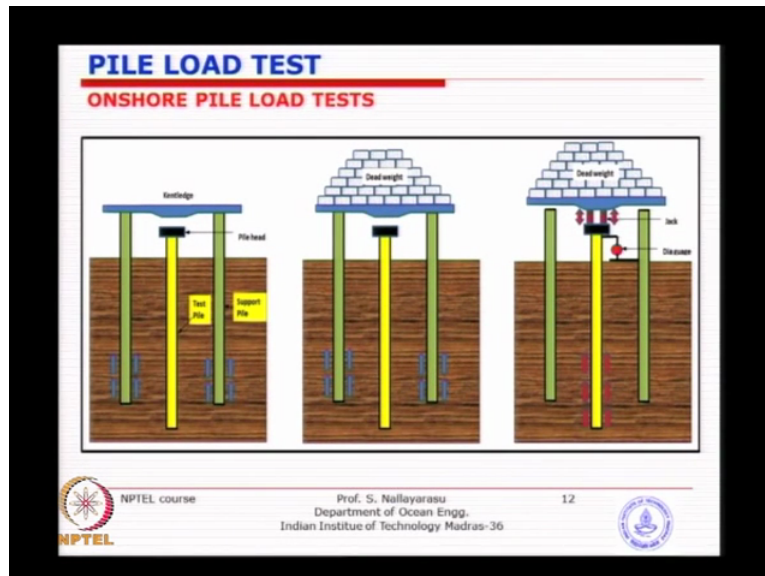


Foundation for Offshore Structures
Professor S. Nallayarasu
Department of Ocean Engineering
Indian Institute of Technology, Madras
Lecture-26
Pile Load Test II

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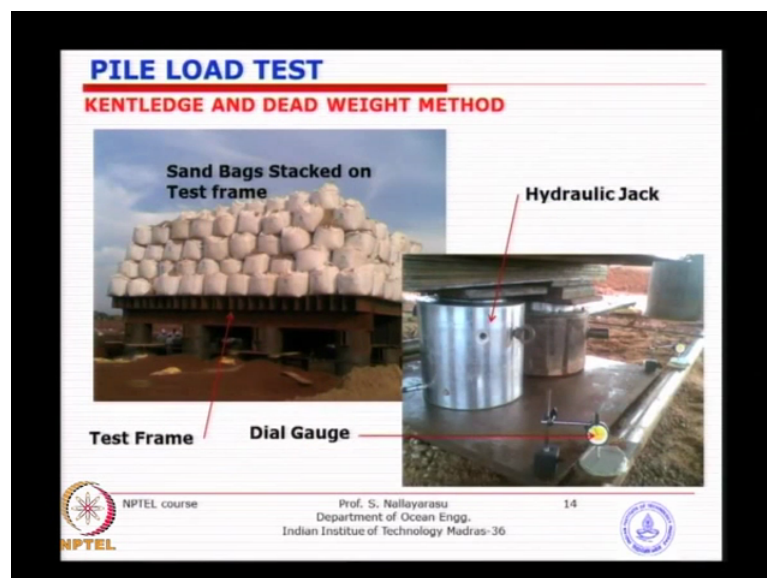
Let us continue with the pile testing, so by this I think you could understand the 3 concepts; concept 1 foundation by means of simple spread footing for the cantalage itself. And basically pile foundation where the ground condition does not permit Load distribution around the test pile, the primary concern is we should not put undue load to the pile soil interface which is being tested, so that is why we have to space it larger enough so that the pressure from the thus upload pile cantalage support pile does not affect or influence the result of the test pile itself that is one concern.

The 2nd concern you know when you are doing measurement of a displacement of the pile being tested, you need to have a firm ground or a darter line by which you will be able to measure the settlement. For example, in this case the ground condition is good and also you have accessible ground, so you just put the darter line which is not going to change over period of time during the testing. So if there is a uh easy way of putting a dial gauge with respect to the ground and then measure the movement of the pile. Now if you go to the offshore condition what happens if you have no firm condition or firm ground, you have to use only the pile which is supporting the cantalage but at the time of testing it is not loaded

anymore so you can use that as a reference and use a beam or some welded connection so that you can use the dial gauge.

So what we need is the firm place it is not moving during the testing so that is one of the 2nd concern. And then when you are doing the testing in any case it is not influencing the soil-pile interface or the capacity of the test pile which is being done the now-that is one of the idea so you need to keep it faraway 3 to 4 diameters so your cantalage anyway will require a larger space to stack up the waste and things like this. Very rarely in coastal areas we do this because it is very expensive, one of the tests could take months to set up and do it and bring back.

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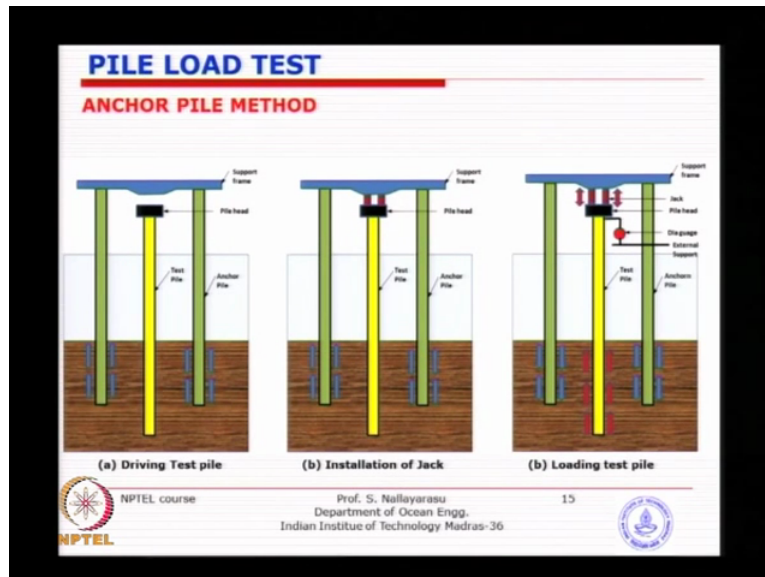


A typical cantalage test which is just on land, so you can see here even in this particular case it was done in one location in Kakinada where last year before, you can see piles were driven so this ground condition was so bad that even you cannot spread the load which coming from so much of sandbags, so we need to have piles going down to a firm ground because the total top 15 meter of soil is play soft clay and if you try to put some spread footing, it will definitely think under this kind of support reaction load during stacking and then you cannot retrieve and every time when you just load and unload, the foundation becomes no use.

