Foundation for Offshore Structures
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Module 1
Lecture 17
Pile Installation 2

Anyway we will continue with pile installation, we were discussing about main pile, skirt pile and the skirt pile of one special category is the vertical skirt pile I think we discussed and introduced this system in order to help reduce the offshore time that means you do not have offshore welding the whole length of the pile is welded together in the yard transported in single piece and inserted into the sleeve in single piece means there is no splicing is done and that means the reduced amount of time only driving time is required but then (())(0:51) to this whole issue of single segment is the strength required to be sustaining the loads arising during the installation itself.

For example you have 100 meters you have to take this pile from horizontal position to vertical position and using the crane you have to drop into the sleeve which is under water, first thing is this is not above water. So in order to locate it is not a easy job.

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You can see from this first picture for example when you see this picture you can see this sleeve is 100 meters below typically and then the pile is taken from the barge and hanging onto the crane and imagine this pile is going to be assaulting all the time due to wave load, wind load and the crane which is actually is lifting this is also floating crane is not going to be static it is going to be moving so that means the full control of this pile all the way down to the jacket sleeve at the bottom is going to be a challenge and accidentally if the pile hits the jacket, the jacket will damage. So there is a lot of issues of handling.

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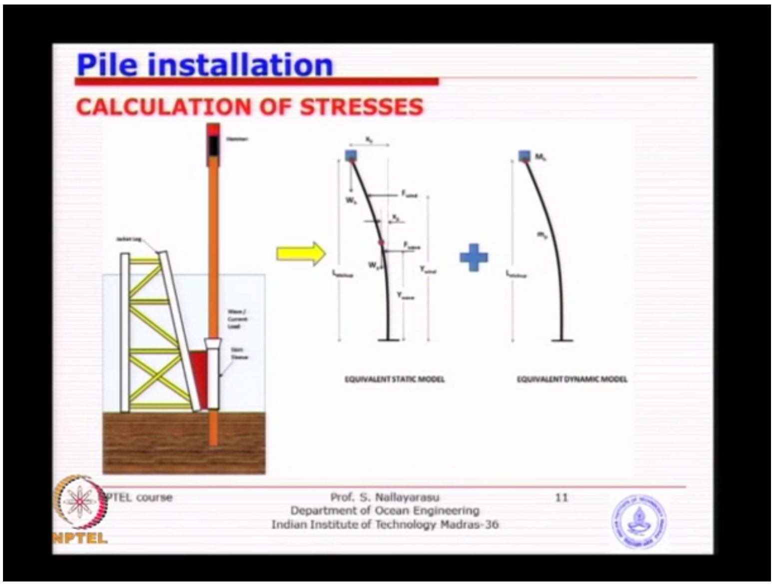

Even otherwise if you are able to do that handling and after you place this pile inside the sleeve like what you see in this picture, this is the skirt sleeve which is nothing but a large diameter pipe attached to a jacket you know and you insert this pile. Once the pile is inserted because of the weight of the pile it is going to penetrate the soil which is weaker in the last few meters of the top layer and because of that it will just start to go down.

Now when you release the crane at this time at this instant of time it is still safe because it has gone through this length of this sleeve is typically about 10 to 15 meter most of the time and once you have gone into the sleeve and into the soil by some amount the pile will not be able to tuple unless this sleeve itself is very small imagine if the sleeve itself is 1 meter and not sufficient penetration has gone into the bed then actually the pile tuple and come out but most of the cases we design this sleeve length in such a way that it has got sufficient length.

So when you are actually releasing the crane the pile will still be able to stand vertically and then once the crane is removed self-standing pile design has been done that means at that instant of time the pile cross section should have sufficient stiffness to resist the wind and load, current load, wave load and its own self weight and in addition because of the wave and current load you are going to have horizontal displacement and when you start placing the hammer at the top for driving further (())(3:33) weight of the hammer and then associated bending moments due to deflection induced the effect we call it second order effects, you know basically the axial load is when you see this picture it is an axial load.

But actually you are placing this axial load at the time when the pile is horizontally displaced. So when you do a linear stiffness analysis you may not be able to capture this which will not be taken into account because the load is applied on a displaced geometry whereas when you do a linear analysis you will take back the geometry back to the original scheme apply the axial load which will not account for.

So that is why most of the time for cylinder structures you have to do the second order effects into account and that means this length is a matter of concern for us the longer the length sticking up is going to be bigger size required, bigger wall thickness required or higher strength required that is only a part of the study. The second study requires is the dynamic associated with this system this is a typical single degree of freedom system we can just ignore the other degree of freedom just lateral motion of this pile.

So you can see the longer the length you are going to get the slenderness come into picture and the period may actually coincide with the period of the incoming waves. For example you have 100 meters length and this assaulting period is say 5 seconds if 5 seconds is coinciding with the incoming (())(5:02) also 5 seconds then there is a potential danger of resonance which could cause a larger amplitude displacement and then fail instantaneously and that is one of the cause of the worry that you need to make sure that diameter is reasonably adequate enough to tackle this the dynamic issue.

So you can see we wanted to save some amount of time for welding and splicing the piles instead of doing it offshore we wanted to do it onshore and that is causing so many technical issues and needs to be resolved so that when you actually bring this pile it does not fail prematurely. So the challenge of single vertical skirt pile is purely a technical issue and needs to be solved in the design rather than tackling at the site.

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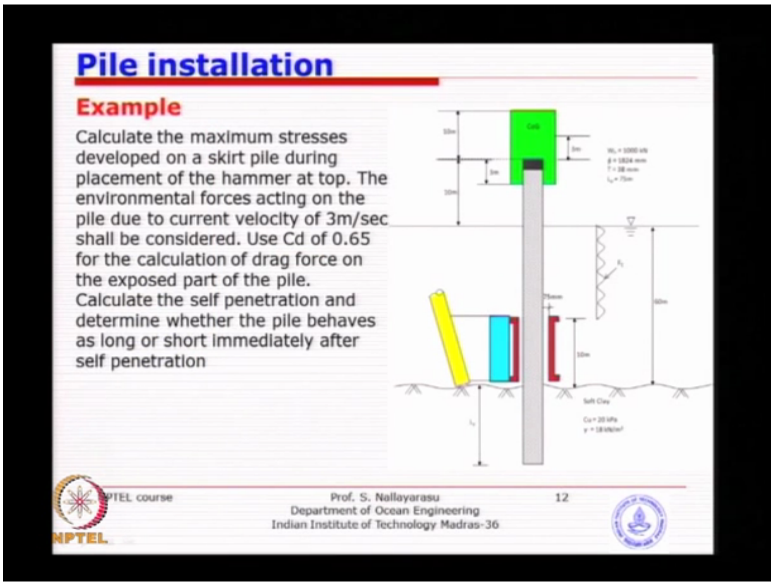

So one of the example that I have just compiled here you could go through when you get the slides is a typical water depth of 60 meter and the current is around 3 meter per second which is in the west coast northern west coast I would say and then you have a Cd value is given. So you need to find out the self-penetration which is very easy to find out a self-penetration is potentially a simple bearing capacity problem.

So you know the weight of the soil, you know the weight of the pile, you know the weight of the hammer and you have the soil properties. Calculate the capacity and compare them so whenever the pile weight is equal to the capacity of the soil at that depth pile will stop otherwise pile will continue to go. But one of the important thing what you need understand is at that instant of time should we take the long term resistance of the capacity of the soil like what we have been doing for axial capacity is a long term capacity means soil was disrupted during construction but what we were doing is taking the strength of the soil after several years of consolidation and that property we are using that is why it is called a long term capacity.

