Foundation for Offshore Structures
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Lecture-23
On bottom Stability of Jackets I

So the last session we had on the pile drivability was segmentation and sequence of placing. This subject is very much related to stability of the system where in after the placing of pile is over how the jacket is going to stay on the seafloor without instability so that is what we are going to investigate. Of course this is related to the bearing capacity which is we have learned several classes before especially for spread footing, circular or rectangular in shape triangle in shape. So it will be similar, only thing is added stability check needs to be taken up so that the system as a whole will be able to stand by during the pile driving.

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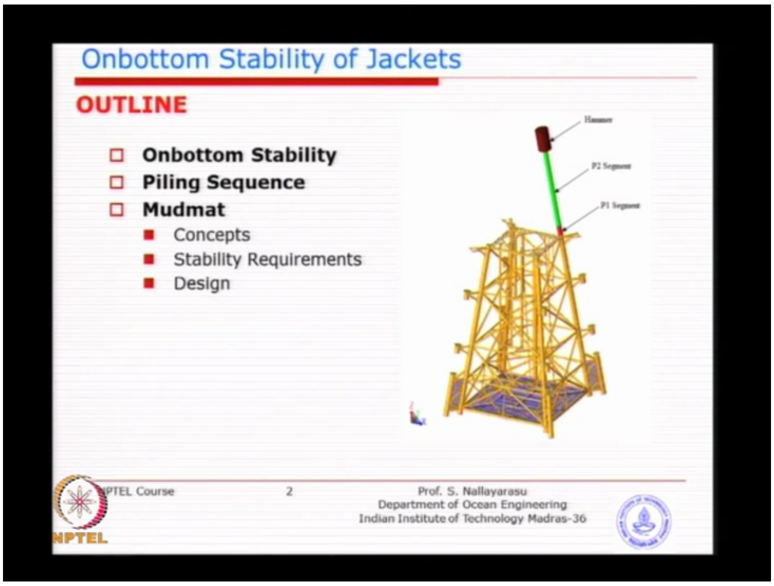

So if you look at this picture on the right-hand side you can see the jacket is treated as a rigid body, you just forget about the structural strength of it just at this instant of time because that we can investigate separately. As a foundation design requirement when you are trying to drive the pile as you can see from this picture to insert the pile into the jacket leg or sleeve and then placement of hammer involves a temporary stage where the the system stability can be affected depending on where you are placing the pile.

So if we can see here this pile plus the hammer adds additional weight to the system that means it needs to be transferred to the ground by means of a simple bearing which I think you can calculate the applied bearing stress due to weight and the allowable bearing stress due to soil strength and you can compare whether the system is able to take the load or is going to have undue displacement in vertical direction which is what is supposed to be prevented. You know if the jacket is settling 2 meter into the ground you lose so much of steel into the ground number 1 and also the height of the structure which you had planned earlier has been reduced which is not correct.

So that is the idea of providing sufficient foundation area, the larger the area you could get better bearing capacity. So this particular exercise of trying to evaluate the foundation requirement for a temporary support of a jacket is called on bottom stability. So if you look at the whole picture, it is not only the bearing capacity but also the stability in terms of sliding which is also as important as the bearing. So you can see here sliding stability arising from horizontal load induced from and environmental conditions, vertical loads arising from the weight of the structure plus the weight of the pile and the hammer that you are trying to place which is a vertical equilibrium.

So the combined effect of vertical loading due to gravity effect and horizontal loading from environment conditions could also pose a potential threat to a rotational equilibrium which is basically overturning, which is also needs to be investigated so that the jacket is in stable condition. So this on bottom stability is highly related to these 3 conditions and basically it depends on where you are placing the pile and the hammer, I am sure you are not going to have 4 hammers you may have only one hammer or maybe one substitute hammer in case the hammer is failed. So for sure the hammer has to be placed in one location not all 4 locations that you must understand nobody is going to have symmetrical situation.

But the pile segments can be placed one by one or some stage you can actually have 4 of them together which you will see later on. So the sequence needs to be arrived based on the conditions of requirement, the contractor wants to do this way and also the acceptable tea of the system stability and bearing capacity. You can place all 4 of them but the system is unable to take, the foundation requirements become too large for example, I want to put all the 4 points together the foundation requirement may be very big, bigger than the jacket. Normally nobody prefers to have a foundation bigger than the base width of the jacket because it becomes a problem of fabrication and transportation.

Imagine I think we were talking about transportation, if the foundation is double the size of the jacket base so what will happen, how you actually transport, how you actually place it on the barge. You will have a serious problem in that situation so that is why foundation must be within the peripheral boundary of your jacket or maximum you can go up to the skirts leave which is another few meters you can get but do not want to protrude out certain geometric so basic design requirement for on bottom stability is to determine the suitable foundation area between the practical situation and then to limit on a reverse way. If we cannot provide foundation of requirement for the piling sequence somebody have told you then you would restrict what piling sequence you can actually allow them to do based on your calculation so vice versa you have to look at either way.

So on bottom stability is an important exercise of making sure that there are offshore piling system will work so that is why it should be part of the pile driving analysis so that you can decide because after all for example the first segment of the pile is going to be placed on the jacket. After the pile is driven into the ground you may not need to really worry because already the pile weight is transferred to the soil. For the first time when you are actually placing segment 1 here on all 4 corners that is the time the weight of the pile is taken by the jacket. After you allow the pile to penetrate the soil and there is nothing great worry there because the soil is already taking the weight of the pile.

So this intermediate situation will determine what will be the sequence of piling so this on bottom stability is related to pile driving because the first segment length will be governed by the foundation requirement rather than structural requirement of a pile length or pile driving sequence, so we will just quickly go through various activities involved.