So that is the picture that you are seeing, the pile is being tested which is at the middle and basically the pile will be provided with a pile cap steel plate and these are the jacks which are just placed between the cantalage and pile head just to stack of you know. And the dial gauge can see here is placed at this place and this is the reference to the pile head itself and this is

the bottom line which is not moving. So when the pile is moving up, the dial gauge will show the displacement every time when your how much pressure you are applying.

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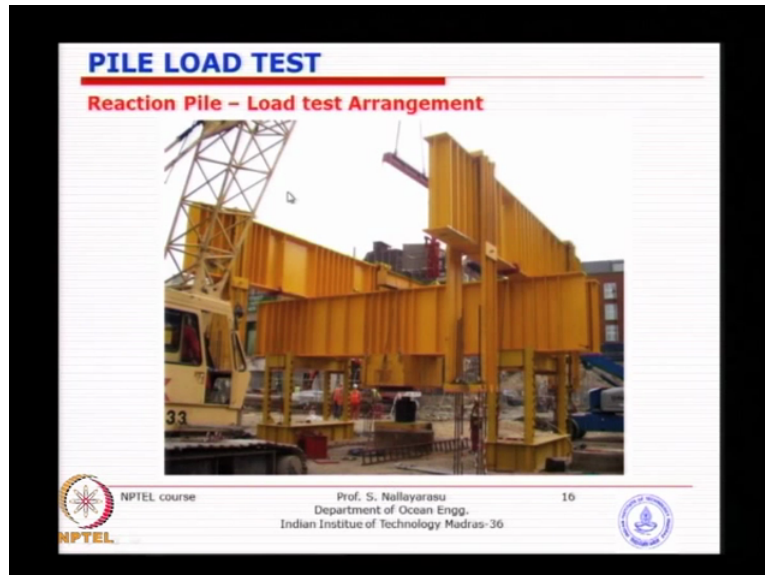


The alternate ways also because instead of instead of going for cantalage with self weight or deadweight, we can actually use this method by using the pile itself as a reaction frame. So you do need to stack up weights, only thing is the load is produced onto the test pile by means of the compression load because you are just holding this cantalage frame on the sides using the pile so this is being a welded connection. So always this anchor pile will be under tension, so you need to have sufficient capacity of the anchor pile so that so that means if you are testing a 3000 tonnes here, each one of them will have to be divided by 4 and recently have designed with the adequate penetration because it is only tension.

At least this pile have the N bearing, whereas the anchor pile will not have N bearing so you need to have sufficient penetration sometime it may become very large. And basically bigger than the test pile because you need bigger capacity in tension than the test pile is being a compression capacity so you have to be little bit... So that is where this method becomes little bit difficult because it might become very expensive and when you compare with this, maybe better because you do not need to mobilise so much of material movement every time because it is not one-time, you will see that later on the sandbags have gone back and forth several times because you have to do loading sequence and unloading sequence and you have to repeat the test at least 2 times and that is where you find this is a time-consuming process and also very expensive.

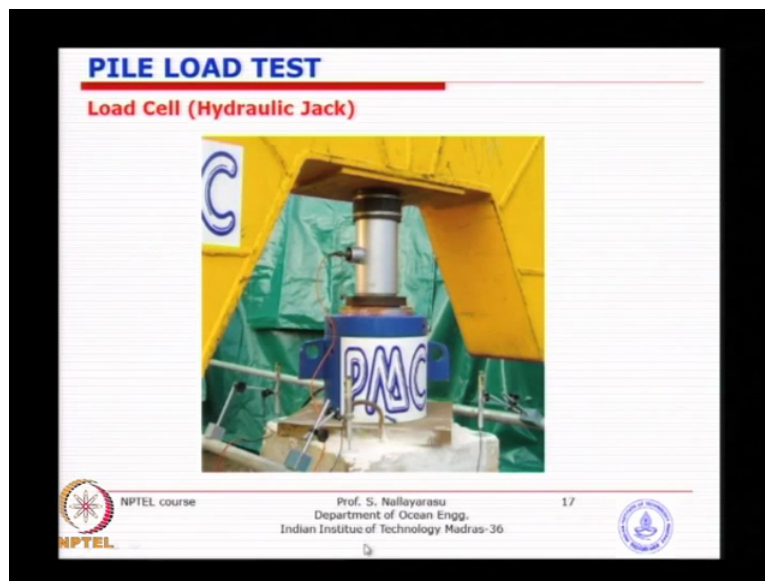
Anchor pile seems to be very good but then caution needs to be taken in terms of design, make sure that when the pile is being tested, this is the anchor that you have designed, it is not going to much otherwise you will be measuring actually relative movement of the pile anchor pile and the pile being tested.

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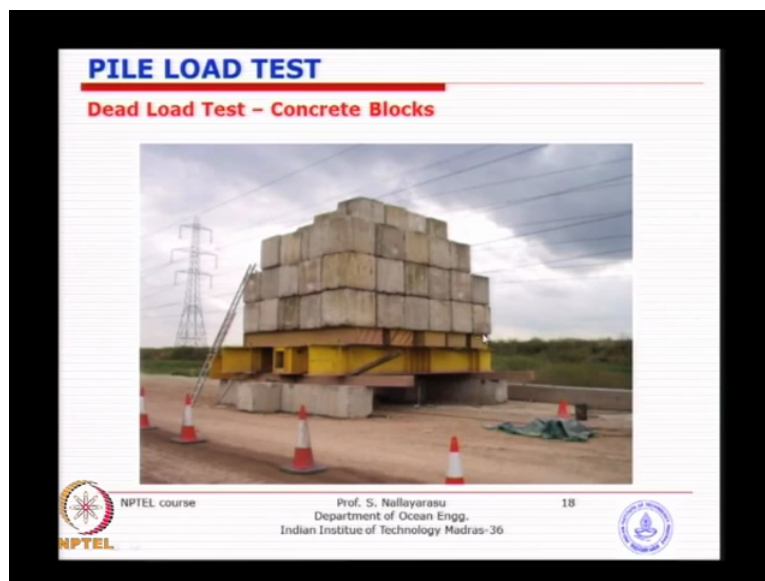
Typical reaction pile setup, so you can see here this is the pile being tested, pile requires to be tested otherwise you have the jack being placed at the and these are the pile heads, the left side and right side you see the pile heads which the piles are being driven with the pile head. And when you just push this hydraulic jack upwards, the reaction being applied to the test pile and these the reaction piles on the left side and right side should have sufficient capacity and basically that should be designed.