The short term capacity is at that instant of time when the soil is basically disturbed. For example during driving of the pile or placement of the pile on the top of the soil the soil gets disturbed basically the pile shears the soil into two pieces should we take the capacity at that time of pile placement or should it be long term capacity, long term capacity is always going to be higher than the instantaneous disturbed capacity.

So estimate it very carefully both you have to estimate both cases of upper bound and lower bound, you can find out the strongest soil, you have a clay soil kPa you assume full capacity is available calculate the capacity, calculate the weight of the pile and compare it you will find self-penetration will be lesser but assume the soil is disturbed because of the pile is placed may be the strength is reduced from 5 kPa to 2 kPa and then find out what is the self-penetration, the self-penetration may be more.

So now you have a range of self-penetration then you know how much should be allowed for design of the cylinder cantilever section. So that is why we need to do both sides of the story and look at the criticality, you either under predict are over predict both are going to cause you trouble at the site. So what we have asked here is immediately after self-penetration what will be the pile behaviour whether it is going to be a dynamically sensitive. So you need to find out the period of vibration and compare it with the wave period, find out the dynamic amplification, I hope you might be going through this single degree of freedom systems very easy to calculate and can be easily evaluated.

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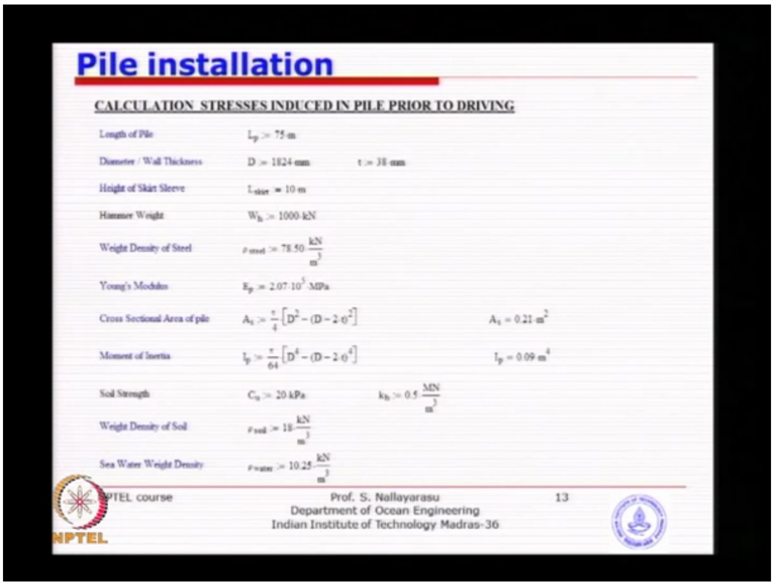

So this example and the design course you already have studied how to calculate this applied allowable stresses as per API compute the unit texture, I do not think we need to repeat that but this is a complete example of such exercises.

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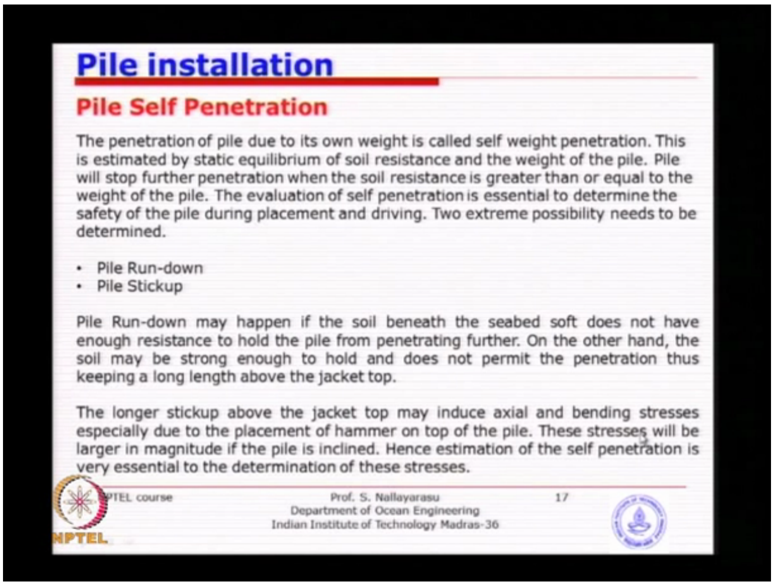

And this is where we were talking about this pile self-penetration. So one of the problem we always have is the pile run-down which is potentially have happened several times in the offshore pile driving you underestimate the self-penetration. For example you know you assume that soil is always going to be as theoretical as what you have been given in the text or in the geotechnical report then you take the values, you calculate the self-penetration, you have self-penetration only say 5 meters and you have predicted that the pile only stickup 10 meter because that is wall thickness we have.

So length of the jacket plus self-penetration plus stickup and you calculate and you do that, you take the pile and insert inside unfortunately the self-penetration is more than what you have estimated the pile disappears. And it has happened in many many cases and retrieval of the such piles has really become a bigger issue. So we need to avoid pile run-down at any cost. So how do we do it? We always weld a piece of steel metal sticking outside the pile, so that in case even if the soil behaves unduly different from what you have understood from the theoretical aspects still the pile will not go down because it will stop because you have a stopper to stop the pile.

So the idea of pile run-down is to prevent the disappearance of pile into the jacket leg and then retrieval becomes a issue, so pile run-down is one of the biggest problem in offshore pile driving specially the main pile, skirt pile may not be a problem because you have sufficient length, if the skirt pile disappears I think something is wrong with the basic fundamental of the location itself for sure you will not get a self-penetration of 100 meters.

Then the opposite side of the story is the stickup is exactly opposite, you are worried about pile run-down which is obvious which is difficult to remove but then if it happens in the other way you expected a self-penetration of 10 meters and unfortunately pile is not at all penetrating into the soil because there is a big boulder at that particular location the pile is fully sticking up upside, you expected a stickup of 10 meter but instead it is 20 meter now.

Now you have designed for 10 meter length sticking up and you decided that this wall thickness is adequate for placing of the hammer because of the bending stresses axial stresses but unfortunately the stickup is double the your expected length. So what happens is you will do place the hammer because the pile will (())(12:00). Now how do you encounter such a situation?

So that is where stickup calculation also you have to be careful because means careful means you have to estimate all possible scenarios and take a risk based assessment which will happen and what should be the remedial message, not in the offshore but on the design time itself so that you are ready for any eventuality. If you have not done the exercise and then you have gone to offshore and then place the pile, if the stickup is larger than what you have expected what can we do?

Basically you cannot place a hammer that of your choice, you have to bring in a smaller hammer place it on the top such that the stresses are still within the limit and start driving if it is possible if it is possible to a depth where the stickup will be within the limits of placing a bigger hammer, you understand the idea now. So but if it is possible only, if you put a small hammer but you cannot drive for example then you have no other choice other than cutting the pile and driving to a depth and then splashing it again.

So this is where every small mistake of such kind it could be a simple mistake of assuming that I will take 100 percent strength instead of say 70 percent strength during placing hammer is very small mistake but can cause a bigger problem at site. So the pile run-down and pile stickup are linked cases but both of them are related to the basic soil mechanics problem of estimation of soil resistance at the time of pile placement. So it is a disturbed capacity is not going to be a capacity that you have been doing for pile actual capacity in the long term.

