Foundation for Offshore Structures
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Lecture-22
Pile Driveability Analysis V

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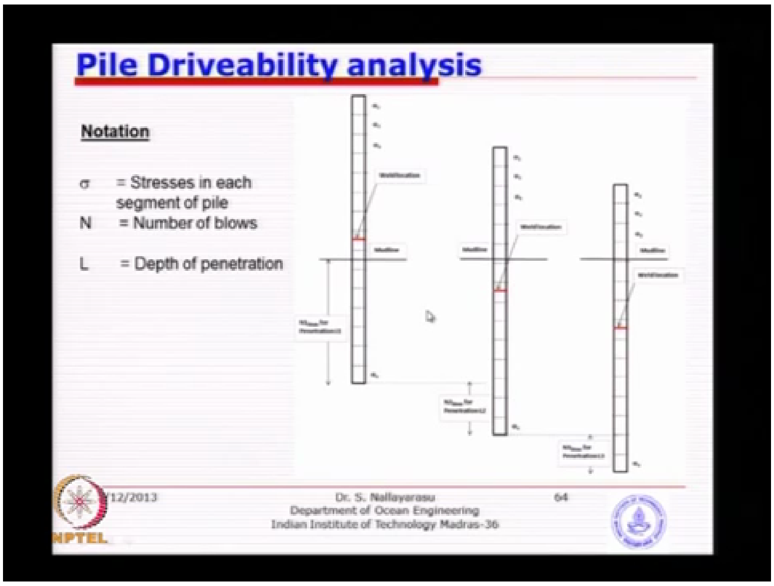

So if you look at the sequence of driving, you know if you look at the pile sequence from one step to the next just in order to look at the stresses at each stage I have just indicated one connection here you know the piles are made is of plates I think most of you are familiar. And there will be a connection between 2 segments which is just circumferential weld which is what is going to be subjected to such type of fatigue. Of course you also will have fatigue along the longitudinally scenes but not very critical because the stress concentration will be lower so the most critical one is the connection between 2 obvious pieces of pile segment inserted into the soil.

Now you see here the pile has been divided into several sub-segments along the length and you will be monitoring the stresses at each of these locations because if you look at the pile driving analysis you will be able to find out the stresses at various levels during driving so what we are interested is the stresses at the level where there is a interconnection between 2 segments. Elsewhere evening the stresses are available, the stress concentration will be lower because of the continuous thickness, the place where there will be change in thickness or there will be change in connection so that is the point of interest so during each blow the stresses are compressive in nature travels downwards and then gets reflected.

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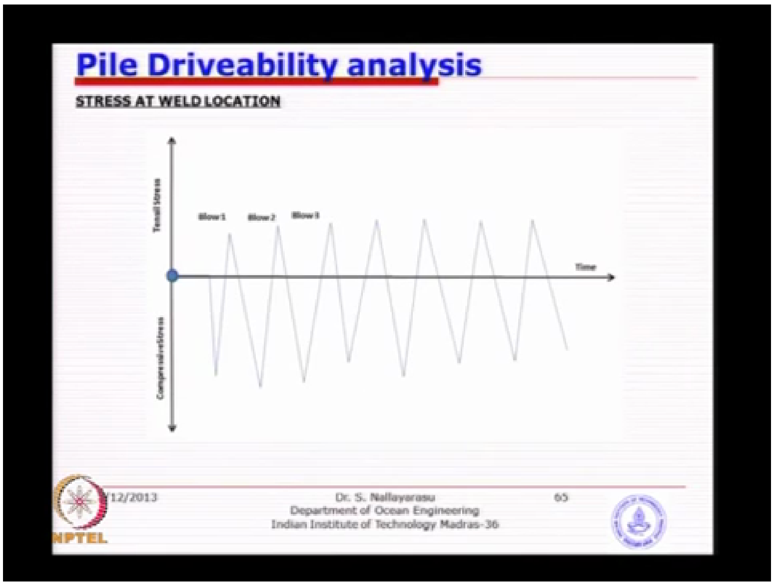

So each of these if you look at it is one cycle, very similar to wave cycle I think when we are looking at when we use the fatigue you will be able to understand you know one of the fatigue criteria is the load must be cyclic you know it has to change from positive to negative or even at the positive or negative level there should be a variation in the stresses. In this particular case it happens that there is a compressive stress, there is a tensile stress at slightly different time intervals because the stress wave travels through and then returns back with some amount of reflection and usually unless it is a hard-driving the reflected stresses will be very small.

For example, in the starting of driving you may get lesser tensile stress but at the end of driving for example, trying to reach the final penetration. You will see that the set value will be very small and number of blows will be increasing and basically that is our time you will see the tensile stress is maybe higher. So the difference between the compressive and tensile stress will give you the range of stress that is which is causing the fatigue and the number of times that you hammer is the cycles that is offering this fatigue crack propagation along the weld. So this is something these 2 phenomena of evaluating the stresses at a particular location and the number of times that occurs is just the count of number of times that you keep blowing the hammer.

Now if you look at the reason why we divided into so many sub-segments is just to find out the stresses along the length, does not mean that we are going to evaluate fatigue at every location because not required. As I mentioned the fatigue is of most interesting and more critical where there is a higher stress concentration elsewhere, the stress concentration may be smaller.