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And just a closer view of how the hydraulic jack is placed in the girder so that it reacts against the test pile as well as the reaction pile.

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Another load test using concrete blocks instead of sandbags, many times people use this because it is easy to handle and can be used in multiple places, only require storage. But in any case in construction sites you will find many of these concrete blocks spare capacities available there but many times people use these sandbags because easy to dispose because they can be used for construction work, no extra storage space is required and each one of them will be weight before placing it on the top so that you know the weight what it is, only

the stability of them sometimes bit of a worry because even a small eccentricity caused by either placement or by you know stability, the whole thing can be turned.

In many places if you notice pile load test failed because of the cantalage tilted or cantalage failed, which will cause quite a bit of problem. Whereas using concrete blocks is quite useful because it is very stable, sometimes these concrete blocks will come with a sheer case so you can have an opening at the bottom and you can when you place it, it will not go anywhere and horizontal stability is well-established. We can have precast blocks specially for testing not just for any other purpose.

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PILE LOAD TEST

ULTIMATE LOAD TEST

Ultimate load test are carried out on piles which does not form part of the permanent structure. Hence the load test shall be carried out on a sacrificial pile and can be tested to load beyond the working load.

The load can be increased to ultimate load to obtain the failure characteristics of the pile.

Generally, the factor safety for the design of pile varies between 2 to 3. Hence the ultimate load test can be carried out 3 times the working load.

ULTIMATE TEST LOAD = 3 * SAFE WORK LOAD

Ultimate load tests are done on one or two piles before the working piles installed. Based on the results of the ultimate load test, the pile design can be verified and modified.

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So the ultimate load test is basically done to the load, which is taken to the maximum failure capacity of the pile which will be 2 times or 3 times depending on what the factor of safety used in the particular project of particular core of design. It is most of the time for IS codes we design for factor of safety for 3 which is for concrete piles which actually says 2 to 3 but then mostly we use factor of safety of 3 that means you find out what is the load that is designed for working conditions, take it to factor of safety of 3 and then find out. So typically if you look at 300 tonnes is a working load, most of the 1 meter-1 and half meter diameter piles, then you multiply by 3 you will take to nearly thousand tonnes, so imagine thousand tonnes, what could be the requirement for dead weights.

Working load test is typically one and a half times safe working load, so we want to go for slight overloading but not to the ultimate stage. As long as you want to see passing of the working load and also have little bit of budget, get depends on how much design margin is

available at sometimes be reduced to 25 percent, we normally call it overload test. Even mechanical devices nowadays everyone of them, the working load test is not acceptable, you have to go for slightly overload because if the load exceeds the working load even by slight amount it should not fail so that is why overload test is about 25 to 50 percent.

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PILE LOAD TEST

CONSTANT RATE OF PENETRATION (CRP) TEST

Constant rate of penetration is useful for initial load tests and is carried out by adjusting the jack pressure such that the rate of penetration is constant throughout the loading.

This type of test is very fast and BS8004, indicates a rate of penetration of 0.75mm/min. is suitable for piles installed in clay type of soil and about 1.55mm/min for piles end bearing on granular soils.

MAINTAINED LOAD (ML) LOAD TEST

In this method the load is increased in steps from starting load as multiples of fixed amount until the final test load.

In each step, the load is maintained for certain duration to monitor the settlement until the no further increase is noticed. This ML method of testing piles is suitable for working piles. The load shall be maintained constant until the settlement rate is decreased to 0.25mm/hour and further decreasing before the next load step.

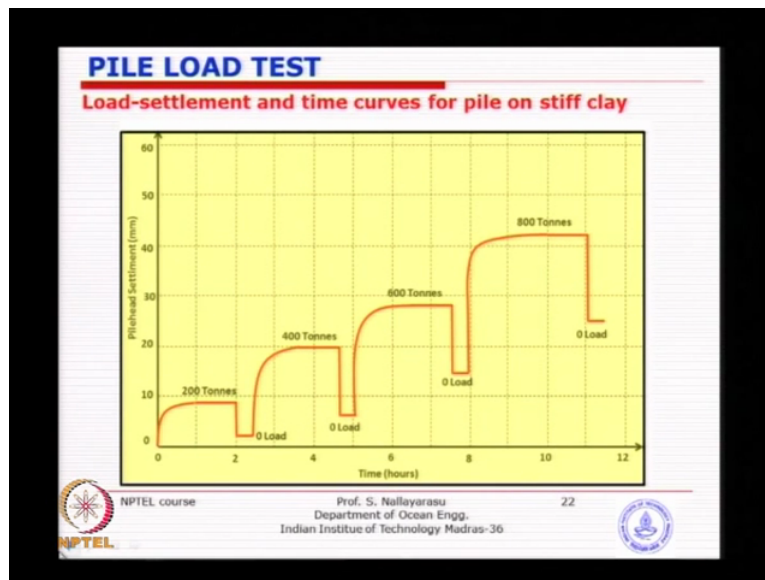
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So the 2 methods of testing that we were discussing the other day is constant rate of penetration or maintained load, constant rate of penetration is just you can see here 0.75mm per minute so it is a quite slow process and that eventually required by the British code, 800 is for design of foundations. And maintained load test typically used in most part of this construction site in India is very easy to carry out, you do need a sophisticated loop back system, simply put the weight and get, whereas the constant rate of penetration you need a good amount of instrumentation to read the penetration backward and adjust the pressure accordingly and it can only be done by hydraulic system, not by dead weight and cantalage method, it is just not feasible.