So we need to estimate how much disturbance can be done due to the pile shearing the soil down if it is a clay soil, if it is a sandy material what really happens. So we just need to estimate and sometime we call it the soil resistance to driving we call it SRD, after this time pile is in a static condition, it achieves its equilibrium means the pile weight is equal to the soil resistance is a dynamic equilibrium you know every time when the pile is shearing the soil it achieves additional penetration additional penetration means additional resistance is going to come.

So initially pile weight may be say 100 tons, resistance from soil is 0 because it has not penetrated as it goes down it is continuously increasing and the more that it penetrates more resistance is going to come. So it has to achieve its equilibrium whenever the total resistance of disturbed equilibrium of the soil to the weight of the soil then the pile will stop, in here you do not need to apply important thing is no petra safety is required. You understand the idea na, here our intension is different we are trying to find out what depth the pile will go through at the time of placement. So do not apply petra safety for such type of scenarios.

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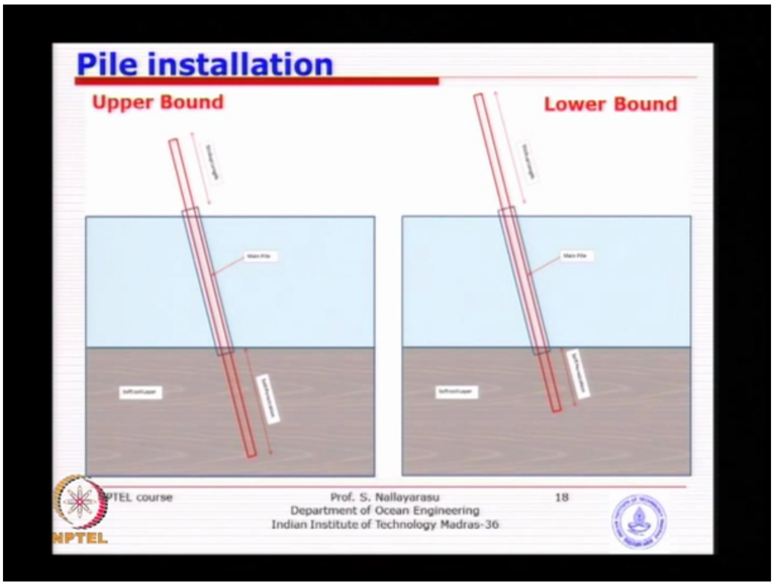

So you can see here this is what we were trying to discuss. So pictorially you can see upper bound, lower bound, stickup versus self-penetration is exactly opposite. So upper bound you see the larger self-penetration, lower bound smaller self-penetration but the same pile provides you with upper bound stickup for the lower bound self-penetration, so just opposite because of the same pile that is getting penetrated to into the leg as well as to the soil.

So when you try to find out the upper bound estimation of self-penetration that means longer length of penetration you need to find out the disturbed soil parameters. Now this is a highly research based subject a lot of studies has been done over the several decades of specially the clay soil because that gets disturbed quite easily specially the soft clay between you know 5 kPa to 20 kPa gets easily disturbed but having said that it comes back very quickly remember you placed a pile it is get disturbed but the next few hours later the remoulding of the soil happens and it will get back to its original strength very fast.

So next time when you are starting to drive you place the pile, you go and relax for say 6 to 8 hours do not assume any more the same disturbed capacity because the capacity might have increased because contact between the pile surface and the soil will be recap. So that is when your assumption of disturbed capacity is at the instant of time of pile going through but not after several hours of you know break.

For example you place the pile, you start driving immediately may be you can consider the disturbed capacity but after 6 hours you give a break for several reasons it could be the driving hammer gets spoiled or you are not ready with the hammer or something not right because the environmental conditions are that not permitting or the hammer driver is not available so many reasons and you give a 6 hours break and you come back, you place the hammer you will definitely experience larger resistance then what the resistance was at the time of placement of.

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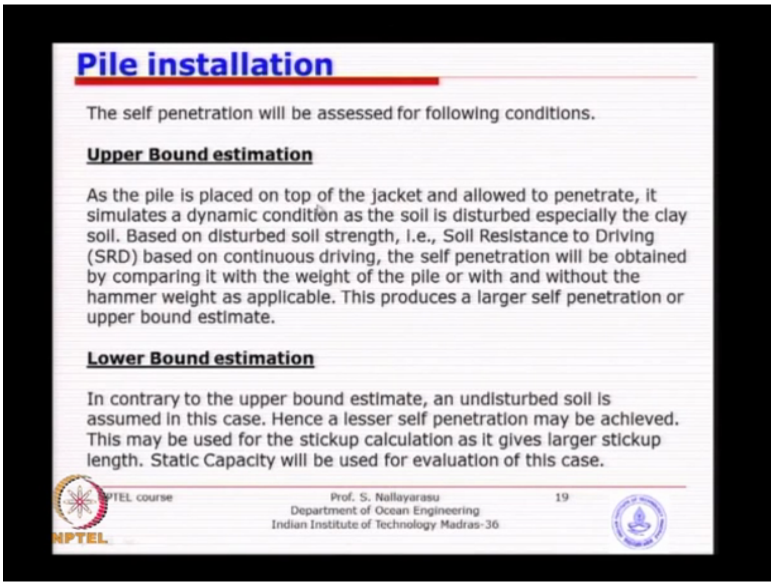

So upper bound estimation is only applicable to at the time when you are placing the pile or at the time of driving but in between gap we call it the restart or basically a remoulded case where the soil gets back to its original strength. This will be the case for soft clay but for the case of hard clay, for example once you shear of you know the soil is going to stay almost for larger duration and will not get back until such time the pile actually moves back and forth due to cyclic may be the soil might come back or it may be just in touch but you will not get the frictional resistance as it was originally offering so that is one of the problem where the hard material is not really so good.

What about sand? Sand is a slightly different picture because of it is granular in nature, when you place the pile what happens it is trying to vibrate, densify the sandy material specially at the end of the pile and compacts and that means it is going to get better and better due to any disturbance (())(19:07) to a loose sand but if it is already a dense sand in any case you will not be able to pack it up any further but loose sand will get better and better during pile placement as well as pile driving.

So it is a pure shearing will happen but then you leave as large longer time does not make any big difference because anything to happen it will happen only during the time of placement. So sandy material you do not expect a larger penetration though the resistance to driving will be larger than the static capacity that we have taken. So many times you will see that the soil resistance to driving will be higher than the capacity that you get when you are actually the place pile in longer term capacity.

So that makes us to worry that means driving in sandy type of soil is going to be bigger problem than driving in clay type of soil which I think easy to understand. So lower bound estimate is basic idea is soil is slightly better than what we have expected so you estimate the lower bound penetration corresponding upper bound stickup.