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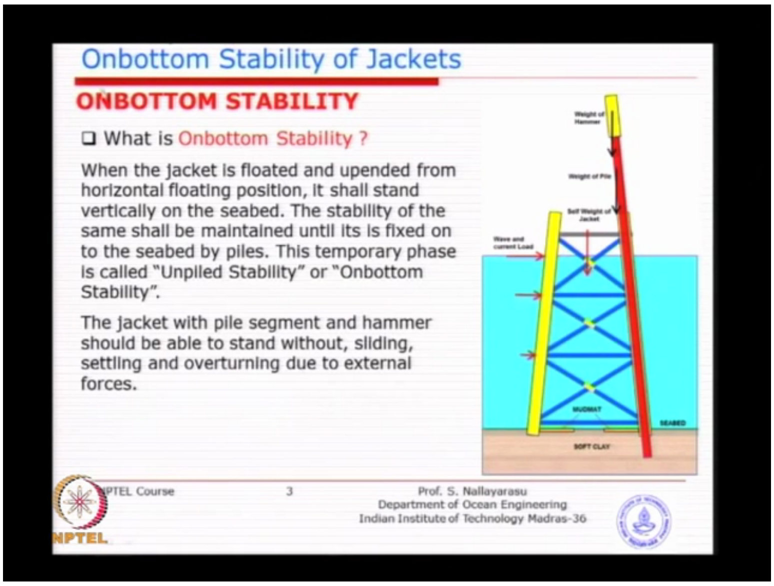

So on bottom stability is verification of system stability during placement of initial segment of the pile before the pile is being driven into soil. So once the pile is partly or fully driven into the ground, most of the pile weight will go into the ground except there is a overturning moment applied at the top because the leading effect of pile will also come into picture for example, you have annulus gap of 38mm as the pile goes through the leg you supposed to have a equal annulus space everywhere along the length of the light but you may not have because the pile will try to bend towards the top corner by providing support at the top. What will happen? There could be potential low transfer of some amount of weight with an equal and bending moment from the seabed level.

So the distance from here to here could be half of the weight can go down to the ground, half of the weight can be transferred to the top of the jacket, which can cause a little bit overturning moment, other than that primary load weight load of this pile itself has gone to the ground so partly piled versus unpiled mostly unpiled stability will become a problem because at that time the whole pile will be hanging on to the jacket with the stoppers on top. So this on bottom stability at that stage could be potentially critical but in some cases the partly piled stability that means pile has already penetrated in the ground but some of the moment is still coming to the top of the jacket, sometimes it may govern.

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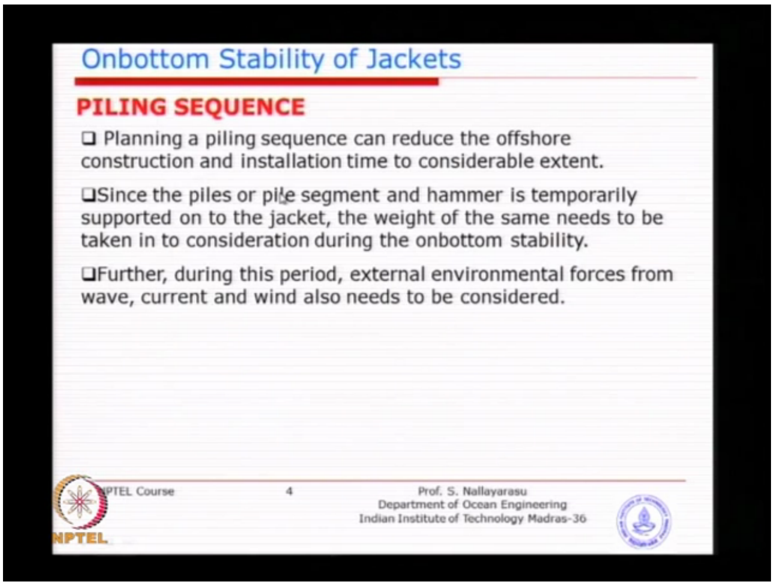

So this piling sequence is something that we need to arrive based on the COG of the jacket, sometimes some of the jacket's COG is towards one side, in such a case you better avoid going and placing a pile on that particular location. So planning a piling sequence actually can reduce the offshore time and also can save the jacket because if you place the jacket you know the pile on a wrong location can lose the jacket instantaneously.

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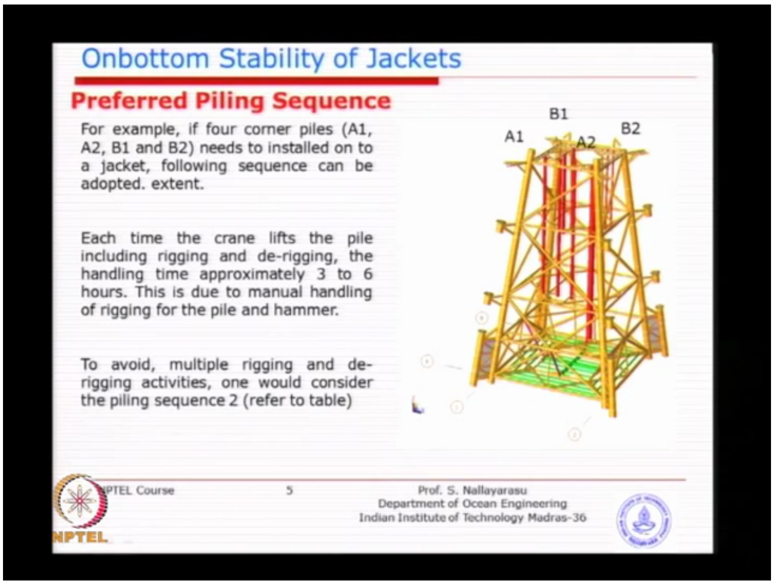

So typically if you look at 4 legged jacket with 8 number of piles, in this particular case you see here 4 main piles which are going to be driven through these legs which are longer, where as if you look at the skirt is only a little bit of length probably 10 meters to 15 meters but then the pile has to be inserted from the top all the way down to the bottom, so these 4 main piles plus 4 square piles, the configuration why it was worked out is typically based on the pile data plus the loading arrangement. Now the first thing what we want to do is, we want to drive the main piles so that the jacket can be secured to the seabed after that you can drive the reminder of the 4 number of skirt piles.

So the unpiled stability or so-called the temporary stability is only just prior to piling the main piles, after you do the piling of main piles the jacket is well secured to the ground then during the driving of these piles you really do need to worry about any load transfer from pile to jacket, jacket to seabed.

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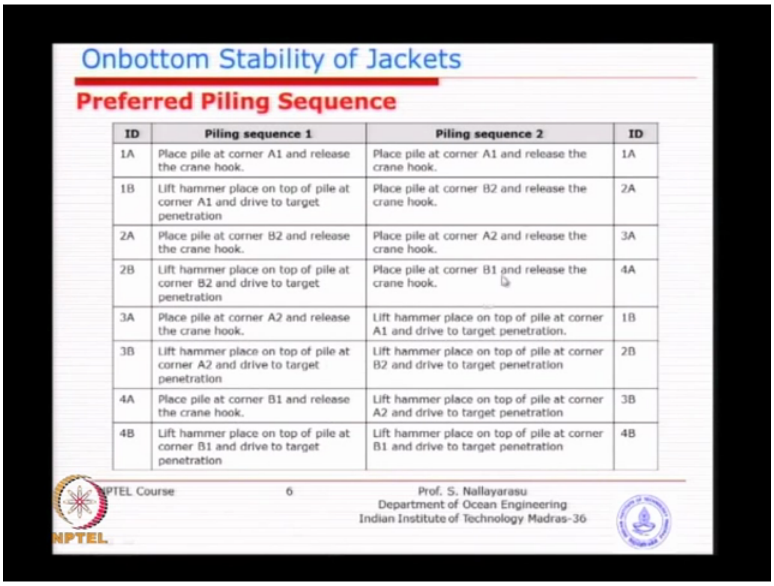
Onbottom Stability of Jackets