Whereas the maintained load test even in a very simple method which you need a deadweight and a jack. And the load shall be maintained constant until settlement rate is decreased to 0.25mm per hour, so what we normally do is use you set up your cantalage, put the weights, safer example 900 tonnes divided into say 5 steps or 6 steps, so the step 1 of the load and this activates hydraulic jack to transfer the load to the test pile relieving the Anchorage piles or support system and then monitor the displacement. Initially displacement of the pile may be larger, slowly reducing reducing indicating that the soil has achieved its failure state at that load and then it will go constant or may slightly increase in a very low implement.

So once you see that it becomes flat, the displacement graph is flat that means you are not expecting any more images settlements, you may actually expect long-term settlement which may be several years which is we are not interested in that. So basically then how do you decide when to stop the or when to restart the the unloading process because every time you are going to unload it, bring to 0 then stack up to the next increment. So 1st time say you arriving 200 tonnes and bring to 0 that means you have to take out the load and load it again to 400 tonnes so that process when you want to start, as soon as you see the displacement relationship is going flat that will be better but if the rate is still within this then you can go that means when the displacement is happening you cannot do unloading process.

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So maintained load test is quite simple, we will see the procedure later on, something like this, so you see here you put the 200 tonnes and then that the displacement is increasing. So what you will see is, when you are doing unloading process if there is elastic part it will come back. There is permanent deformation of the soil that will not come back, that will be residual so it will keep on stacking up so that is what we are interested in. Similarly we go to the 2nd step, so when the 200 ton weight is placed on the cantalage, when you relieved the hydraulic jack, the load will go back to the support stock then put another 200-300 tonnes on top of it.

It will become 400 ton, take the hydraulic jack and load it on to the pile and just repeat the procedure until you reach the total test load, it could be ultimate test load or it could be working test load. And every time you do this, you will see a loading-unloading curve you can see, so basically you will be taking this as a displacement, 9mm, 8.5mm for 200 tonnes so you can go and plot here load displacement in a different relationship. And typically we

will take several hours because get this flat curve sometimes you may have to wait longer time depending on type of soil, if it is a sandy material you will get the displacement quickly, after that it will just become flat.

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PILE LOAD TEST

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If it is a clay, it might take little bit longer time but then instead of setting this criteria IS codes actually gives the time to wait, wait for half an hour, wait for one hour depending depending on you know type of soil you may only vary little bit. So if you look at the procedure given in IS codes, it will give you the timing, every time step how much time you need to wait and then start the process of loading-unloading.

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PILE LOAD TEST

Loading and unloading cycle for pile load test

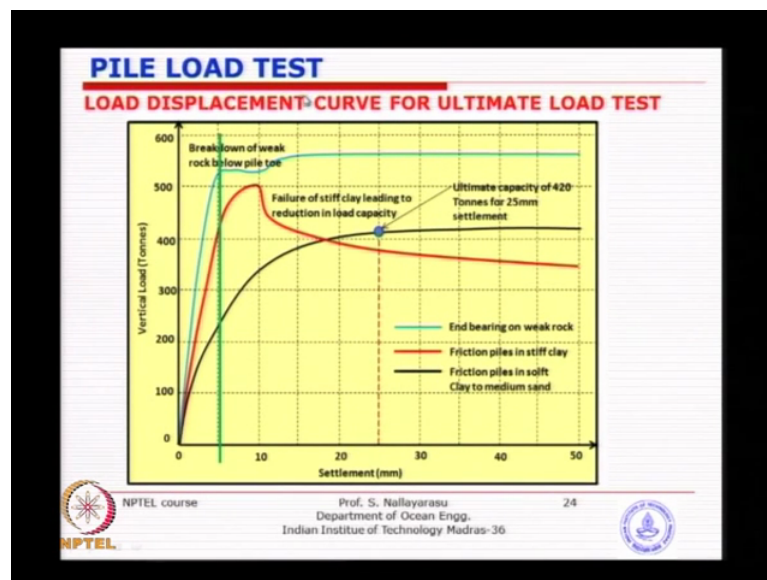
| Load | Minimum time of holding load |
|-----------------------|------------------------------|
| 25% of DVL | 30 minutes |
| 50% of DVL | 30 minutes |
| 75% of DVL | 30 minutes |
| 100% of DVL | 1 hour |
| 75% of DVL | 10 minutes |
| 50% of DVL | 10 minutes |
| 25% of DVL | 10 minutes |
| 0 | 1 hour |
| 100% of DVL | 6hour |
| 100% of DVL + 25% SWL | 1 hour |
| 100% of DVL + 50% SWL | 6 hour |
| 100% of DVL + 75% SWL | 10 minutes |
| 100%DVL | 10 minutes |
| 75%DVL | 10 minutes |
| 50%DVL | 10 minutes |
| 25%DVL | 10 minutes |
| 0 | 1 hour |

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In fact, this particular procedure is taken from pile testing manual which I was talking about day 1. So the design specifications load all it is basically the test load, if it is ultimate test design verification load will be your total load multiplied by the fact of safety, 25 percent, 50 percent, 75 percent, so this procedure is just segmented into 4 subdivisions. 30 minutes, so once you load 25% load, wait for 30 minutes, 30 minutes, 30 minutes and 100% load, wait for little longer time and then during the unloading process only because relieving of elastic compression will take just like this, it is not going to take time, so unloading time they are just allowing you to only little time 10 minutes.

And then again we start the process; 0, 100% and you are going to do a overloading test, there you are going to wait for little longer time beyond the design verification load if it is a working load test and then repeat the procedure. So basically this is just typical time versus increment of load I have just taken from the you know the manual of pile load testing from the Association of civil engineering contractors, everywhere they used this but if you look at the IS codes, they may actually gives slightly different numbers and different timings you know so depending on which jurisdiction you want to use.