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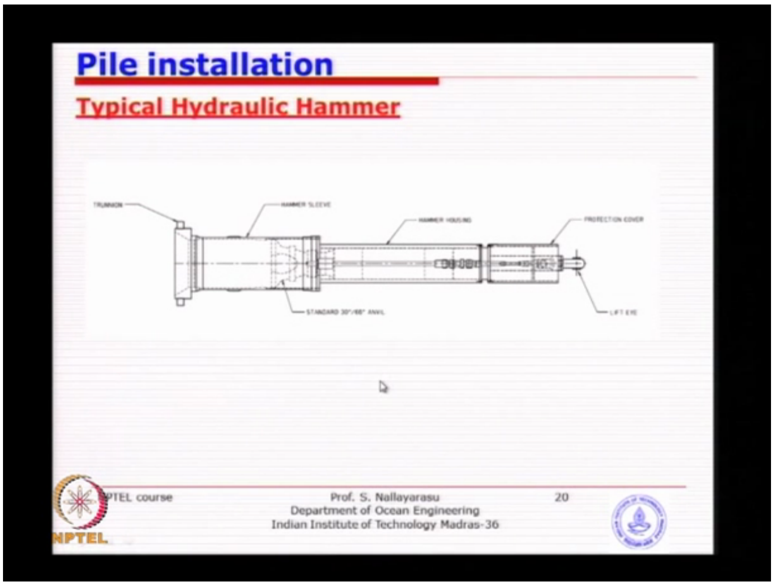

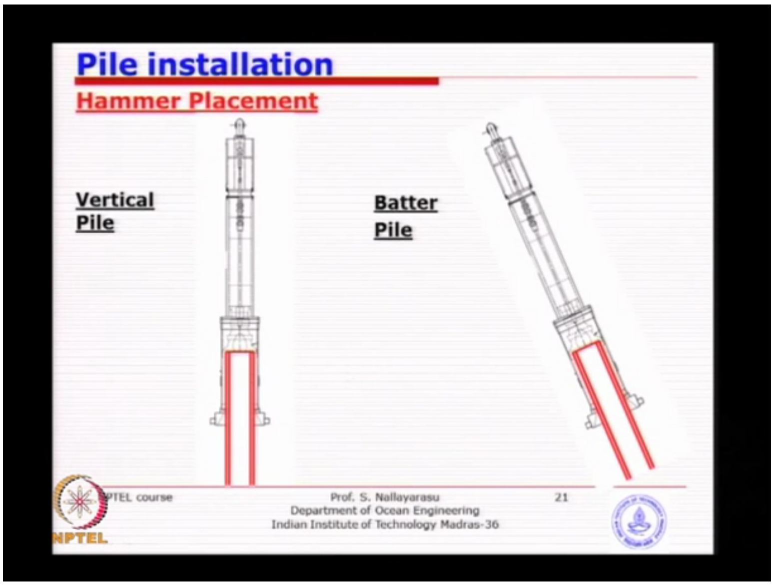

We will just quickly move on to type of hammers I think we will look at several other hammers later on, first I mention hydraulic hammers are very famous and very handy for offshore applications specially under water driving. So you can see this is one of the hammer where you see it supposed to be in in a vertical manner you can see something like this I have taken the same and placed on to a pile is like a larger diameter sleeve placed on top of the pile, this is the pile and you got this hydraulic chamber, hope most of you have understand how the hydraulic system works is very similar to our mechanical engines, diesel engine or except that the fluid hydraulic fluid will move the cylinder up and down very similar to our car engines.

You have a cylinder housing the rod and the piston, so the pumping of hydraulic fluid up down will make the piston rod to move up and down, so just basically that is the idea. The rod will be attached with a hammer basically which has got certain weight, certain height of lift and it has to come down up or down. You have variety of hammers single acting, double acting we will go through some details later on is basically lift off allowed to fall is a single acting hammer or you can actually lift back and forth both are motions which you can have a double acting, you have a diesel hammer, you have a steam hammer normally used for onshore applications, you will see if you go around anywhere people are driving piles you will see mostly diesel engines driving the hammer.

In this case the whole activity is performed by a hydraulic machine which is very similar to our wave makers if you have seen our wave flume or wave machine you have a power pack which is pressurized fluid (oil) fluid hydraulic fluid which passes through this cylinder there will be two inlets and two outlets. So it just pump out and in the hydraulic fluid which moves the piston up and down.

So you will see that in that picture what I have shown there will be small diameter hydraulic hoses which will be connected to the machine in the barge. So this hammer will be placed at the top and nobody will be supporting it at the time of driving it has to be self-sustaining and total weight of the hammer is placed on top of the pile itself nobody is going to hang, you cannot hang a hammer and start driving.

So you have to be getting the clear picture that the total weight of the hammer is simply resting on top of the pile itself and this piece of the material you see here is like a bell which is what is the anvil and on top of the anvil you will see the RAM or weight of the hammer goes up and juts falls down. So that means there is a energy imparted on to the top of the pile by means of work done by this weight.

So weight time the displacement will give you the energy and that energy makes the pile to penetrate the soil by breaking down the soil pile interface. So that is the idea behind pile driving, the larger the pile diameter, larger the penetration, larger the resistance this machine capacity needs to be bigger. If we have a smaller hammer and larger resistance pile may not be able to penetrate to required capacity.

So we need to do a very important study called pile driving analysis which makes us to understand what will happen in offshore. So that when you go offshore the pile will definitely be able to drive to the required designed penetration that you have come up so that is the idea behind understanding the hammer. So if the pile is a vertical one it is very easy just place it like this.

But imagine if the pile is a inclined one like most of the jackets we have a batter piles. So you can see here if you do not have sufficient length of sleeve what will happen the pile will not be able to hold the hammer, the hammer will just tuple. So that is where the sleeve length could be substantially longer sometimes 3 meters, sometimes 4 meters, or 6 meters depending on the size of the hammer.

So that when you place it this steel hammer will be held on to the pile itself. So you can imagine because of the batter itself you can see the weight of the hammer, centre of gravity of the hammer is going to be somewhere here. So you will see a large bending moment applied on to the pile. So now you can realize the importance of the sticking up length, the larger the length larger the bending moment and larger the bending moment you are going to cause bigger stresses which is not very good.

So that is why you will divide the pile into several small small small segments increases the time of installation offshore instead of 2 days it will take 10 days the number of days more you will have to spend more money on installation. So you can see the importance of this calculation the more you optimize you can save lot of offshore time and lesser risk lesser money.

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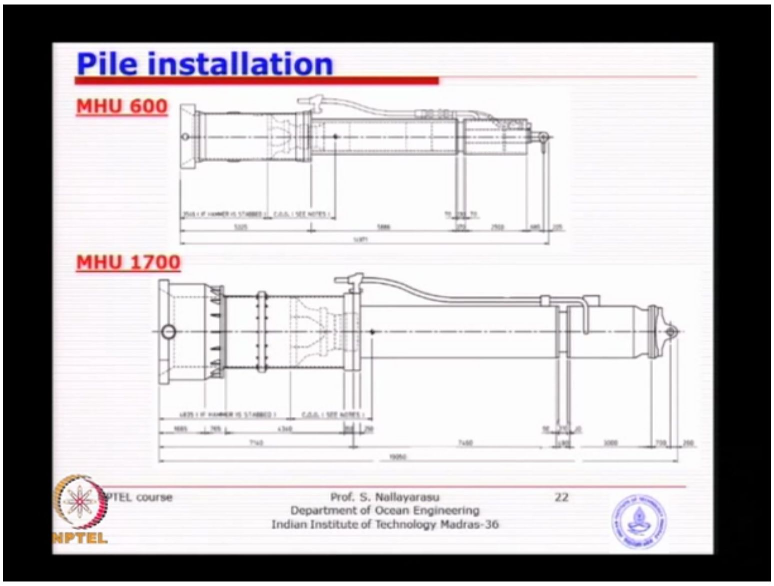

Typical hammer, so you can see all those hydraulic pipes the inlet and the outlet, anvil, housing and all those components typical number I can see 19 meters if you read it carefully is about 20 meter, this is one of the biggest hammer in offshore industry. So 20 meter long imagine it is quite bigger in size if you have a 100 meter pile, 20 meter long hammer and the weight is this particular hammer is nearly about 180 tons.