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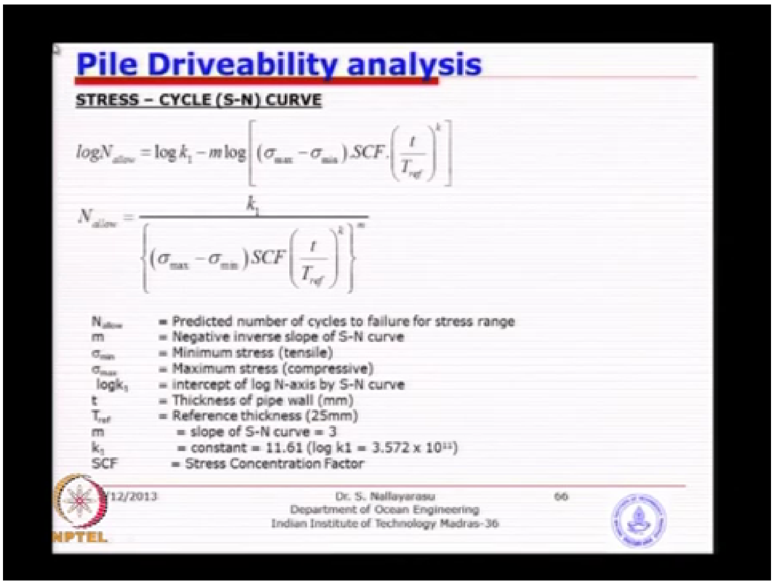

Typically we use S-N curve for tubular connections which we have learned in our design course you know different S-N curves from old coat to new coat whereas in this case there is no tubular connection, this is only one tube this available and in that particular case what we are now looking at is the S-N specifically for such type of detail, I think we also discussed the non-tubular connections, non-tubular areas where the S-N curve can be described in a slightly different manner but the general format of the S-N curve would not differ so you can see here log N will be equal to log k 1 which is a material constant minus m log of the stress.

Now this stress is the one that we are interested here into so this stress is nothing but the min-max stresses between 2 cycles of wave in here we are looking at the number of blows that you are continuously doing so between 2 blows what is the either (())(4:34) or trust to crust, so in this particular case the compressive stress to tensile stress or tensile stress to compressive stress what is the range. So Sigma max and sigma min is just the variation of the stress and stress concentration when you multiply this you know you will get the hotspot stress range multiplied by correction factor to account for the thickness which was used for testing versus what is the thickness.

So I will just cumulatively put all the parameters together which I think we normally use it in separate in the design time we were looking at so in here I had all of them together all the components which causes the cracks to propagate and basically the stress range and becomes hotspot stress range when you multiply the system at this impact, correction factor to account for that variation in thickness between the testing done to establish S-N curve to the plate thicknesses that is normally used in practice which is an unknown, only the user will know what thickness is being used so basically that will have a effect, the larger than or smaller than the test thickness.

Normally the test thickness is about 25mm, whereas 16mm for tubular connections whereas here it is 25mm, difference S-N curve different testing was done and then m is the slope of the S-N curve which I think we have discussed in detail. And log k 1 is nothing but for different types of material this log k 1 is a constant value which is the demarcating the change in slope, in some cases we see that there are double slope curves which we were discussing whereas, for this particular time of connection tube to tube connection we have a single slope curve. Of course (())(6:20) does not give this guidance either you can look at DNV code or you can look at the Department of energy guidance where we are describing about the simple seem connections.

So once you know the material constant which is readily available for a particular type of connection, slope of the S-N curve is available so what you need is the Sigma max Sigma min obtained from your drivability analysis, stress concentration factor have to be calculated depending on type of welding. Now we were discussing about the pile being outer diameter constant, inner diameter changes, wall thicknesses is may be very along the length, we need to find out what will be the stress concentration factor for that particular connection.

It depends on the thickness change, it depends on the welding detail whether you are welding from both sides or you are only welding from inside, so all those things will be influencing stress concentration factor which I think we have discussed in detail about tubular connections but not about this particular aspect so we can look at that. So if you rewrite this equation in terms of N allowable instead of log of both sides, we just take anti log of and then you can express in this format which is very easy to calculate your N allowable. So once you have these N allowable values that means the number of cycles to failure then you know number of blows that you are actually blowing on the top of the pile which causes this much of stresses and then the ratio will give you a feel whether the crack will actually fail or the damage is going to occur so that is the idea behind.

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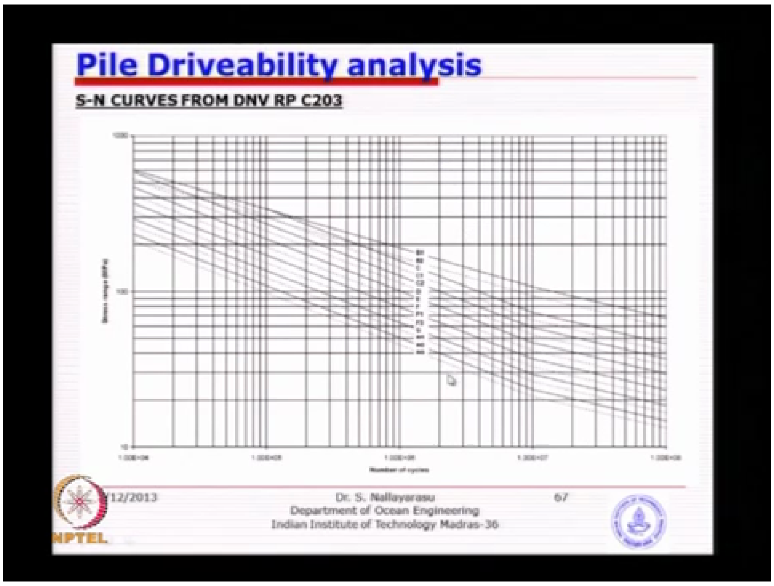

So one of the set is to calculate the allowable number of cycles very similar to allowable stresses, the other one is applied number of cycles the ratio will give you the fatigue damage. This is the the different varieties of S-N curves you can see here are the threshold levels here somewhere here slight change in the slope. So most of the stresses on the higher side will be using the first initial slope here so you can see the stress level for a particular graph for example, if you look at the F3 graph, these various types of graph I think we did discuss about it hopefully regarding various types of connections both in terms of plate connections as well as in terms of plate and tube connection but not tube to tube connection which is separate dealt with tubular connections.