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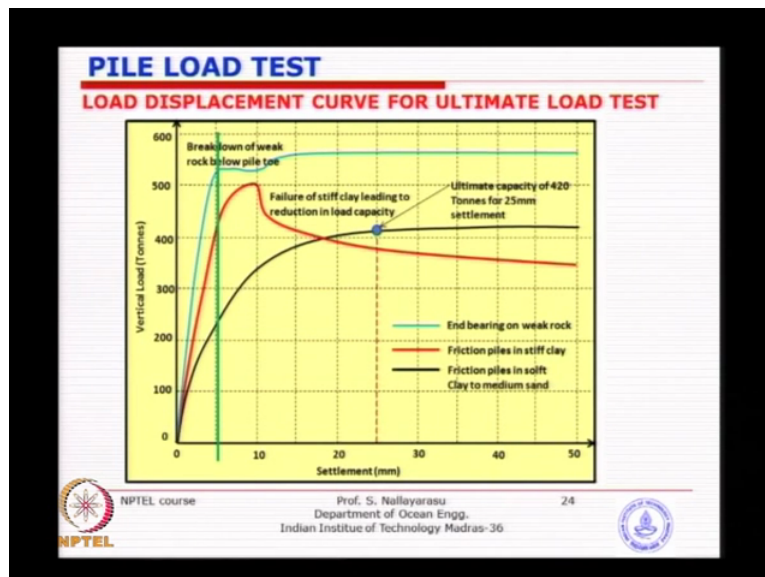


So if you look at this graph, load displacement curve for ultimate load test up to failure. So you can see, depending on type of foundation material you will see 3 types of so if you look at the blue one, N bearing and V crock, basically it increases and then suddenly fails. So you will see a you know certain capacity reaching, the rock is trying to fail, so almost like elastic and perfectly plastic so something similar like this. And if you look at the black one, friction

pile in soft clay or sand, you will see that highly nonlinear it keeps increasing and then the failure rate will be slow down achieving certain capacity.

Or else if you have a fiction pile in stiff clay also will be very similar but then there will be a downgrade effect because the stiff clay broke down when it is achieving the, so typically you will see something similar when you plot the when you extract the displacement from such such plots. Nowadays you can automate these kinds of things so automatically we will get a time bound graph then you can later take the displacement, come up with the displacement versus the applied load graph is something like this and basically you need to decide now what capacity is to be taken as ultimate or working load.

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So depending on what the allowable all ultimate reflection that you want to permit, remember when we were doing the TZ curve for clay and sand, we were talking about 0.1 inch for sand and then 1% for clay something like this. So that corresponds to the ultimate failure whether you want to consider here for steel piles has to be decided by what is your you know the ultimate failure to state you want to define. So once you define that limiting load or limiting displacement, then you can go onto the graph, you can take this is my ultimate failure load of the pile beyond which we will not be able to take it.

Saturday is the idea behind construction of this diagram is just to make sure that your TZ graph you have made is going to be reflected here. And if you get a representative from here and that will be realistic because this is based on test where as the other one is based on historical data and empirical methods. So you see here in this particular one, the ultimate

capacity at 25mm settlement is taken as 425 tonnes so though it is highly nonlinear, some amount of plastic deformation have happened compared to when you go to the blue, if you look at it this is completely elastic and after that only becomes the plateau so you can see the difference. So that is the way we want to determine when you do a testing, I want to determine what is the ultimate capacity.

The thing is you have to sum up what is the displacement at which you would like to take for example, when you are designing a structure you will always have a limiting deflection in both horizontal and vertical working load conditions. So then if allowable capacity you want to find from this then suppose your fix rate 10mm is the allowable displacement during service life of the structure then 10 you just go to 10mm, the pile has achieved a 350 tonnes. Now if you take the ultimate capacity, apply a factor of safety of 3 or 2, you will only get something like 120 tons so that is what will be revealed here.

If you do not know about this graph is going, what you are trying to do is if you take 420 tons join from here straight away to 0, make a straight line that is what you are doing by means of factor of safety, 420 divided by factor of safety of 3 on load. Whereas if you have this this graph, you know very well that you can allow maximum of 10mm during its service life with the factor or on factor load then you can decide how much margin you have, almost large margin is available. When you take 10mm and restrict to 10mm is the displacement, 420 divided by factor of safety of 3 you will get around 130 tons that is what you are going to permit.

But actually the pile has got deserved capacity up to 350 at the same 10mm displacement so that will be the difference when you have nonlinear load deflection curve, especially after testing. So this will give you a picture how much extra margin you have because of the soil behaviour and if you take this one you will not get anything better is not it? Because you are grabbing almost linear relationship, if you take that will be the capacity of say 550 tonnes divided by straight away factor of safety of 3 you will get somewhere around 180 tonnes. Whether it is 10mm or 5mm, you are going to just linearly prorate so does not matter.

So that is the idea of constructing or establishing load displacement characteristics up to failure, if we have only established up to for example, some lower displacement because you are not going to do a failure test, you are going to do a working load test just up to the linear portion then you may not actually reveal how the behaviour after this, this is why at least one

or 2 piles at the site you have to do up to failure to see how much margin you have. It can behave this way which we do not know unless you do the testing.

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PILE LOAD TEST

HORIZONTAL LOAD TEST

Horizontal load tests are carried out to determine the lateral load carrying capacity of marine piles. The horizontal load test requires good reaction system. Unlike land based structures, reaction system in marine structures will be another pile. Hence at least two piles shall be installed for testing one another of similar size and capacity.

Horizontal load test usually carried out using load step method similar to maintained load for vertical load tests.

CYCLIC LOAD TEST

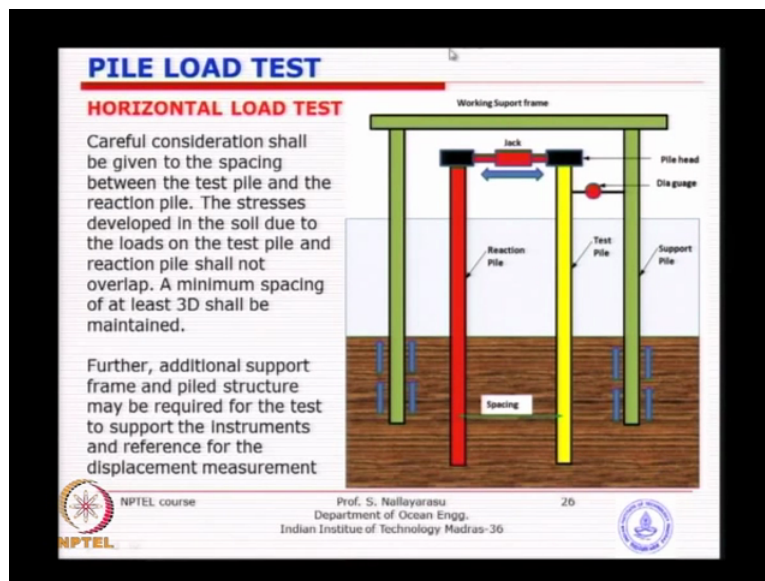
Cyclic load test is essential for determining the sensitivity of the pile-soil system against cyclic loads.