Preferred Piling Sequence

ID	Piling sequence 1	Piling sequence 2	ID
1A	Place pile at corner A1 and release the crane hook.	Place pile at corner A1 and release the crane hook.	1A
1B	Lift hammer place on top of pile at corner A1 and drive to target penetration	Place pile at corner B2 and release the crane hook.	2A
2A	Place pile at corner B2 and release the crane hook.	Place pile at corner A2 and release the crane hook.	3A
2B	Lift hammer place on top of pile at corner B2 and drive to target penetration	Place pile at corner B1 and release the crane hook.	4A
3A	Place pile at corner A2 and release the crane hook.	Lift hammer place on top of pile at corner A1 and drive to target penetration.	1B
3B	Lift hammer place on top of pile at corner A2 and drive to target penetration	Lift hammer place on top of pile at corner B2 and drive to target penetration	2B
4A	Place pile at corner B1 and release the crane hook.	Lift hammer place on top of pile at corner A2 and drive to target penetration	3B
4B	Lift hammer place on top of pile at corner B1 and drive to target penetration	Lift hammer place on top of pile at corner B1 and drive to target penetration	4B

So if you look at the sequence that has been normally followed is placed one pile on a corner which could potentially be on a higher side. See anyone corner, now if you decide a freedom to the contractor that they can place anywhere that will be the best situation because they will not know when they go offshore there could be a undue elevation change in the ground by a few hundred millimetres so you decide to do only allow one particular location and not allow other 3 locations because your pile condition does not permit then they cannot go and place the pile at that particular location so that is the limitation that you are going to give.

Or if you give a freedom to place anywhere they like, the first pile on A1 see you look at these notations what we have given is just a A1, B1, A2, B2, depending on the grid notation. So if you allow only to place the pile the first pile on A1, the remainder of the location they cannot place and that is some restriction that many people will not like but if you allow them to place the pile on any location they can place anyway among the 4 locations that will be hundred% flexibility but then that should be investigated.

Normally, when we want to place a pile on a particular corner we should place it on a corner which is higher so what they normally do is when you place the jacket on the seabed, you do a survey and you find out which corner is higher than the other 3 corners or other leg locations by doing a simple theodolite survey from the barge and you will evaluate which is higher. So when you place a pile on that side, the higher side will go down because of its weight and if you place it on the lower one which will actually force on the situation so that is the idea behind and after surveying you find that one of them is higher you can place there.

But then depending on the requirement if you look at you can place the pile and then take the hammer and then start driving for example, use 1A as the case where you place only one pile and start driving, once you drive this pile to this level probably just close to the jacket level then remove the hammer then go to another corner probably most probably it is exactly opposite diagonal that is the best situation because once you drive that side and then the opposite side might actually come by because you are growing so many number of blows and you are adding weight so jacket might try to tilt towards the corner or place the pile and drive. So you go to the opposite direction and place the pile and drive, normally you do that so that the counterbalancing of levelling will happen.

Now what happens is once you drive here, remove the hammer, bring one more pile, place it bring the hammer, this takes you know 4 times of changing the crane from lifting, the crane pile to the hammer and the hammer to pile again to hammer, so they take typically about few hours every time, which takes probably by doing this you spend double the amount of time that you will spend if you place the hammer after replacing all the 4 piles instead of changing every time you place the pile all the 4 piles together that means one by one you place the pile and the last you take the hammer, start driving this and then go around and try one by one that means you are not changing, you are only just by using the crane changing the location only so this is what normally people prefer.

So scenario 1 is one pile, scenario 2 two piles, 3 piles and 4 piles, this all needs to be investigated for various pile locations. You can see when here when you place the pile here the COG shifts towards this, once you place the second pile COG shifts backward to the original condition. Similarly here, shifts towards that one and finally you are bringing back the COG so all these cases needs to be investigated. At the end you are going to place the hammer anywhere along the 4 numbers that freedom also you can give so that you can investigate all those 4 cases. So the piling sequence is something that we have to work out depending on what is the capability of the soil and the foundation system available.

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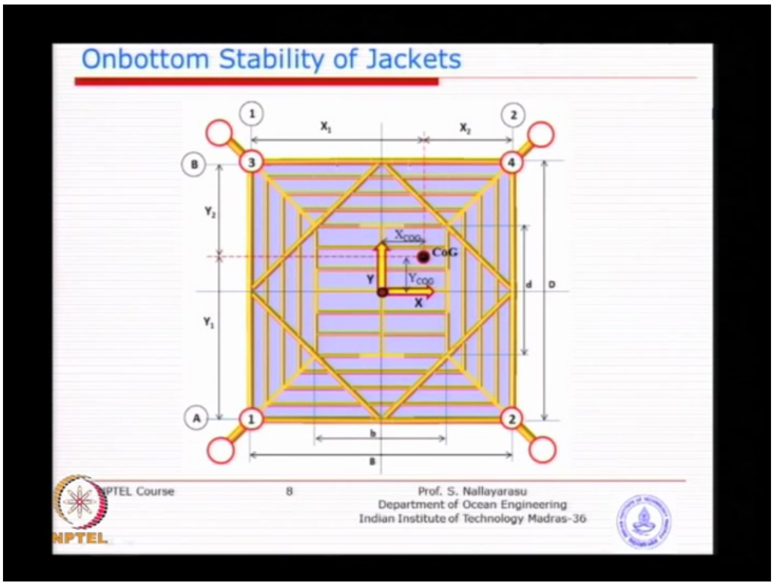

So if you look at this plan view of the jacket, you can see here that the COG is somewhere on this corner, not always all jackets are going to have a COG at the geometric centre of the system unless the jacket is so symmetrical that there is no extra weight is added any other places, then the COG may be exactly at the centre but many cases you will see asymmetry either in structure or in other utility of say for example some attachment structures will be there. So in that case COG is going towards this means more load is going to transfer to this corner, so if you think of it you want to counterbalance you place the pile on A1, which is very easy to understand and simple commonsense so that is the idea behind placing the first pile.