So in here each of these notations from W to W 1 and B 1, C 1, C 2, all those things each one of them are particular type of connection. Basically if you look at F 3 it is for a 5 and another pipe welded with a circumference weld. And if you look at C 1 is actually a plated type connection, similarly W 1 W 3 is gusset type of connection so each connection the behaviour of the stress range with respect to number of cycles to failure is going to be different and that is why they have given so many numbers of S-N curves. So typically if you look at some of the values is 100, 200 and it goes almost up to 500 I think, 300, 400, 500, 600 so this is the 600 mega pascal stress which I think you can see the magnitude you will never reach unless you have higher load effect and then gradually reducing down to 10 power 7 million cycles.

So basically at this point slide change in the slope if you look at the old S-N curve it is just the single straight line. So but most of the time we will be operating our S-N relationship within this area, if you come across or go beyond here your stress levels are so low that it may not be even governed by the petty condition. So this S-N curve is taken from code called (())(10:29) where as the API does not have the guidance on such type of non-tubular connections so you will have to use this.

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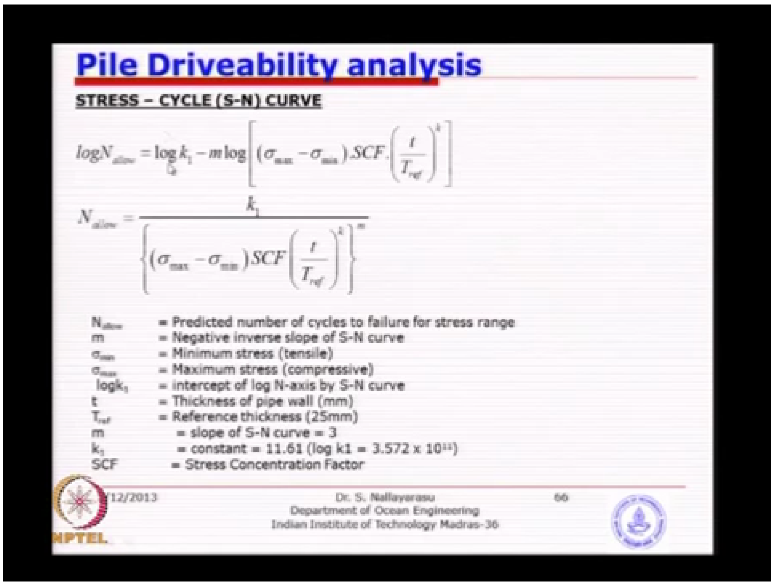

The second thing the same the graphical display of the S-N curve relationship is displayed here in terms of coordinates using this equation, the equation that we saw here, of course without SCF and t reference so you can use the values to reconstruct if you are interested in reconstructing this S-N curve, if you are writing a computer code or developing your own design program so you can use this basically the values of m 1 which is just slope of the S-N curve in the starting side, slope of the S-N curve in the second side, it should be 3 and 5 and then also the thickness exponent which is used for correction in here if your thickness is bigger or smaller, you can use the thickness correction.

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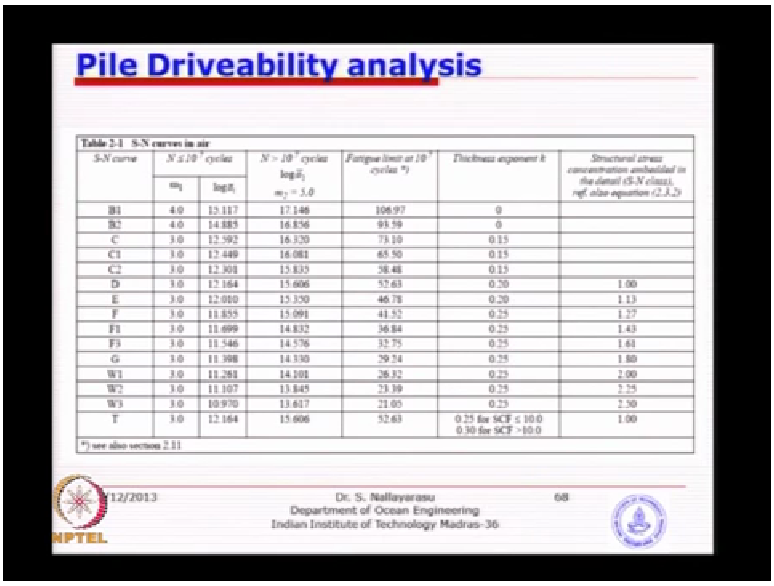