So you could imagine it is substantially bigger weight, diameter is nearly 2 and a half the 3 meter diameter you can drive such type of piles. If you have a different diameter then the hammer you can put a adaptor you know you can reduce the diameter or increase the diameter. These numbers what you see here is indicating of most of the time is the energy capacity of the hammer in terms of joules.

So that is how the hammer manufacturers they give the notation for the hammer. So that when you select a hammer you can find out what is the energy required for driving, so you can select the catalogue of which hammer most of the hammers they the number here means is the energy capacity.

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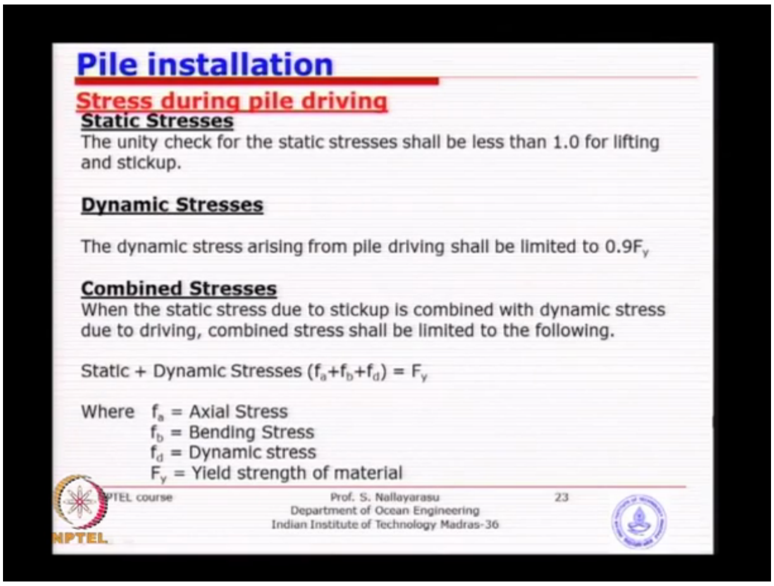

Now during driving you have placed the pile you have found basically the self-penetration, stickup. So you are having a stress at the jacket pile interface at the just starting of the cantilever portion there is a bigger bending stress. Now you place the hammer, start driving now what happens? When you are driving two things will happen the energy imparted from the hammer to anvil, anvil to the pile is going to travel through the pile material along the length and when it reaches the soil, soil is going to behave like a dampener absorb some energy and then the remainder of the energy will pass through the pile along the length of the pile try to go to the tip of the pile and if the tip soil is also soft it will also absorb some energy.

If it is very hard then it may not absorb energy because the energy absorption is directly proportional to the amount of deformation the soil will go through basically again. So if the soil is very strong what happens the stress wave travelled through the material of the pile will hit a hard rock and reflect back. So what will happen is the compressive stress level or stress wave travel through the pile will be reflected backward as a tensile stress will come and hit back the anvil and the hammer itself.

So at that time if you have made another impact we need to find out what is the time it takes travel back and forth and if you place the hammer one more time before the stress wave get relived what will happen is the build-up of stresses, few times you strike the hammer will break down and that is one of the major problem in offshore if you do not do this analysis correctly what will happen is edge of the hammer will break down or even if the hammer is adequate enough to take those kind of stresses the pile may fail at the tip because the stresses coming from impact, the stresses reflected from the bottom is getting accumulated and basically pile you will see that the pile at the top has got severe yielding, you know the material is getting yielding or may be localized buckling.

So we need to make sure that this does not happen neither the hammer break down nor the pile fail. We need to do an analysis at that instant of time what are the stresses? One is the stickup stress, the other one is the driving stress. So that is what we need to just evaluate. The dynamic stress is called the driving stress because it is due to the dynamic force arising from hammer placement by impact, we can allow the stress to 90 percent of the yield that is what recommended by in some cases we do even go to yield but mostly API recommends you the limit to 90 percent.

Static stresses during handling I think you can allow up less than 1.0 for unity check, I think most of you are familiar with your design for static loading. When it comes to combined stresses due to dynamic and static the maximum stresses are limited to yield because this is only a temporary phase, this is slightly different from what we learned in our design course and you can add up the axial stress plus bending stress plus the dynamic stress arising from the driving due to impact and cumulatively it should be less than yield this is one of the criteria we will be using some example problems.

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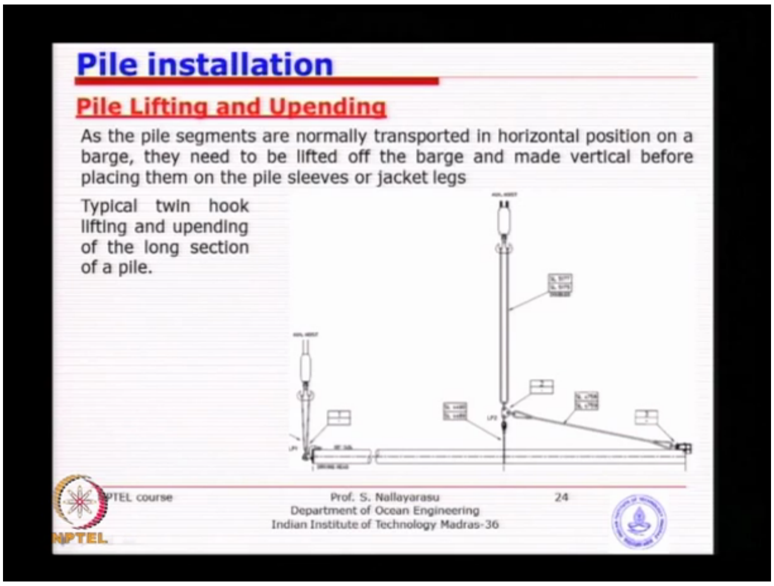

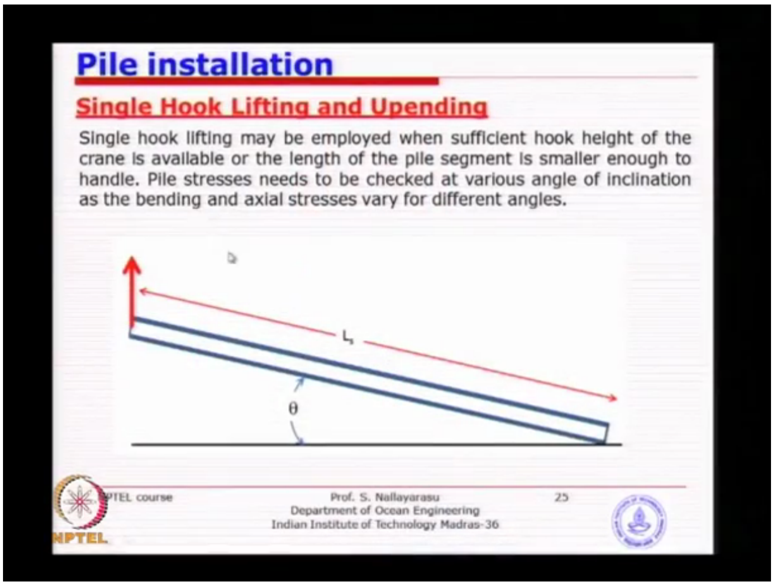

Lifting specially the longer segment piles, you see here these picture you could lift only at the end 100 meters if you try to lift from one end something like this picture you will see that the slenderness I think you could easily understand what will happen to the allowable axial stress the longer the allowable axial stress will be very very small.