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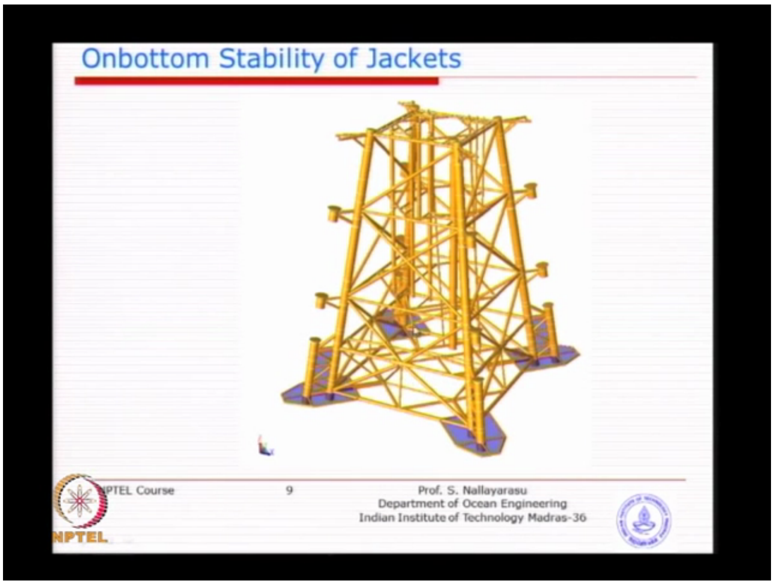

So some cases you can see here instead of foundation system throughout if the soil is very good, you can actually have a corner foundation similar to our isolated footing, I think most of the buildings are designed small buildings specially you design with isolated footing and columns. So you can have a very simple foundation type which can actually take the load as long as the soil here is very good. You know in some locations we encounter sandy material at the seabed some locations, most of the location you see soft clay except in very few locations you will find very good sand then you can limit your foundation to corner area.

But one great advantage of this corner area is the spacing is more, the load transfer of the pressure induced on seabed is going to be smaller because the decoupling effect will be better off. But if you have the same all 4 foundation put together at the middle, it is not going to be that great because the overturning effect can be higher so that is why the foundation going to the peripheral or the edges of the jacket will give a higher efficiency in terms of bearing capacity or in terms of overturning stability.

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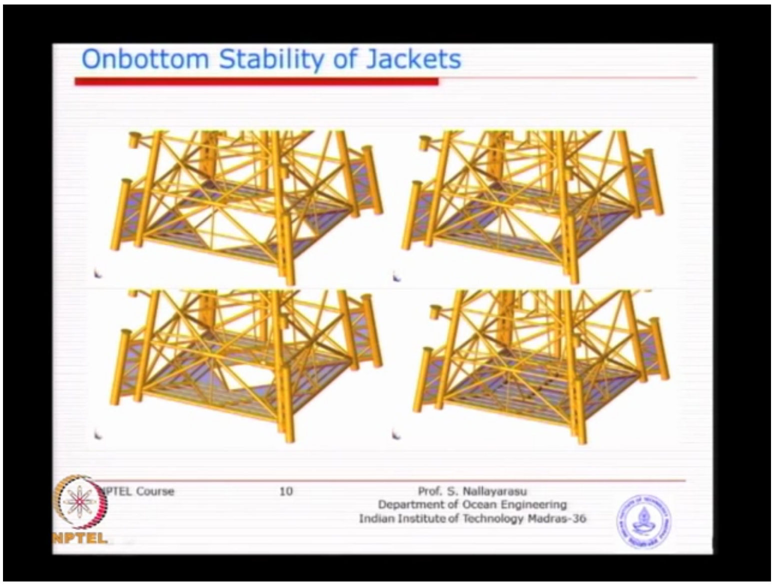

You can have much more or variety of ideas you can come up with so you can have corner triangle mud mat which is what you see in this blue colour and you can have a peripheral footing which is very similar to our rectangular buildings, you have a you know like a strip footing go all around the building all you can have full mud mat sometimes we have this you know because of very-very soft clay, you may require complete jacket to be provided with the foundation or you may have because the central area is in any any case is not very effective.

Because it is not going to take much bearing capacity because the load transfer will always be happening at the corner because most of jacket loads are coming from coming through the legs because always higher stiffness is there and you will see that the bearing pressure if you calculate at the 4 corners that will be maximum, which I think you might have known from your mechanics you can calculate the combined building and axial effect. You will see that the extreme ends will get the highest bearing pressure or stresses, so in this case if you have mud mat in the middle also, it is not going to be that efficient because the bearing load coming from the jacket is going to be very-very small in fact, at the centre it will be 0 because it is not going to be except maybe due to its own self rate the reminder of the load will go to the extreme corners.

So that is one of the disadvantages but in many cases the reason why we try to go for instead of this and go for opening is to reduce some weight, but in very-very soft clay what it does? If you look at this boundation type when the soil is trying to produce bearing capacity by means of compression of the soil from the loading coming from the jacket, you know the soil at the middle will try to squeeze away, you can easily imagine with a central hole soft clay means it will try to come out as the pressure is applied on the mud mat. And because of the squeezing effect the capacity will actually reduce because the jacket will try to penetrate, whereas if you have full mud mat like this without an opening, the squeezing effect will not happen, the soil will not be able to come out very easily because you are totally covering the whole mud mat.

So some of the cases we prefer to have even if it is not flow transfer is good but at least to increase the bearing capacity to a higher level, we would like to provide full mud mat rather than mud mat with opening. As long as the soil is good then you can have a larger opening so that you do not need to waste your structural steel because imagine if you fill up this area the amount of steel that you spend is few times larger than mud mat at the corner because that larger span will require bigger beams and bigger thicknesses of your structural members.

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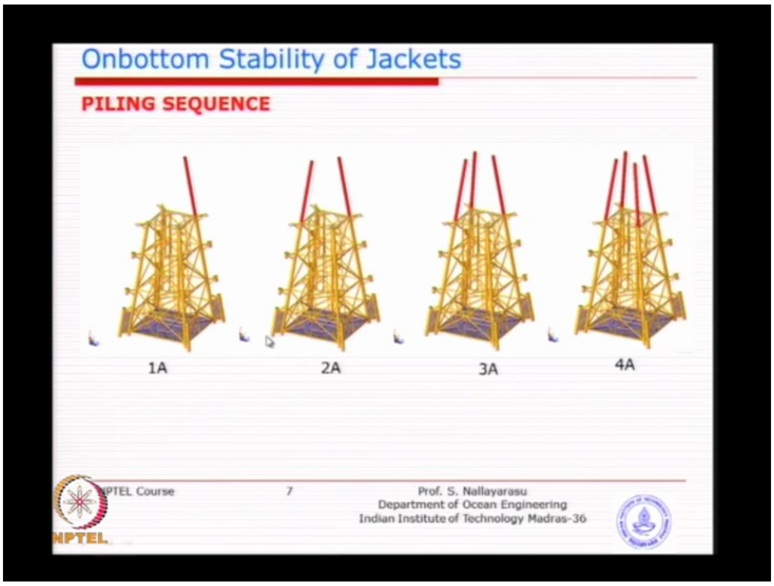

So the sequence what I have just displayed here is basically each one of the scenario, every time when you place one pile or one particular location will be one scenario where you have to investigate that means due to that particular scenario you calculate the stresses on the seabed due to weight of the structure plus the pile. Then go to the next scenario you calculate the stresses on the seabed on the soil, not on the structure, we are not worried about the structure right now and find out what will be the applied bearing stress and what is allowable overbearing stress. Like this I just listed down you know basically one by one, pictorially it is easy to understand, this is the case that we are trying to investigate and basically listed as the several...