Pile Driveability analysis

Table 2-1 S-N curves in air						
S-N curve	$N \le 10^7$ cycles		$N > 10^7$ cycles $\log \bar{a}_2$	Fatigue limit at 10^7 cycles *)	Thickness exponent k	Structural stress concentration embedded in the detail (S-N class), ref. also equation (2.3.2)
	m_1	$\log \bar{a}_1$	$m_2 = 5.0$			
B1	4.0	15.117	17.146	106.97	0	
B2	4.0	14.885	16.856	93.59	0	
C	3.0	12.592	16.320	73.10	0.15	
C1	3.0	12.449	16.081	65.50	0.15	
C2	3.0	12.301	15.835	58.48	0.15	
D	3.0	12.164	15.606	52.63	0.20	1.00
E	3.0	12.010	15.350	46.78	0.20	1.13
F	3.0	11.855	15.091	41.52	0.25	1.27
F1	3.0	11.699	14.832	36.84	0.25	1.43
F3	3.0	11.546	14.576	32.75	0.25	1.61
G	3.0	11.398	14.330	29.24	0.25	1.80
W1	3.0	11.261	14.101	26.32	0.25	2.00
W2	3.0	11.107	13.845	23.39	0.25	2.25
W3	3.0	10.970	13.617	21.05	0.25	2.50
T	3.0	12.164	15.606	52.63	0.25 for SCF ≤ 10.0 0.30 for SCF > 10.0	1.00

*) see also section 2.11

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So all those information is given in terms of table so in terms of calculation for manual methods for example, you want to do a design check of your pile driving fatigue , you can take the equation full of these numbers you will be able to get the relationship, the number of cycle allowable to stress range.

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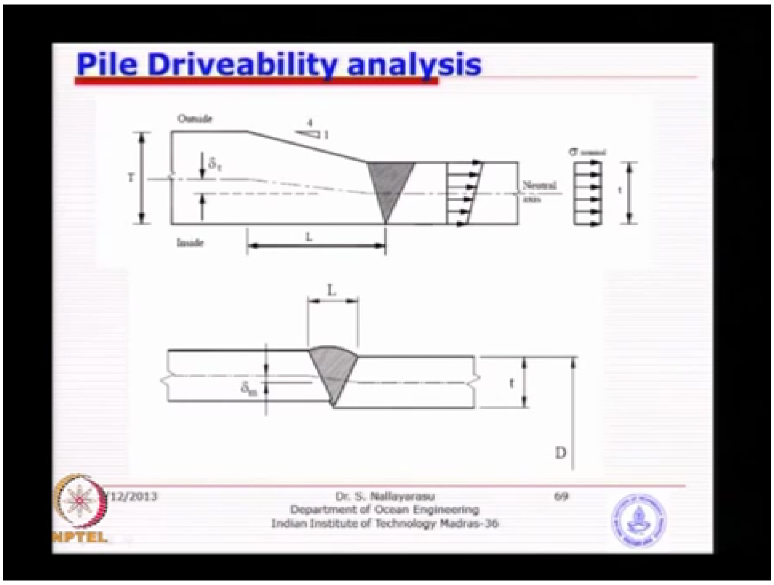

Typical detailing that we need to just look at what causes the failure, so if you look at this picture you have a thickness 1 on this side, probably smaller thickness and the bigger thickness and we wanted to keep one of the face as fresh that means the either the inside this particular case the picture shows the inside is made fresh that means the diameter is constant throughout and you have access to welding from only outside. When this will happen? This will happen only when the diameter is too small, unable to go inside and do the welding is not it, if the diameter is say 600, 700, is very difficult for anyone to go inside and weld so you will be doing only welding from outside that means single level direction.

And that means the penetration of the weld to the toe of this particular location maybe not possible to 100% confirm, so there is a chance that the fatigue crack actually may happen or start or initiate from this particular location because there is no possibility of inspection number one, there is no possibility of verification of weld penetration. So even though in this picture nicely shown like this, you may see that there is a discontinuity or maybe disjointed connection, a just small this joint existence will actually start the crack from there and as the propagation of number of cycles keep going you will see that the crack will propagate from toe of the weld towards the body of the weld, which is many times is a big worry.

And that is why for such types of connections you may have increased inaccessible inside and basically welding from one side, you will see that the stress concentration factor equation will be slightly different, so you will have to imply that means you cannot avoid but then you can take higher factor to account for such type of uncertainty. And also there is one potential problem which normally caused by misalignment is the building misalignment. You can see from this picture our intention was not to create this Delta m.

But effectively when you are trying to do welding when you place 2 types of same thickness in fact this particular case this picture is the thickness in this side and this side is same but still when placement you can see that there will be a inherent error in of course if you look at 2 hundred% tubular sections or circular section it may actually match. The problem arises because when you make a circular section, if it is a (())(14:23) by 1% and it may not match in location, it may match in some locations it may not match in some locations so that is the problem with the eccentricity so we need to look at what kind of eccentricity could be allowed and I think we discussed in the fabrication time classes that we can allow 2% of the time it will which is permissible by the course.

So we could see that what the 2% means, what is the realistic number that will come when you are allowing for such things. So when you allow for such thing, what happens is the stresses even though it is going to carry axial stress but because of the misalignment what will happen, there will be additional bending stresses caused by this eccentricity across the wall thickness so that is something we need to take into account.

