should be less than 5 and half mega pascal, so these are some of the limits to which these formulas…

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Special Topics

Design a skirt pile connection with shear key for a pile diameter of 2134mm with a wall thickness of 50mm.The maximum design load for operating and storm condition is 24MN and 30MN respectively. Use API RP 2A guidelines. Use grout strength of 30 Mpa.

DESIGN OF GROUTED CONENCTION FOR SKIRT PILES
(QUIZ 2 - QUESTION NO : 3 (OCTOBER 2009)

Grout strength $f_{cu} := 30\cdot MPa$

Skirt Pile Diameter $D_p := 2134\cdot mm$

Pile Wall thickness $t_p := 50\cdot mm$

Maximum Operating and storm Loads on the pilehead $F_{ope} := 24\cdot MN$ $F_{stm} := 30\cdot MN$

Assume shear key parameters $h := 12\cdot mm$ $sp := 500\cdot mm$ $w := 20\cdot mm$

Special Topics

Empirical Parameter limits

$\frac{h}{sp} = 0.024$ < than 0.1

$\frac{D_p}{sp} = 4.268$ should be between 2.5 to 8

$f_{cu}\cdot\frac{h}{sp} = 0.72MPa$ < 5.5 Mpa

$\frac{w}{h} = 1.667$ should be between 1.5 to 3

Since the pile sleeve diameter is not given, check the interface strength at the pile outer diameter only. Hence the length of grouted length required for operating and storm condition shall be found using allowable grout stregth from API RP 2A guidelines

Special Topics

For operating condition

$$L_{s1} := \frac{F_{ope}}{\pi\cdot D_p\cdot\left(0.138MPa + 0.5\cdot f_{cu}\cdot\frac{h}{sp}\right)} \qquad L_{s1} = 7.188m$$

For storm condition

$$L_{s2} := \frac{F_{stm}}{\pi\cdot D_p\cdot\left(0.184MPa + 0.67\cdot f_{cu}\cdot\frac{h}{sp}\right)} \qquad L_{s2} = 6.715m$$

$$L_s := max(L_{s1}, L_{s2}) \qquad L_s = 7.2m$$

Hence provide agrout length of minimum 7.2m with a shear key spacing of 500mm.

One of the examples just to I think this is one of the previous year question paper, so design a skirt pile connection, design means you will have to come up with all the parameters, so you have to just think about all these ratios and come up with the initial parameters and then manipulate. The maximum design load is 24 mega Newton and 30 mega Newton, diameter and wall thickness is given, use API methods and 30 mega pascal is the grout, so you can see here is a simple calculation only thing is you have to start with right parameter to assume and then as progress, height is taken as 12 mm typically it will be not more than 20 mm you know make it 20 mm.

You already have the annular gap normally is given how much? About 2 inches maximum 3 inches, so if you have this one bigger and bigger, it is not too good you cannot insert the pile inside, so normally less than 15 mm and in many cases use 8, 10, 12 that kind of so you should remember, do not assume 100 mm and then the pile will never go inside, is not it? And spacing some between 100 to 200, 300, 500 but not too close not too big and basically with is 20 mm, so the aspect ratio as to be satisfied.

So while selecting the parameters you selected in such a way that you will get an enhanced capacity and then check the parameters of all these values all of them if they are within the limits it is good and then use the length preparation, basically what we are asking is in this particular case, design a skirt pile connection means you are trying to find out what is length required because this is going to determine the sleeve length, so the length just use that formula calculate the allowable bond strength, pi D times L time FBA and FBA is available, so L is not available so what we are looking at is a length of the sleeve required and there are 2 conditions one is operating case the other one is storm case and basically the factor safety are different.

So that is where for operating case factor safety is 2 for storm case is factor safety is one and half so that is what we are using here, so which will be governing 2 means 48, 30 means 30 plus another 15 is 45, so which is operating is going to definitely (())(40:01) and that is what you are you are head getting a higher length requirement from operating case compared to storm case is 6.7. So this 7.2 meter length with a shear key spacing of half a metre with a 12 mm rod with a 20 mm spread is able to get you the capacity of how much? 30 mega Newton and 24 mega Newton for both cases, so this is basically a simple calculation, only thing is you need to just select these parameters appropriately.