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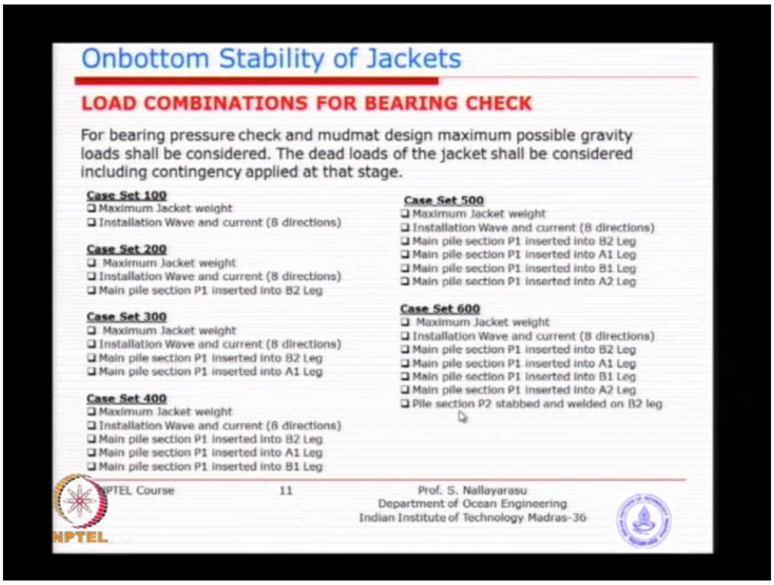

So you can repeat each one of the case, the first one is maximum jacket weight and insulation wave and current that means at that time what will be the wave and current. In association you can also have a pile placed at the one of the corner then you go to the second corner, third corner, fourth corner and then the corner with the hammer. So you are not placing the hammer at this time for example, if you decide not to go in this particular sequence if I decide to go and place the pile immediately take the hammer there which will actually worsen the situation in one corner. Whereas here you counterbalance all the piles with all four corners so the weight of the hammer is going to additionally generate increase the pressure.

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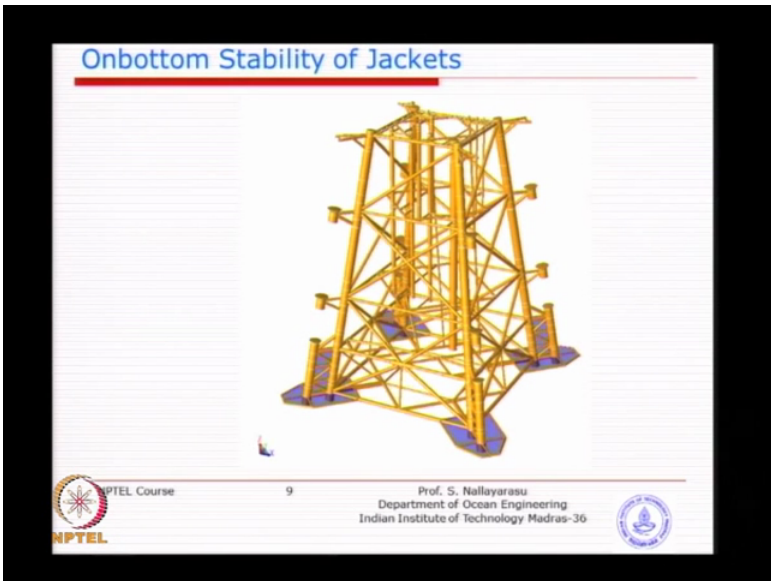

So this sequencing has to be overcrowd, if this is not going to work for that particular location, you have 2 choices either to change the foundation system or to change the sequence of piling itself that means we will not allow this we, we will only allow the other way. So that needs to determined based on what is feasible, you know sometimes after doing all this investigation you find that this jacket is unstable for any activity offshore then you may have to increase the width of the base of the jacket, so you go back to the basic design, make the jacket width bigger because the soil is too bad or if the soil is very good, you may not even require any foundation type so that is the idea of on bottom stability which affects final design of the jacket itself so, so many cases you can read.

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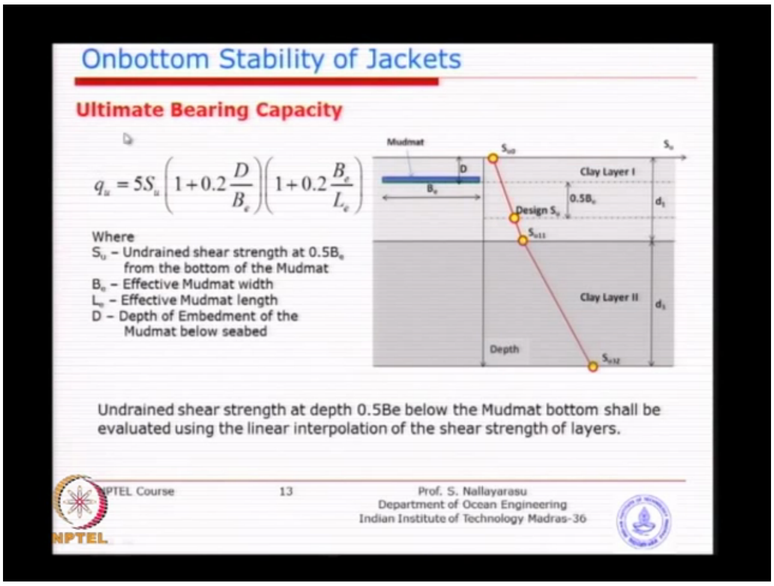

The second thing what we were looking at the last time we were investigating on bearing capacity of soil wearing instant, I think we were looking at one of the methods which gives you the accounting effect of variability, similar thing I have just given in one of the particular case where the mud mat effect is taken because the larger the mud mat the bigger the effect due to this. So this particular case in one of the particular project where if the soil was varying considerably from 5 mega pascal to 30 mega pascal over 2 layers, the layer 1 and layer 2 of course the radiation is slightly different and this if your shear factor, but what will be the correct methodology of considering which shear strength you suppose to consider you know basically half the depth of the width of the footing.