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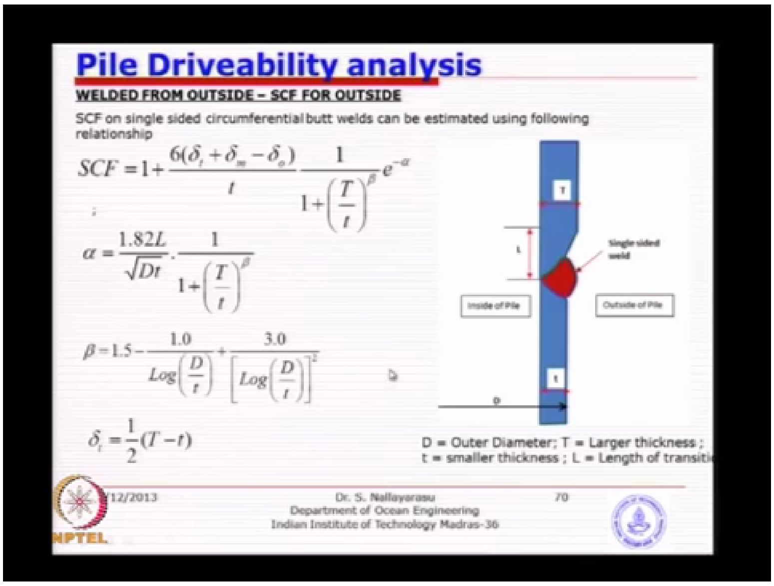

So there are 3 welding details I would just discuss in this particular class, basically here inside of the pile which is made (())(15:20) and outside of the pile having access from welding only from outside. So this actually normally not practiced for most of the outward conditions, this is only applicable for small diameter coastal areas where the piles are not driven through guides, it is simply driven through like in open condition so such types of cases but still not preferred to have outer diameter changing because of our friction problem. But in any case if you are having that situation, you can see here welding access from outside, sloping tapering only on the outside and the equation is given by DNVs having 3 components, minimum of 1 + mismatched effect which is basically the Delta m which we saw here something like this.

And then the difference in wall thickness which is causing the tapering Delta t and Delta 0 is the amount of misalignment which is already accounted in during the generation of S-N curve. Now remember S-N curve is not attained by theoretically means, S-N curve is obtained by carrying out experiments. So during the experiment itself some amount of misalignment has been considered which is in this particular case is 3mm which is already taken into account during the generation of S-N curve.

So in this here the Delta t is the half the difference between the bigger thickness to smaller thickness and Delta m is the misalignment which may be caused during fabrication minus Delta 0 which is already taken into account in the S-N curve so that is the second component multiplied by 6 + the slope effect, the more slope you make it better, is not it? Suppose if we make just no slope it is a abrupt change from small thickness to bigger thickness, the notch effect at this junction will be a cause of a bigger worry and that is the slope effect and the slope is defined with respect to the length, length is the tapering length, longer the tapering length, more work you need to do is not it, because you need to grind that plate particular plate thickness.

So to take into account that sloping effect we need to find out what is the difference in thicknesses and then Alpha values and Beta values depending on what is the length of taper. The length of taper is just obtained by 1 in 4, 1 in 2, 1 in 3, depending on, so if you have a 25mm and 50mm the difference is 25mm, you go for 1 in 4 the length will become 100mm, so you will have to grind 100mm by just making a taper which is a lot more hard work then simply going for 1 in 2, 1 in 2 is only 50mm. so basically this weld from outside or weld from inside this tapering is required just to manage the thicknesses of the smaller to bigger.

Similarly you will have... This is SCF for outside that means that stress concentration on the outside of the wall or the the non-uniform diameter area where the weld propile like this so there could be a stress concentration at this junction and there could be a stress concentration at this junction depending on the type of propile that you get. If you have a smoothened propile, SCF can go down as much as to 1 and that is why sometimes what we do is we do a propile policing so that the propile at that junction is become almost smooth. This is SCF for inside but still the situation is outside is welded, inside is no access and the stress concentration here is almost similar equation except that Delta 0 is not there, which is the misalignment case is only for where the thickness change is happening so misalignment is taken into account only here.

And here delta T minus Delta m so in here is delta T plus Delta m so that is the difference between stress concentration factor outside and stress concentration factor inside. The realistic case which we normally use is this type of connection where in we have outside is flash that means this wall the wall surface is constant; the diameter the outer diameter is kept constant for all the sections. Welding from outside, welding is not from inside but the tapering is done in inside and no access is provided for weld buttering or weld you know repair but this is not the case.

Most of the cases our diameter of piles are large so what happens is we do weld from outside but do an inspection and repair in case if the penetration has not happened so that is why most of the outer piles of stress concentration factor can substantially reduce because of that kind of access because if the diameter is 2 meter diameter is almost like height of this room, so you can go inside and just properly inspect and if there is a penetration sufficiently not enough you can actually do welding. So this equation is almost similar except that Delta m is not there and basically the reminder that the tapering effect is still there and calculate the stress concentration factor and minimum stress concentration factor at least 1.5 should be implied for such connections.

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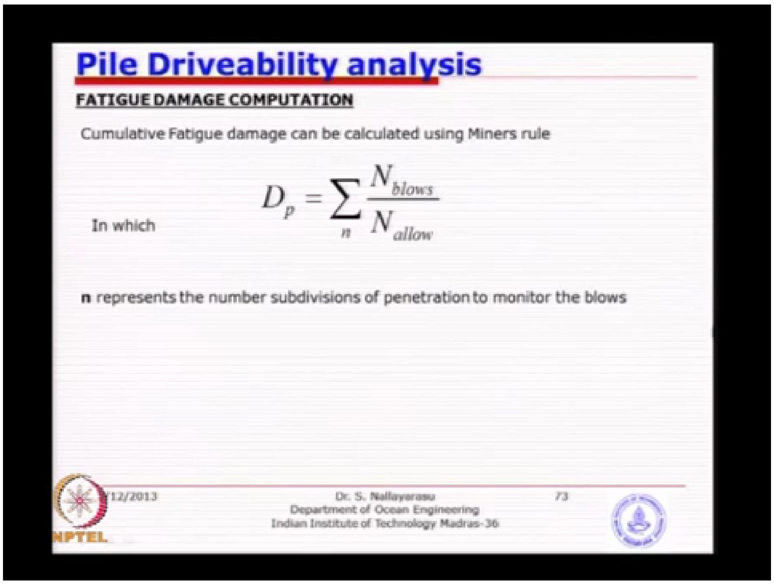

Typically one will not be acceptable, one will be acceptable only when you have same thickness and after welding you use smoothen the propile you know completely smoothen the propile so how do we calculate the fighting damage? Fatigue damage is so the allowable number of cycles to applied number of cycles the ratio so the number of blows is the applied number of cycles which is your counting. The only difference here every time when you blow a hammer onto a top of pile, the stress levels are not going to be same like similarly when we were looking at wave induced fatigue of different waves we group the waves in one particular group even if there is different waveguide but within the range of acceptance we count the number of cycles. It is not there every time wave is same waveguide and same wave period.