Loading and unloading process at each load step is repeated few times and the changes in the load deflection process is noted.

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Then we also move onto horizontal load test, basically similarly you can do horizontal load test. One of the biggest problems is doing reaction, she just now we have learned about vertical load test with support arrangement somehow we can make it because it is similar piles can be driven, but when you do horizontal load test you need to have some ground or firm support condition just to measure the horizontal displacement of the pile and also to transfer the reaction from the jacks, which is going to be a big challenge. So doing it onshore itself is a challenge, then when you are doing it in coastal or offshore conditions, it is even a challenge because you have to design a system stronger than the test pile itself and install it.

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And also you can carry out cycling load test in cases of coastal structures where cyclic behaviour is required for degradation effects. So typically you see here some working platform is required, and I would have just straightaway gone to the coastal areas where some of the berthing structures we still do this lateral load test to establish the capacity in horizontal direction but most of the structure on land normally we do not do you know horizontal load test not really required because predominantly it is not so much problem so far for buildings and bridges predominantly gravity load.

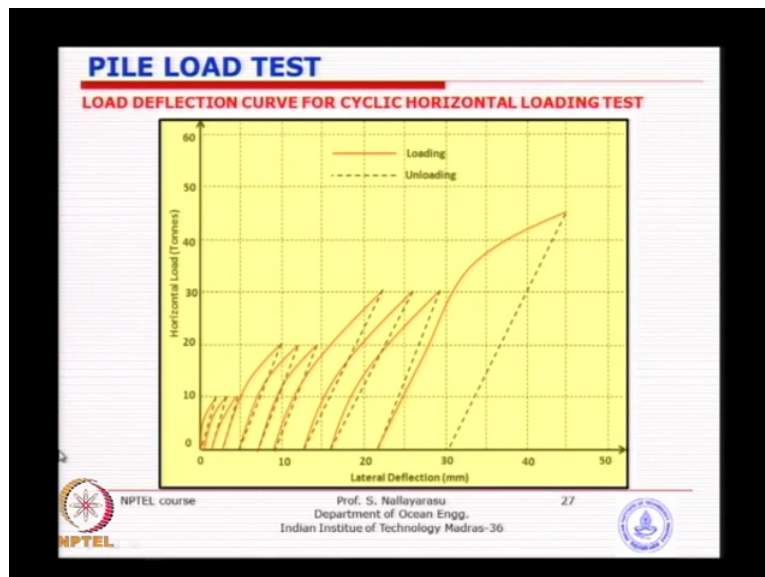
So you see here, we have a test pile which is in yellow colour and we have a reaction pile and just the jack. Now you see here, the jack is placed in between attached to both the pile heads and the jack is trying to expand by giving horizontal load through the test pile, the reaction is transferred to the reaction pile. Noise they reaction pile stable, the reaction pile displacement is smaller or ignorable then what you are measuring is the pile head displacement otherwise he will be measuring the, the relative displacement of because this pile is also moving, the other pile also moving and how much we have to find out. So you need a chilli credit system to find out what will be the displacement which will be quite tough because you can theoretically calculate but then it may not be correct.

A reference will be used, another few numbers of piles is required or system is required to support all this as well as access to these places so you will see that horizontal load test becomes reasonably expensive because you have reaction frame and you also have a reference frame, the reference frame the green colour what you see is a reference frame

against which you will do the measurement of displacements. And they are need to be placed sufficiently you know wider spacing otherwise what happens when you are doing when you are doing reaction here, when the pile is trying to bend it puts undue pressure on the soil and that soil gets affected by this particular location and behaviour of the lateral capacity is going to be affected to some extent and that is why you have to have minimum of 3 diameter or for diameter or 5 diameter.

Once it become wider spacing, mounting of the jack becomes a problem, you need to design a frame and that is going to put you onto support system together it has to be mounted onto the 2 piles which needs to be free to move so that is one of the challenge.

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A typical cyclic load test results or plot how you carry out loading and unloading process, basically horizontal load versus lateral load displacement. You take it one cycle at particular load level, bring it to 0, repeat it few times just to get the repeatability and again increase the higher load, repeat it again, load and unload, since there is no dead weights are involved, it is only hydraulic jack, doing such load test is very easy then you repeat it again and again for various loads and stop when you actually reach the expected displacement for example, ultimate load test you are trying to do for 100mm maximum.

If you are doing a ultimate horizontal failure load test then you can go up to failure of the pile and stop, otherwise you have a predetermined load by which it will not be a larger capacity, most of the pile if you look at 50 tonnes or maybe maximum 70-80 tons unlike the vertical capacity where you have thousands of tons or sometimes very large number. Here it all be

you know restricted by the pile horizontal shear because if the soil does not fail what will happen, the pile will fail. So if you look at the Shell capacity of the pile that will give you the maximum magnitude by which you can test, in fact will apply factor of safety on it. What you do not want, you do not want the system to fail before the soil fails, system means the pile itself or the anchor pile itself.

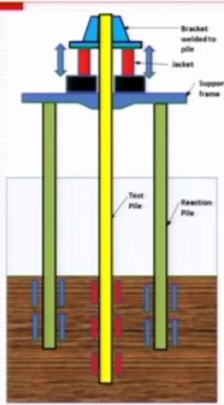
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PILE LOAD TEST

PULLOUT TEST (TENSION)

Careful consideration shall be given to the spacing between the test pile and the reaction pile. The stresses developed in the soil due to the loads on the test pile and reaction pile shall not overlap. A minimum spacing of at least $3D$ shall be maintained.