Of course during the initial stage this is no more axial stress problem this is a bending problem, is it or not whereas when you actually come very close to vertical somewhere around 70 degrees you will see that is a combined problem of bending and axial. So you will see that pile fails terribly that is why many times we introduce a mechanism by which it supports during the initial lifting but at the later stage it can get relived easily.

You could ask why we have to do all this, you could actually weld some piece of metal at this point some lifting tool but then when you drive it will not go into the leg because you only have a very limited clearance between the jacket leg and the pile that is why you have to have a tool, you have to start thinking how I can remove this but how I can get support, so that is why this idea of sleeve support which is sliding continuously as you lift what will happen it keeps.

So lot of see in offshore you can come up with your own ideas which can help make the installation easy at the same time provide the design requirements without hindering the final purpose. So you could do that so various ideas you have to make sure that at that time the stresses are within the limit.

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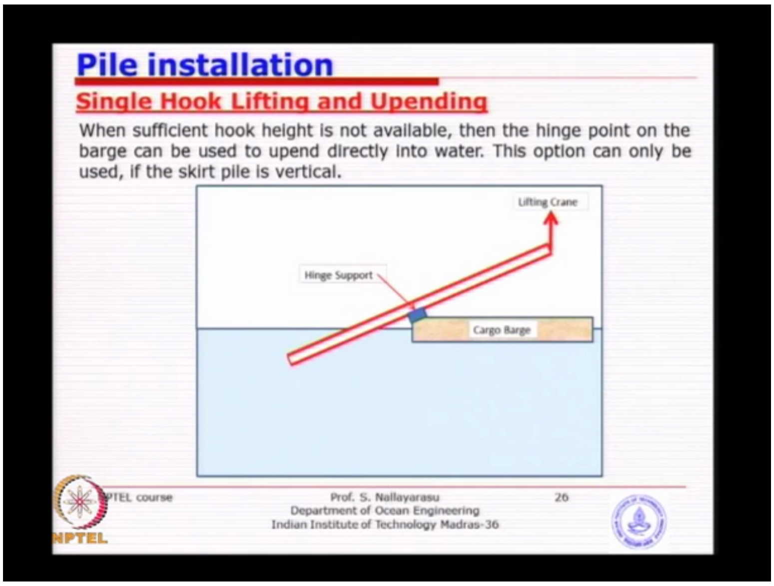

Sometimes we do this idea instead of lifting 100 percent resting on the barge several times the length of the pile is longer because it is 150 meter long. So some of the pile length will be on to water so that you do not need to lift vertically upwards which we will provide by means of a rotatable mechanism at the end of the barge so that it goes into water so straightaway you can get additional support instead if you actually lift from this the total length of the bending is larger so that is.

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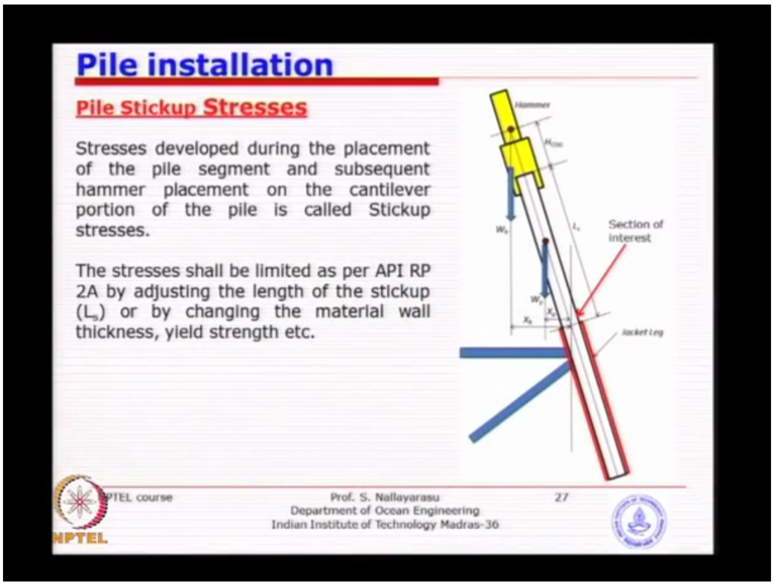

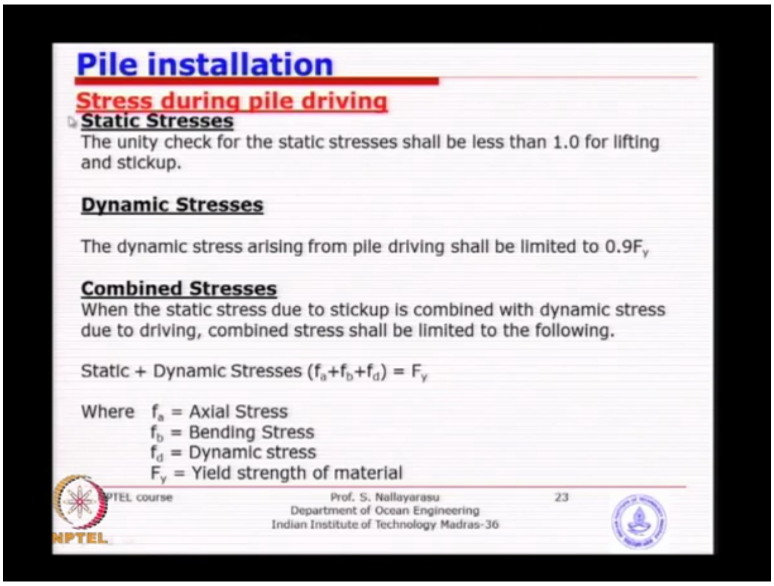

Typical example of a main pile placement on top of the jacket so you can see a picture here this is exactly what the problem we were looking at file is inclined, bending stresses are very high at this point, hammer is placed, weight of the hammer is eccentric and the weight of the pile itself is also eccentric and basic bending stresses at this level plus the axial stress and in addition you will be able to calculate the stresses due to driving because the stress waves go travel through unreflect.

So these three tresses you have to calculate and then satisfy their design condition that we have reviewed here and the dynamic stresses due to driving has to be calculated by some methods which we will be discussing about the drivability analysis later on. So this for a given hammer you could find out what will be the maximum length of sticking up, is it or not you want to place this hammer because you know very well without that hammer I cannot drive because the soil is very hard.

So you determine the hammer first what type of hammer is required to drive for that particular depth of penetration and once you decide the hammer you look at what will be the limiting length of stickup or vice versa, I need this much stickup what should be the diameter, what should be the material of thickness so that you can design the stresses.