It is not the shear strength at the bottom of the footing itself, which is what we consider in most of the cases. So in this case there was an experiment done at that particular location and then the depth effect because the larger the mud mat or the larger the footing, the effective stress distribution below them the footing itself is not highly depend on the shear strength of the soil near the foundation, it also depends on the shear strength slightly down. So in this case the particular recommendation by Stephen is given that you know the half the depth which is equal to the half the width of the foundation itself that means if it is 2 meter width of the footing, you go 1 meter down and take the soil strength instead of soil strength at the layer where the mud mat is bearing at that particular location.

So it is the idea behind based on that this formula was derived and one of them is your shear factor, this is just multiplication and the other one is the depth effect factor which is your depth of embodiment of the of the mud mat below the seabed and 5 times S u will be taken at that particular distance rather than at this place, so that is something that we will normally use for most of the projects.

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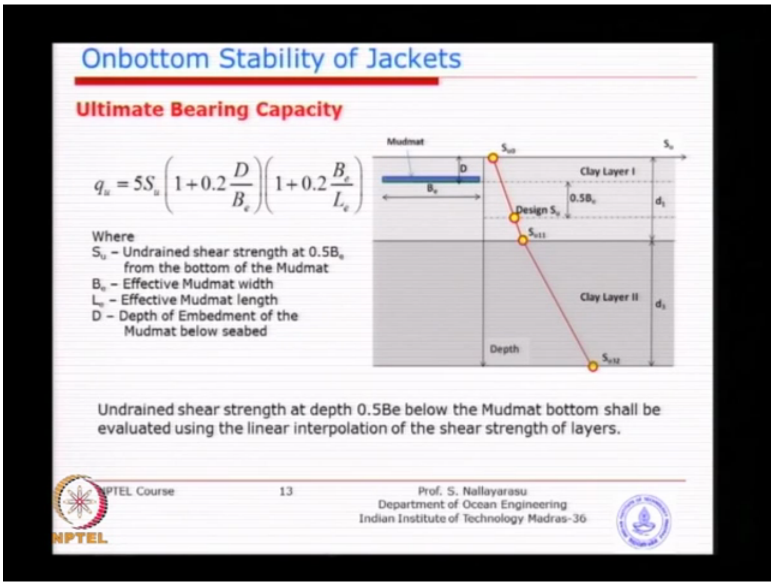

Mud mats can be of any type of material but normally we have steel most of the cases, some cases we may also use timber you know I think very very rarely allowed because environmental considerations normally many countries have banned the use of timber for mud mat but some places still people use. And some cases we do use Fibre Reinforced Plastic or FRP but normally not allowed I think, in many countries it is banned. So most of the time we used steel so we need to find out what is the steel frictional factor between the steel plate and the type of soil whether it is clay a type of soil or for sure you will not use concrete so you can forget about, it is too heavy.

So what the idea is we want to make sure that it has got sufficient strength and lightweight of course as minimum as possible, so FRP and timber provides that particular aspect of reducing weight considerably but then because of the environmental considerations normally not allowed but of course timber can be used because they are not harmful to the environment but then so many trees needs to be cut so that is why many countries have banned the use of industrial timber for such uses. But you know at least in some projects people still use because consideration of weight reduction (())(25:55) weight reduction and also the use of CP system is not required because timber automatically will degrade over several years and does not require to be protected.

Whereas if you steel mud mat or steel plates with stiffened effects, you can see that they have to be protected otherwise what happens is the mud mat will also be attached to the structure, the structure will corrode if you do not protect the mud mat itself because the CP system will not isolate, it will work together so that is one of the area where use of steel is not normally preferred by some clients.

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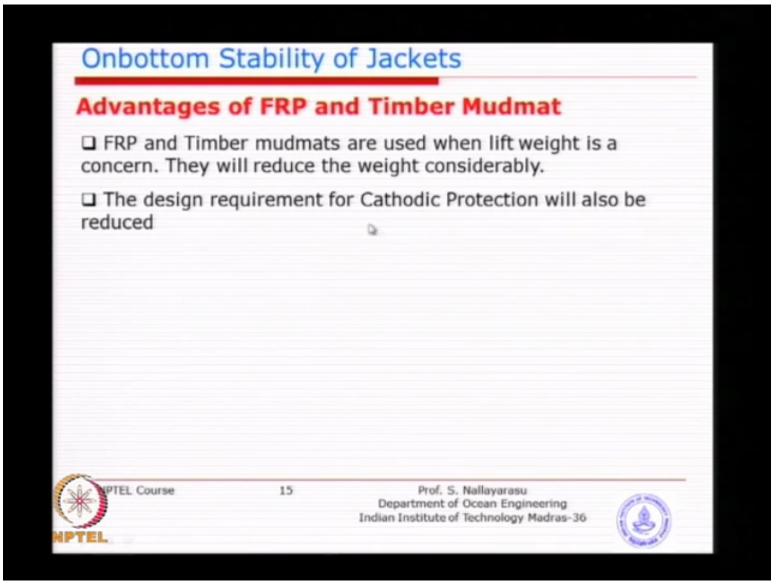

FRPs and timber as you can see here is quite useful where the lift weight of the jacket is you know very much critical, you want to reduce the weight, in such cases you can use the timber and FRP. CP system which we have discussed will be a definitive reduction if we use such material.