Further, additional support frame and piled structure may be required for the test to support the instruments and reference for the displacement measurement



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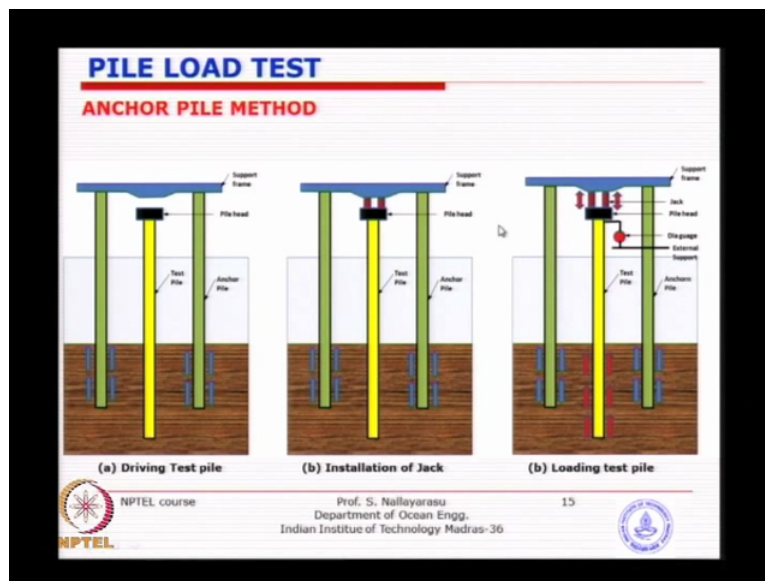
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So you will find out what is the bending capacity of the pile or structural capacity and shear capacity. Make sure that you have got sufficient factor of safety available on the structural system prior to go to ultimate load test because you do not want the system to fail when there will be a catastrophe. And in some cases in the coastal structures like berthing structures we may require pullout test because some of the piles are actually going to have tension capacity requirement, especially when you build a berthing structure the front pile will be in tension, the back pile will be in compression when you are having shift or berthing against the berthing structure.

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So such you may require a pullout test instead of a compression test, it is exactly opposite of it only the cantalage placement and the hydraulic jack placement is in the reverse condition. If we just go back to our the this test somewhere here I think something like this, so this this one is anchor pile method you are doing a compression test, just reverse the process and placement of the hydraulic jack you will get the... So basically the cantalage arrangement is attached to the reaction pile and there will be stress blocks and you have hydraulic jacks and then you attach your brackets welded to the test pile itself.

So what you are trying to do is you are compressing the reaction pile and pulling up the test pile, so basically you are just reversing the reaction just to get what tension capacity is available. Many times you will require this for coastal structures but magnitude will be not very big, few hundred tons.

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PILE LOAD TEST

COMPRESSION LOAD TEST - POINT TO NOTE

Following points shall be noted and treated carefully while carrying out the compression load tests for offshore or coastal applications

- The support frame shall be designed appropriately for environmental loads from wave and current
- Support piles shall be spaced away from the test piles by at least 3 Diameter
- Structural capacity of the test pile (Cantilever) shall be checked for the test load using Euler buckling criteria.

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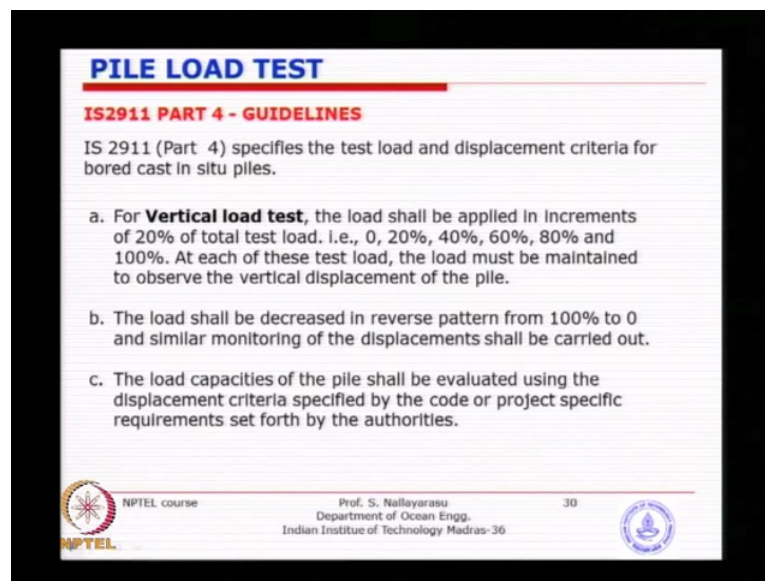
So what are the things that we need to note down when you are doing a compression load test, the support frame needs to be designed appropriately because you have such a large weight to be placed. Support piles need to be placed away by 3 diameters that makes the, so if you have 2 meter diameter pile you need to go for either side 3 meters, 3 times 2 meters, 6 meters so the frame becomes 12 by 12 or 15 by 15. Structural capacities of test pile as well as the support piles need to be made sure that it has good adequate capacity. Special care must be given to the test pile because it is a cantilever, whereas actually the same pile when it is working in the actual structural system it may not be a cantilever, it may be combined pile heads with the other structures.

Whereas when you are doing testing, it is a pure cantilever, you must remember what is the difference between pile in a temporary condition which is a cantilever to a supported pile in the permanent condition because of high level buckling. The load capacity will come down drastically so you cannot think about always you have pile 1 meter diameter in a permanent system which is connected to a bigger structure which may not behave as a pure cantilever, so the effective length and the boundary conditions are different, you are 1 meter diameter pile may work there, whereas the same 1 meter diameter pile when you bring to the test category, it becomes a pure cantilever number 1, high-level buckling load will be definitely half or less than the actual buckling capacity.

When you are doing the same ultimate load test here, you do not want the pile to fail. So what we really need to do is, keep the diameter same because you need you do not want to change

the pile-soil interface is not it? Because we want to test the 1 meter diameter but what you can do is you can increase the wall thickness to increase the bending stiffness, buckling capacity, shear capacity in such a way that structure does not fail but the soil pile interface is being tested. You understand the idea know, so you need to make sure this otherwise if you bring the same pile and testing before the soil fails the pile collapses and then it puts the whole system into problem that is what you have to make sure.

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PILE LOAD TEST

IS 2911 PART 4 - GUIDELINES

IS 2911 (Part 4) specifies the test load and displacement criteria for bored cast in situ piles.

- For **Vertical load test**, the load shall be applied in increments of 20% of total test load. i.e., 0, 20%, 40%, 60%, 80% and 100%. At each of these test load, the load must be maintained to observe the vertical displacement of the pile.
- The load shall be decreased in reverse pattern from 100% to 0 and similar monitoring of the displacements shall be carried out.
- The load capacities of the pile shall be evaluated using the displacement criteria specified by the code or project specific requirements set forth by the authorities.