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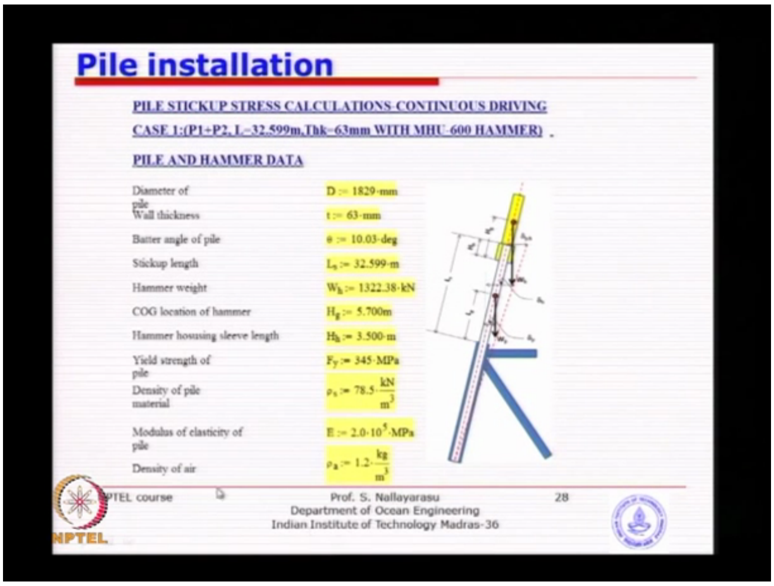

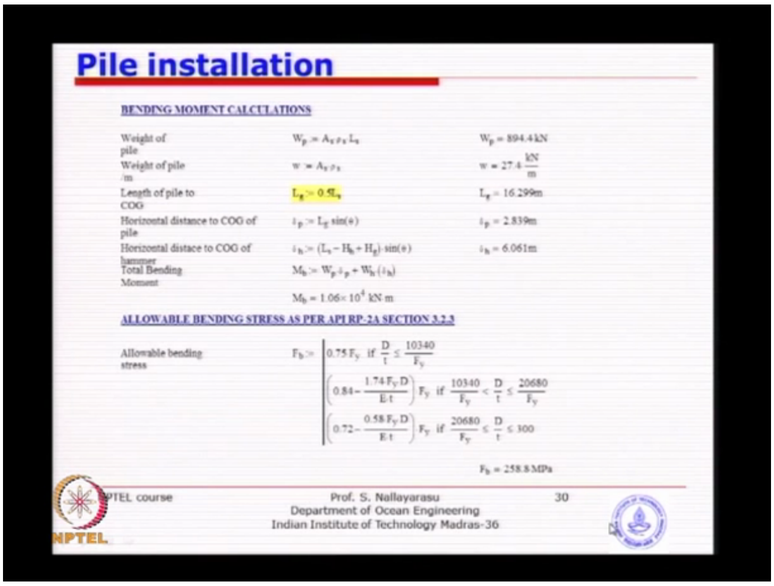

One example I have given you for so that you can go through it is also including some stress calculations based on you know our previous design course with all the slenderness ratio and allowable axial stress, allowable bending stresses which you should be familiar.

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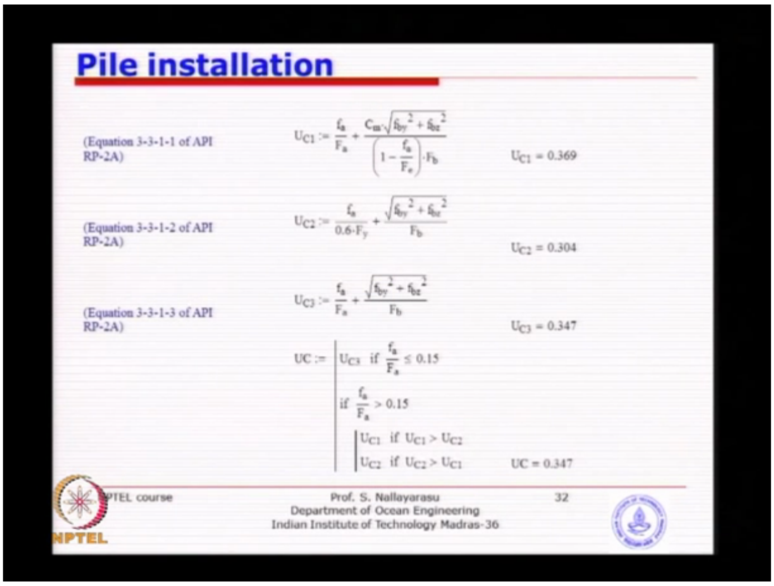

And then the main thing is the unity check based on the current placement of hammer and current placement of pile, the eccentricity is due to batter and calculate. So most of the main piles will not have a issue of dynamics because it is always above water whereas the skirt pile you will see that the wave current interaction is the bigger problem.

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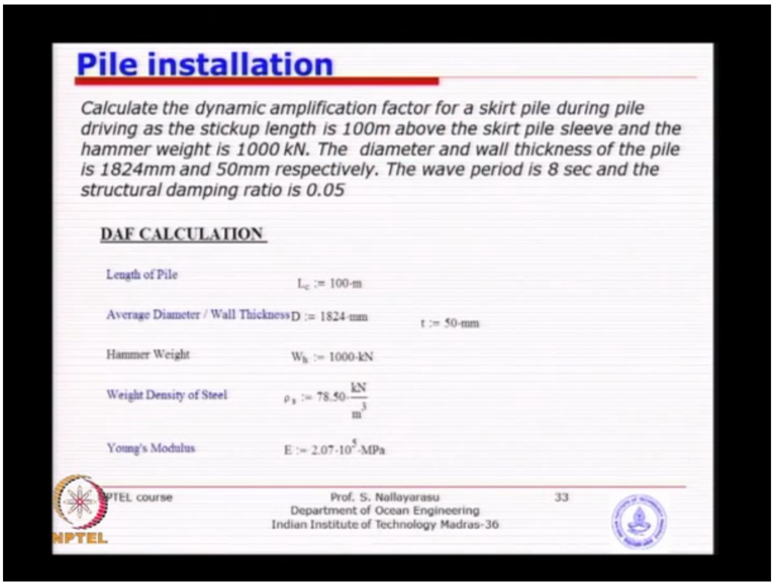

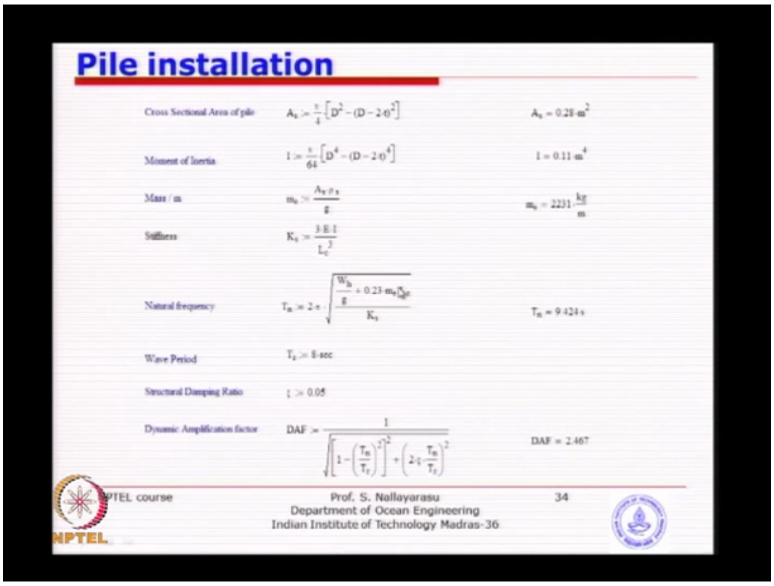

I think this problem also we were trying to solve in the previous course to find out the dynamic amplification factor for a single vertical skirt pile placed inside a sleeve, weight of the hammer is given, length of pile is given and I think in fact we were trying to do this one in our numerical modelling the other day, you can see there the natural period and the dynamic amplification.

So you can see here when you have a pile of 100 meter long placed into a sleeve is going to (())(36:05) 2 and a half times more than a static displacement if you have to calculate the displacement due to wave load. Say you have a 2 meter wave during the time of pile driving, so if it is displacing 1 meter, if it happens to be the dynamic natural period is 9 seconds and wave period is 9 seconds so you can see that 8 seconds you can see here it is going to displace 2 and a half meter.