Similarly here, if you go back to the first picture every time when you blow, the stress levels are different for sure it is not going to be constant but then we need to look at grouping together so that the number of blows of each cycle or if you want to do it in very accurate term every blow is accounted for one cycle, you know basically and then you look at the stress some more number of groups will be there otherwise, if you just look at first 20 meters of driving how many number of blows and within the 20 meter of driving each blow what was a stress they can way the average, so take that stress will be represented by the number of blows that you have counted within the 20 meter of penetration.

Then you take the next 20 meter of penetration and look at the number of blows, take the number of average stress and go to the S-N curve and find the number of allowable cycles. So some kind of approximation has to be done unless you have sufficient time and effort to do each and every blow that you will account as per number of set of data. So what it indicates is damage is nothing but whether the well is going to be intact after the driving because our worry is something very similar to tubular connection because once install jacket, you drive the pile, the pile has broken because of higher fatigue damage but then when the in-service loads are coming in the pile will not be able to transmit. But the compressive load may be able to go little bit but when there is a tensile load what will happen?

The pile will not be able to take then there will be a failure of the pile. So that is why whenever you encounter very hot driving in sandy material, you may have to carry out many cases it may be governing the joint design. So this fatigue damage is nothing but is the fraction indicating nearly 1 means you have a problem of pile failure less than or for less than 1, smaller value indicates that the pile has a sufficient fatigue. So one of this idea is you can take this + add it to the in-service fatigue which you normally know about calculation. So fatigue damage I think we will stop with that, it is a representation of the hard driving, as soon as you have a hard driving you have a pile failure by fatigue.

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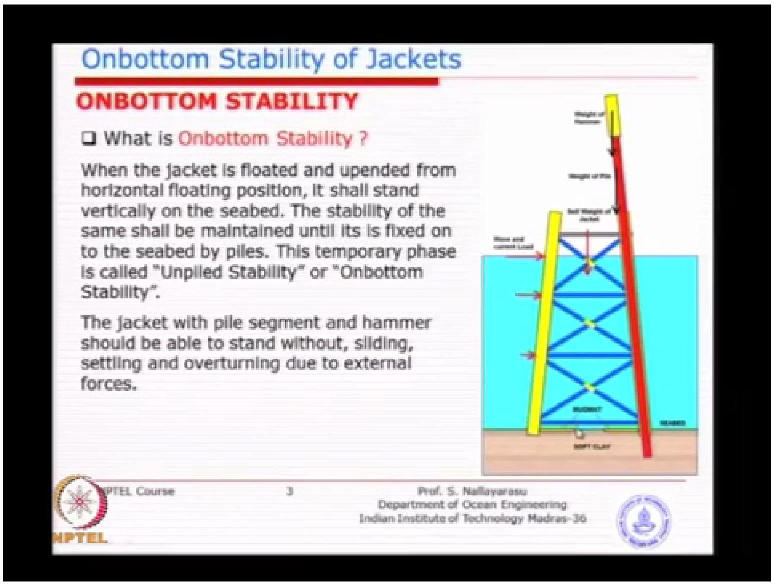

We will go onto a next topic of pile driving stability. I think last few classes we have understood how the pile is being driven into the ground but just prior to that what happens when we have jacket sitting on the seabed something like this and then the jacket is in stable condition because we have provided with some kind of temporary support, it is not that just jackets are placed on top of seabed with only 4 points supports you know like legs or touching the ground, but then the legs are hollow is not it? So you may not actually get the sufficient support area.

So what we normally do is we provide mat kind of foundation at each corner may be or full area depending on what is the design requirement so that when this particular frame is sitting on seabed, it may either fixed down because if it is not having sufficient foundation area, it may actually sink because there are 4 you know circular columns having only a smaller contact area and it is heavier, for sure it is going to be made heavier I think the other day we were talking about appending in jacket in water. You make it heavier than the jacket will sit on seabed, so when you are doing that this is definitely going to be weighing several hundred tonnes.

So when you have such a system sitting on seabed and not having enough bearing area it is going to sink so that is one of the biggest worry. The second worry is when you have this jacket subjected to vertical load due to gravity of its own weight + any flooded weight of water but also subjected to sufficiently larger enough and environmental loading from wave, current and wind and an biggest worry is toppling. Now if you have a larger horizontal port, what will happen is jacket may actually topple down. Once you have such a instability you must make sure that you do a simple stability calculation to make sure that in most possible environmental criteria that may be encountered during the installation time that the jacket will be able to stay upright without overturning.

And also we will be able to sustain the vertical forces, the combined nature of stresses due to gravity force and also due to the horizontal force, the soil is unable to deform that means it should have sufficient bearing pressure and smaller settlement. If these kind of checks are made and make sure that the jacket is safe then only you will be able to take your pile and place it onto the jacket otherwise you will not be able to once you place a jacket, once you place a pile on a jacket the jacket is going to sink further because remember we were talking about during pile driving we may actually place the weight of the pile on top of the jacket 4 of them, 2 of them, depending on what the idea of the contractor.