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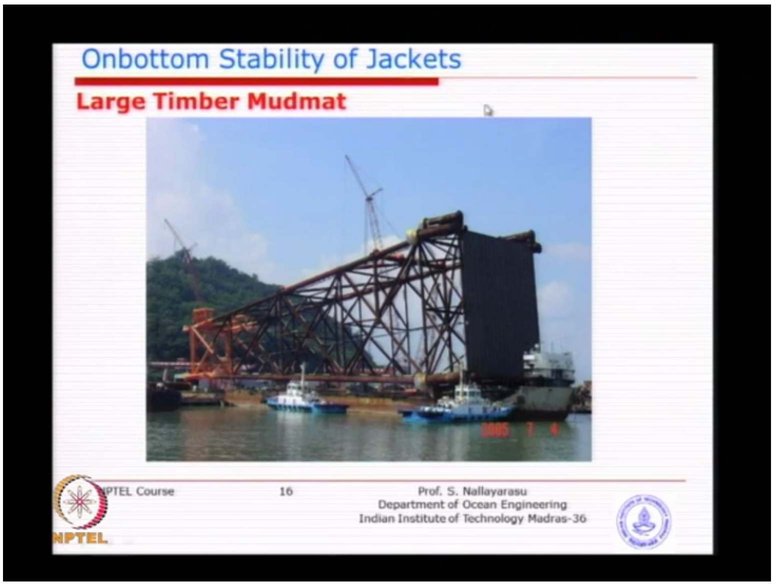

You can see here typical full mud mat, in this particular project we were having a very soft clay 120 m water depth and you can see that the complete base of the jacket is provided with mud mat which you can see because of the soft soil which has got no main pile but both of them all 4 corners you got only skirt piles and in this particular case there is no main pile so the worry is slightly less because only main pile you will have that big length of the pile is being inserted and supported by the jacket itself. In this case it is only purely because of weight of the jacket because for skirt piles once you take the pile and insert, automatically the weight is transferred to the seabed itself. So in this case the weight of the jacket itself was so heavy that we require mud mat of such large size.

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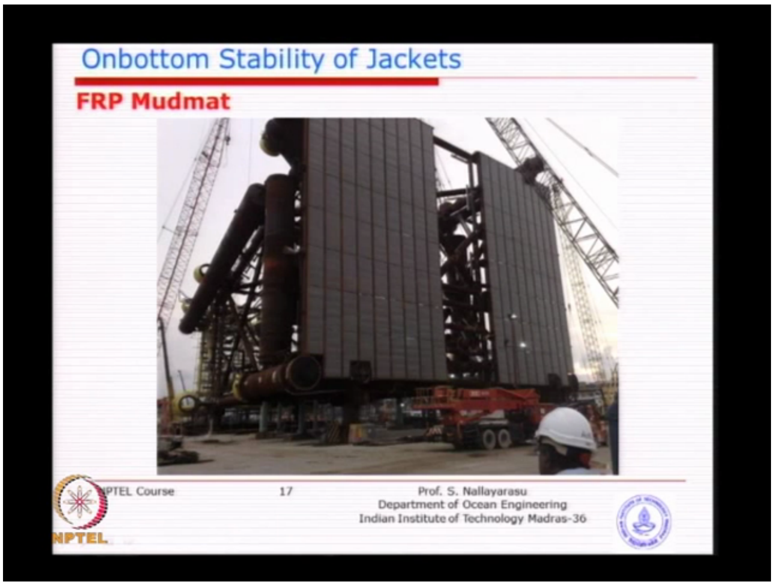

In another project you can see of course this particular project we use FRP because of the limitations and constraints of lift weight of the jacket, the lift weight was very close to the crane and we ended up using FRP because if we use steel mud mat the jacket could not be lifted so that is one of the area where it was very helpful, weight reduction is tremendous because FRP has very high strength as you can design for almost double this strength of the steel and weight of the material is so small that you can reduce considerable effect. But of course the mud mat is not full because the central area is left open because in this particular project central area cannot be covered with mud mat because that is where the wells are being driven, so if you have central area with mud mat no wells could be driven so that is why that well bay area has to be left open.

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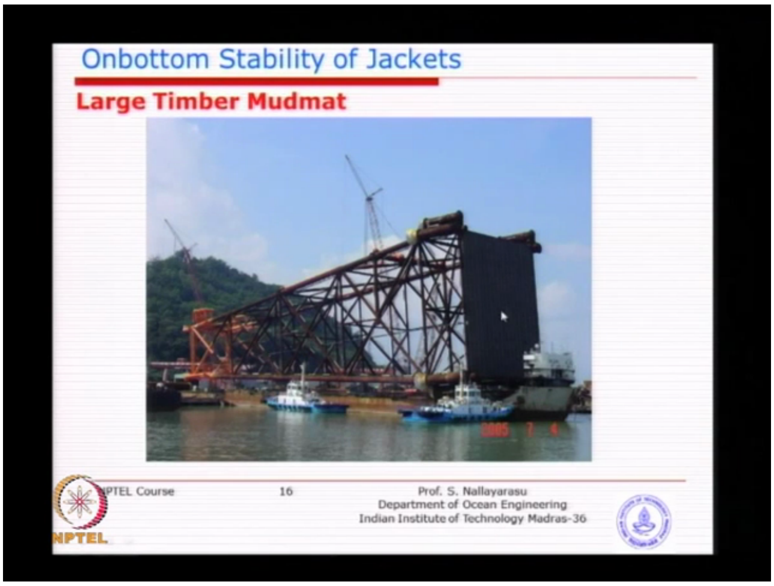

Whereas in this one, this is a process platform so you do not have such restriction of you know well bay.

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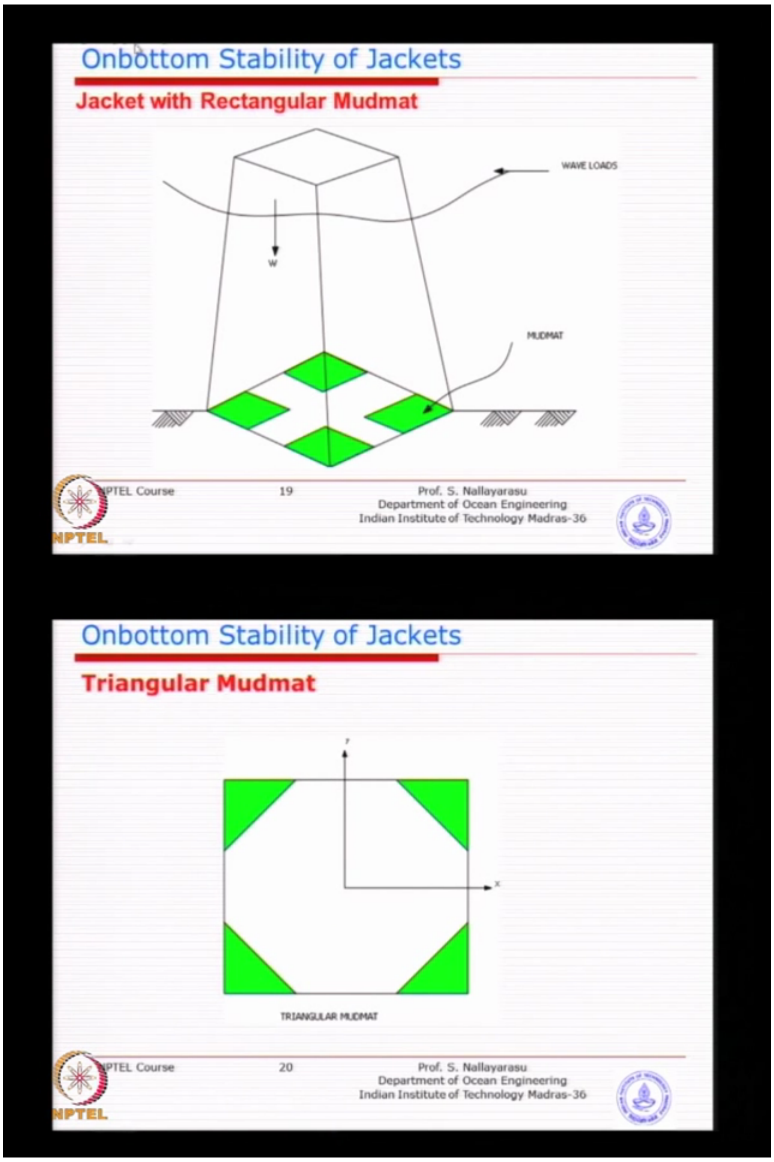