So instantaneously you will see that the pile will fail because of large displacement and hammer is placed there 1 meter it is designed based on static analysis you have already calculated, you calculate the bending moment. But because of this resonance what happens the displacement becomes very larger, hammer is still there, bending stresses will get amplify by 2 and a half times which is going to be a immediate failure. So that is why any time when you are designing a single skirt pile, vertical, driven into sleeve you must look at the dynamic associated with it.

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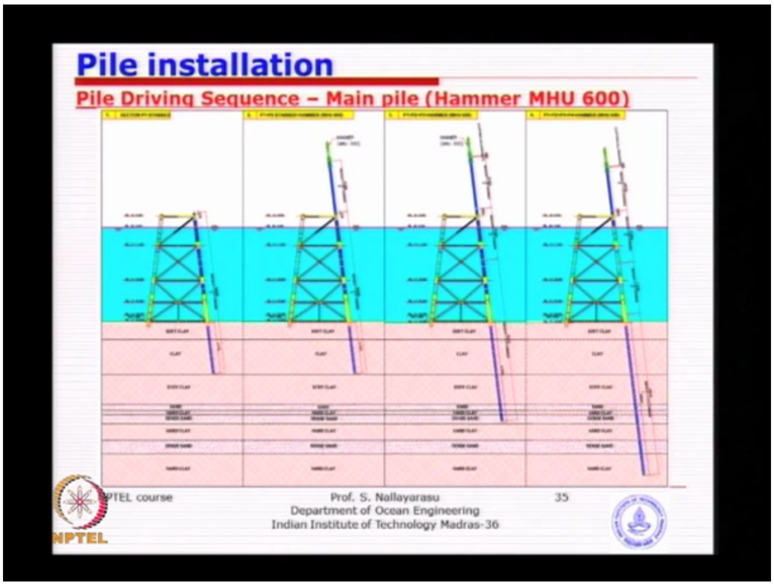

Finally we will just look at some of the sequence sketches how things are done in specially driving (())(37:16). So you can see 1, 2, 3, 4 pictures, so you have placed a longer section of the length of the pile in such a way that small length of the pile is sticking above jacket, you do not want at that time bigger length. Then you bring the second length of the pile weld it on top of the first one which is little bit sticking up.

Now imagine this is where you have to be careful, when you do this exercise the top of the first segment we call it P1 or segment 1, you should always have a piece of metal welded so that the pile is not run-down. So then you bring the second pile segment could be 20 meter, 15 meter weld it after welding that you cut away the the pile stopper we call it pile stopper you can, so that the pile will start going down then you make sure the pile the second segment also does not disappear.

So how do we ensure it? Because you already started to cut once you cut the pile will disappear, is it or not. So what we normally do is at that time when the stopper is being cut, we normally hold it by a crane and just wait and see whether it is going faster or slowly and once it get stabilized probably you can release the crane. Then you place the hammer then you start driving then remove the hammer, weld the next piece, put back the hammer.

So every time you see remove the hammer, place the pile, weld it, place the hammer back, drive. So this sequence every time you will see that it takes atleast 5 to 6 hours, every time you remove the hammer, place the pile, welding, (())(38:57) and then place the hammer back, easily it will take 6 to 8 hours. So every time when you restart driving you will see that it is going to be hard driving because every time the soil gets back to its original strength or nearly original strength and may give a higher resistance then what you actually continuous to drive that is the greatest advantage when you are driving a skirt pile of vertical you do not need to stop unless you want to take rest, is it or not you can continuously drive and finish the pile driving within few hours compare to this will take probably 2 to 3 days and that is the difference between the main pile and the skirt pile.

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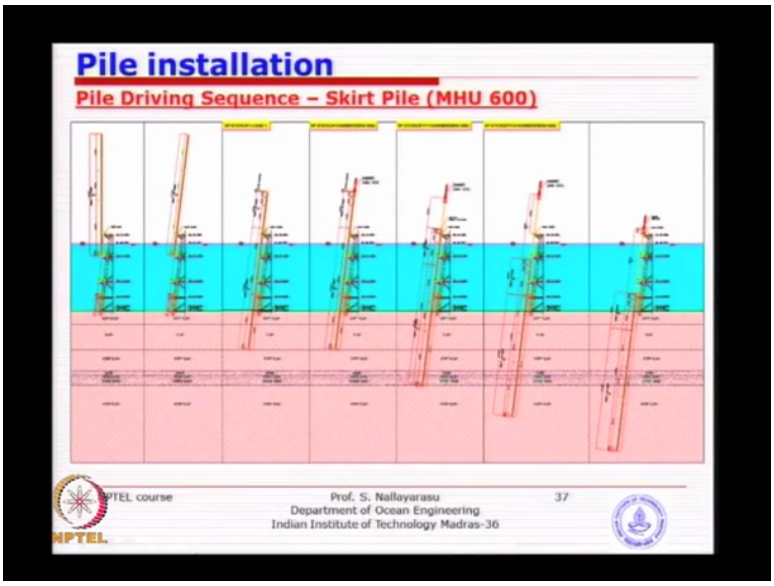

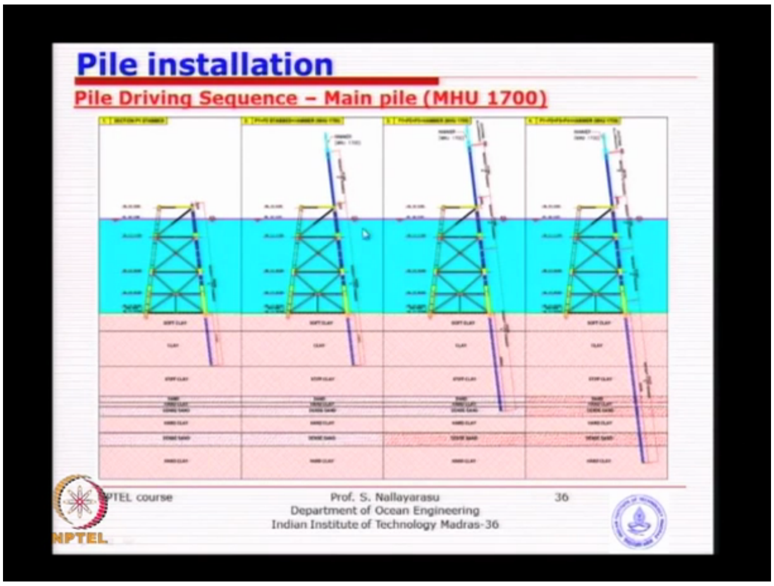

Slightly bigger hammer, skirt pile of inclined say same business the only difference is the portion of the pile will be removed. So how do we do it because this is outside skirt pile of inclined nature the last segment of the pile will have to be removed it is not permanently required, whereas in the main pile case it is permanently inside and it is going to be grouted, whereas the outside one we need to have a connection the last piece needs to be pulled backwards.

So normally we do not do welding instead we have a basically a mechanical connection which is placed and screwed and later on you reverse back and then pull it backwards, it is a special machined connection which will make sure that during driving does not come back because if you simply place it what will happen, when you drive the piles will not be able to stay together.

I think that gives you an idea of pile installation, in the next class we will try to go into the pile drivability means we will go in the theoretical knowledge of how the stress waves travel through the pile into the soil and then do an analysis on that.