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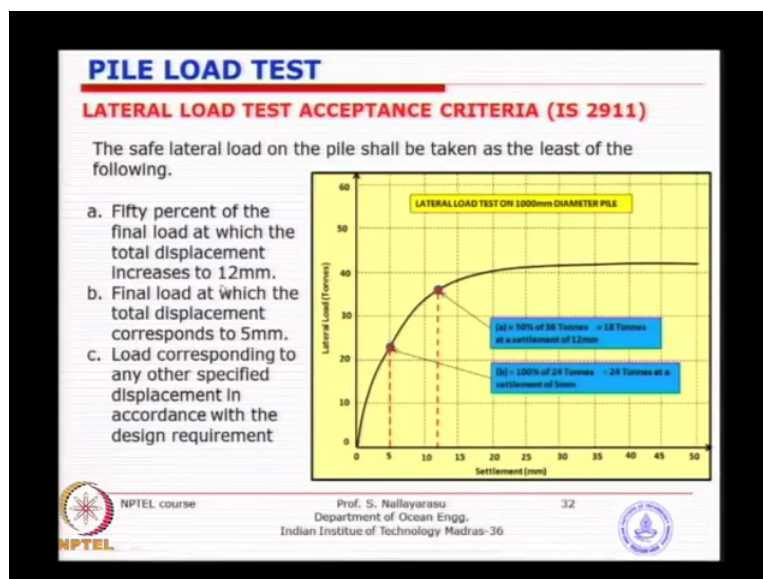
So what IS codes are suggesting instead of what we saw was 25, 50, 75, they have divided into 5 sub-segments of loading 20, 40, 60, 80 to 100 so it is just a little difference. And basically loading-unloading cycles almost similar, I am not very sure whether I have copied the time cycle. You can look at the code, the time is also given 30 minutes up to 6 hours so you can refer to the code, but what the criteria I wanted to look at it is basically when do we decide it has achieved its ultimate capacity and it is applicable only for concrete piles, you cannot apply this one to steel tubular piles it is not under that particular code.

So if you look at this graph, I have just plotted one of the recent last year test, two thirds of final load at which the total displacement attains value of 12mm. So you just look at the graph and just go around, apply the criterion number 1 the safe load on a single pile for initial test should be least of the following, so the criteria is given. Do the testing, comeback here, plot the graph and look at these criteria whichever is lower that is your safe working load, so that is the criteria that you are going to apply.

And of course this is written on the basis of onshore structures, you know 2911 is a code for both the concrete piles for onshore applications, not even for coastal applications that is why you cannot blindly apply this principle to a coastal structure on or offshore structure where displacement get area are different from dawn show structures. You will see that they are very strict in terms of displacement because these are applicable to buildings and bridges or to some extent industrial structures on land where they are controlled by deflection.

Whereas if you go to coastal structures and offshore structures, the displacement are definitely going to be larger, you cannot even think of the criteria here because here they are talking about 25mm. When you think about coastal or offshore structure, you are going to have several hundred millimetres of displacement because of the the magnitude of horizontal load, you have to be a bit cautious and apply the principle differently. 50% of final load at which the total displacement equal to 10% of the pile diameter, so these are the 2 criteria, so if you see there the criteria 1 and criteria 2 you can find out whichever is giving you the capacity.

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I think even the lateral load also similar crater is given; 50% of the final load at which the total displacement increases to 12mm, final load at which the total displacement corresponds to 5mm and then any load corresponds to any specified displacement, this is some at least some option is given for horizontal load, so according to your project specific requirement so you specify I can go out to 50mm then I can look at, so that if that is the thing that we need to have a decision-making process, just doing load test alone will not be good enough, you do

not know what to do with that, what you need is the demarcation what will be the acceptable displacement for that particular type of structure and applicable code in force.

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PILE LOAD TEST

API RP 2A - GUIDELINES

API RP 2A does not give any guidance on load – displacement criteria since the design pile capacity is purely based on "**ENGINEERING BASED METHOD**" and no verification of pile capacity is required. However, following guidelines shall be used to assess the as installed pile capacity

- The piles shall be driven to **TARGET** penetration as designed using engineered properties of soil. This can be achieved by appropriate selection of driving equipment and pile wall thickness.
- Pile design shall satisfy the minimum Factor of Safety against the operational and storm loads (2.0 and 1.5 respectively).
- Piles shall have adequate stiffness against large bending moment due to lateral displacement
- If required, due to premature refusal, the blow count data can be used to back calculate the long term capacity of piles subject to careful consideration of soil characteristics.

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What the API says we do not have a procedure to restrict the displacement, unfortunately there is no requirement because we do not need because offshore structures are subjected to so much higher loading that if you restrict 25mm displacement for example, your structure will be so much bigger and may not be practical so that is why the the adapted method by API is to design by the factor of safety which gives you an adequate safety against pile failure or premature failure and at the same time you have a ductile material which is steel and you are not worried about failure by other means of fracture because the worry in concrete structure is larger displacement either in vertical direction or in horizontal direction can cause superstructure failure by fracture because the concrete cannot fail by the tail.

So that is one of the reasons why most of these concrete cores they restrict the displacement to smaller where as the offshore structures we never build using it except the concrete gravity platforms, all the fixture types of structures are built by steel material has higher tensile capacity and also have a ductile characteristics. In that reason we go by the method of engineering-based design based on soil properties with adequate factor of safety and we leave that, we do not want to apply the restricting displacement. The reason why we developed TZ all that is to make sure that pile is actually subjected to the actual load displacement behaviour and the bending stresses are calculated.

So if we have a larger displacement, what happens is the pile is subjected to larger bending and larger bending means the requirement of section and the diameter and the thicknesses are going to increase so you design for it rather than trying to limit the displacement of the pile to lower value and increase the larger diameter, so that is exactly the the design method adapted by API, so so far I do not think any problem with that idea.

One of the issues with concrete pile supporting concrete structure is the architecture and finishers and serviceability requirement that is why it restricts the displacement to a very small value, in fact the reason why we restrict to 1 inch is because of that. You know if you have the structural system capable of taking the architectural finishes and service functions will be seriously disturbed that is why buildings are designed for smaller displacement.