So the additional weight of pile also may come on top of the jacket which makes the foundation repair cost higher so that is why we have to look at this so-called on bottom stability is nothing but sometime we call it un-piled stability or party piled stability because we here in this picture, the pile has been already placed into the jacket partly into the mud partly hanging there and it may cause additional load due to its own weight or it may be due to wind loading because you sit there one of the picture I was showing you, from 50-60 meter pile is sticking up and if there is a gusting wind can cause substantial overturning.

So what we need to look at is the equilibrium of the system in 3 directions; both horizontal direction and vertical direction so some of the forces and the resistance offered by soil in vertical direction which is our bearing capacity problem which I think you already have derived (())(28:52) equation is and modifications to strip footing rectangular, circular, triangular so you can use that idea to find out what is the total load transferred from the jacket and pile to the seabed, what is the area provided and what is the capacity of the soil and look at the factor of safety. So a simple foundation design which is called you know the mat foundation design and providing sufficient area and at sufficient and right places.

It does not mean that you can provide a foundation here and then there is a smaller foundation here; we need to make sure that equilibrium is maintained. And then we have a horizontal stability because you have a total horizontal force arising from wave current and wind and the resistance between the soil and the structure is only a sliding stability so you need to find out whether we have sufficient resistance against sliding in terms of frictional resistance. So you know heavier the structure, is better for sliding stability I think you can easily understand, the frictional resistance is directly proportional to the weight of the structure itself and the coefficient of friction between the material of construction of this particular structure or the interface.

If it is a timber to clay or steel to clay the friction coefficient differs so we will just look at that. And then the last one is the overturning stability about the point of instability you know for example if the loads are coming in this direction on the space so you just take moment about appoint on the opposite phase see whether the equilibrium forces exist with a necessary petra safety, of course petra safety is not mandatory for overturning at least we will be able to maintain slightly higher restoring forces 10 percent, 15 percent, because codes are not asking for a mandatory Petra safety for overturning whereas, mandatory Petra of overturning for sliding forces is definitely 1.5 but overturning the course gives us the engineers decide whether 10% margin is okay.

Normally we use about 1.2, 1.1 but if you have a higher it is better, so basic idea of what is called Onbottom stability is the temporary stage where the jacket is placed on seabed, piles are being placed on top and then trying to achieve save during driving is an on bottom stability and we need to look at the sequence of things that may happen.

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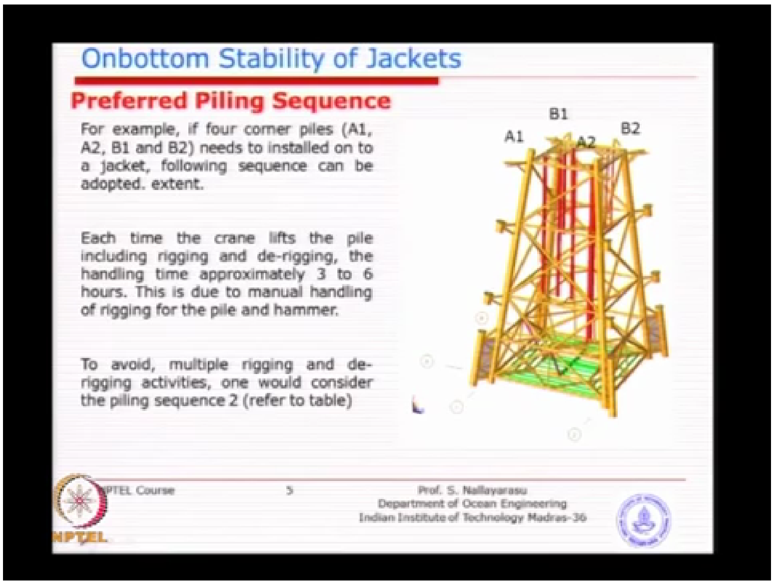

Look at this jacket picture what you can see here there are 4 Corners likes which is going to be main piles and there will also be for numbers of square piles. So you can see in this particular picture that once you do the piles to the main leg, the jacket becomes well secured, is not it? Because after that you are going to drive the skirt piles so you do not need to really worry about skirt piles because only you have done the main pile, jacket is already fixed to the ground then it is fully secured in the safe to do other pining operations. So the most critical one is the first 4 of them is the sequence.

For example, if the centre of gravity of the jacket is towards say corner A2 as we know the jackets are not going to be symmetric nicely built for some purpose so it is going to be centre of gravity depending on the structural configuration and arrangements and also the attachments for example, jacket may be symmetric but you can see several other attachments which may make the jacket and structure slightly eccentric. So if the centre of gravity is towards this leg that means the jacket will try to tilt towards that particular direction, is not it? So that means the the jacket actually try to do overturning about this particular range because there is already a turning moment due to its own weight itself so that is what we need to find out.

And if the loads are applied from this direction for example and it will add problem to us. Now we need to decide whether I will take the pile and put it on this corner or I will put the pile on opposite corner, is not it? So you can decide this piling sequence is something that we need to decide depending on what is more vulnerable, should we check the vulnerable case or should we check the safe case, we always decide to do a vulnerable case because if we have the option to put the pile here and you make sure that the system is safe then in offshore you can place the pile anywhere. But if you restrict them from putting the pile here and only on that particular location is allowed, but when you go offshore if that particular location is unable to do the piling then you have no other choice.

The reason being you go offshore, it may not necessary that this particular location you want the centre of gravity on this side it may not take this way because soil may be better at that location, soil may be weaker on the other direction so it may be tilting the... Or the seafloor slope itself will be sloping on the opposite direction because it is not going to be 100% perfect seabed, seabed at many locations you will see there some undulations, normally we do not do any surface preparations, just sometimes we do removal of debris you know if there is a big boulder lying on seabed but otherwise you do not do a levelling like what you do on onshore construction you know.

So in that case is you cannot have possibility of placing a pile on B1 though centre of gravity is on this side that means we have to possibly check the worst-case scenario then you go offshore than the contractors has the freedom to do piling at any location. So this piling sequence is nothing but trying to arrive at what will be the possible combination of piles that you want to place on top prior to starting to pile. I think I have already explained to you this idea behind why contractors want to place the piles on top before picking up the hammer and drive because each time it takes several hours to change.

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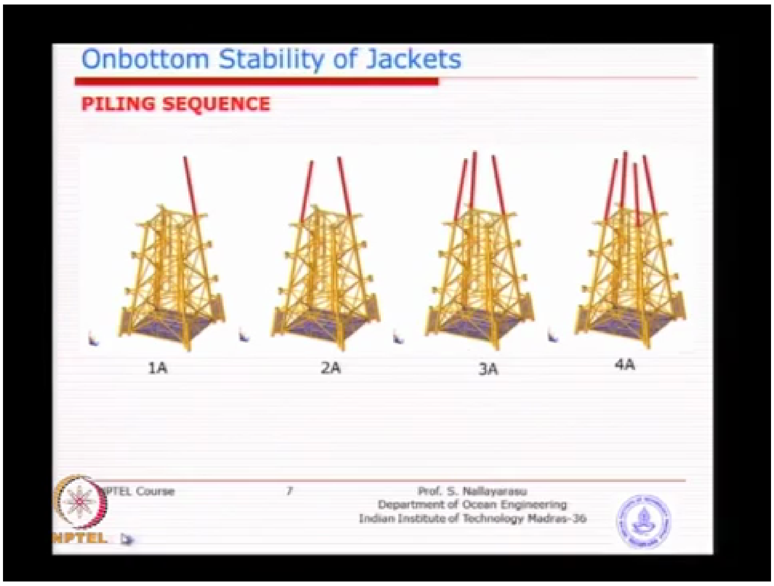

For example, if you go to this picture, if you look at this picture, the pile has been placed with a stopper and top of the jacket but has not been started to drive because in this particular case we wanted to place all 4 piles like this, I think I have shown you a photograph the other day and then you pick up the hammer that means every time when the crane changes from hammer to pile it is one activity. But suppose if you decide to drive here that means you will take the hammer, drive and go back, plays back the hammer, bring back the pile so every time it takes 6 to 8 hours to change so that is why this particular case they have decided to put all the 4 piles one sequence and take the hammer and go around drive by one by one, so in this manner they can save lot of offshore time.

So when you do this what really has happened here? The problem is all the pile bid has been taken by the jacket because it has not gone to the seabed yet, the length of the pile is such that it is only slightly shorter by so that it does not touch and there is a stopper here. So when you want to drive this pile, somebody will go down here and cut the stopper, allow the pile to go down and then hammer it and go to the next pile and next pile and next pile. So this the idea here is, all the weight of the pile is taken by the jacket that means the foundation Mat has to be designed for not only the weight of the jacket but also the weight of the pile that is being placed so this piling sequence will tell us the story that whether it is only so much weight or so much weight of the jacket plus and the weight of the pile.

Imagine in this particular case if you look at the case 1A, the jacket eccentricity is on this particular one corner and we have placed the pile on the other corner so you could see that centre of gravity is going to be shifting towards the right side of the jacket. You can you can design that I do not want to put the pile here, I want to put the pile on the opposite so that I can shift the (())(37:36) backward and it is exactly why you want to do this, what happens when you place there? So you will be doing exactly these 4 cases not starting from this location, I will start the piling from this location or placement of piles from that location case one particular case. I will start another series of calculation by placing the piles starting from here and go one by one.

So you will be doing 4 sets of calculations and you will evaluate the criticality and the risk involved, if they start piling from here what is the risk, if they start from piling, do we have the design case and whether the system is safe and if the system is not safe what needs to be done. So basically this investigation of piling sequence will be something that is elaborate exercise because but you will have all permutation and combination of systems and you can select this is the best possible configurations to go offshore with and start piling.

So the whole idea of the mud mat design and stability and verification of the system against the environmental load is also to decide what is the time that you can start doing piling over or what is the time you can place the jacket on the seabed because imagine if you have larger environmental loads, whatever the design that you are designing you can decide. For example, you can decide for 2 meter waveguide you go offshore, the wave guide of 3 meter, for sure you will not be able to take the jacket and place it on seabed because you know very well that jacket will not be able to stabilise and the system will be problematic.

So that is why you need to relate this calculation with respect to several number of waveguides so you will be doing calculation for 2 meter waveguide, 1 meter waveguide, 5 meter waveguide, and keep it as a design set then before you decide to go offshore you can select which waveguide then wait for the weather window in that particular day and only at that time you will be able to go and lift the jacket. So the on button stability is one of the critical design check for installation and many times you will see I will show you some videos probably in 2 tutorials that you will see that the jackets is disappearing just like this, in 2 seconds you will see jacket is not there because of instability problem or because of the placement incorrectly for example, one of the video you will see. You will see the piles are being placed but instantaneously jacket disappears into water.