So but Matt concept I think we have seen earlier, 4 rectangular corners sometimes used or 4 Triangle corners. Mostly the efficiency will depend on the type of loading and how much is distribution is there.

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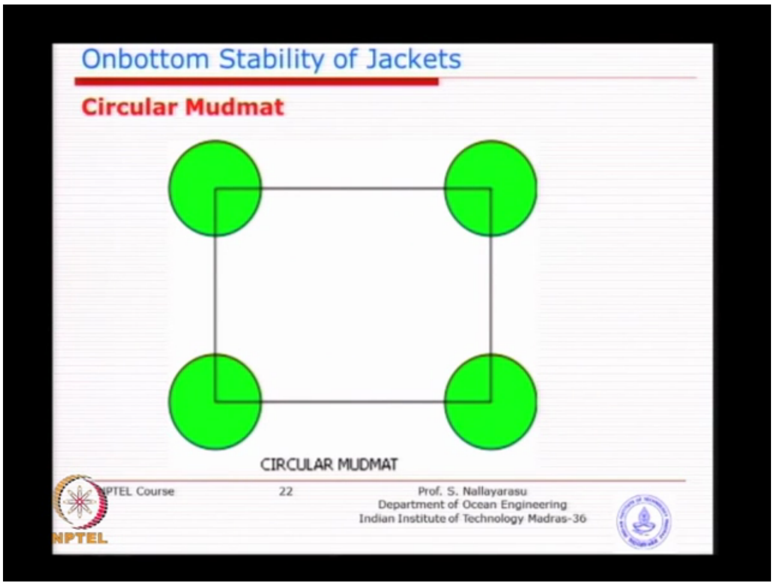

Circular; circular is not normally preferred but do we have used in few projects this will be more effective because the low transfer from the central location and distribution to the seabed is very much uniform. So if you look at this one, this is the efficient way of distributing load an in fact even when you look at the safe factor for bearing capacity, circular shape will provide the optimum, but the construction of such mud mat will become very seriously difficult because we have to arrange the system in such a way that you know fabrication becomes...

But also it is sticking out so much that during transportation is not very easy way of doing it, I think those who are looking at transportation arrangement when we are looking at the other course, you can see that this will never be able to mount on the barge itself which will become very much depending on the dimensions, if it is 3 meters per example may be okay 4 meter, but if it is 10 meter then the jacket has to be elevated 10 meter high which is not very good so that is one of the issue where mud mat sticking outside the boundary is not preferred. Triangle for triangular, most of the jackets with triangular mud mats.

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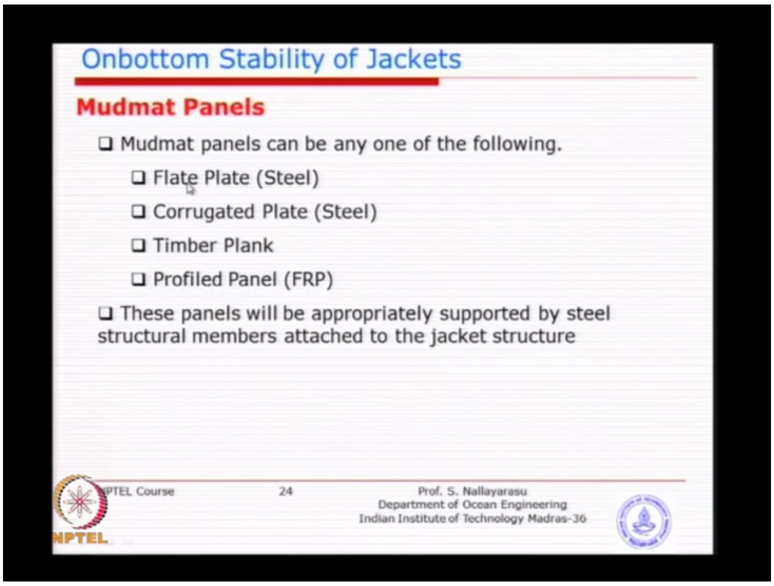

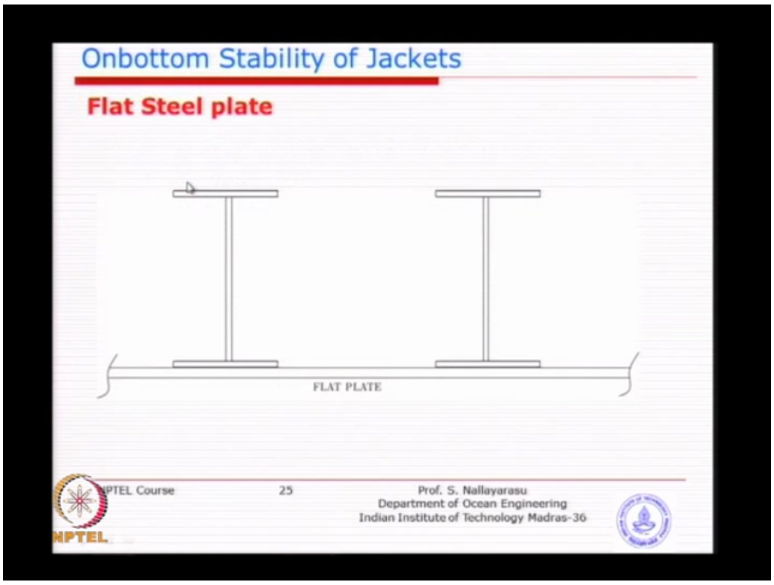

So steel plate we can use a flat plate or you can use corrugated plate, so this is the flat plate you can see the plate is attached to the bottom of the jacket.

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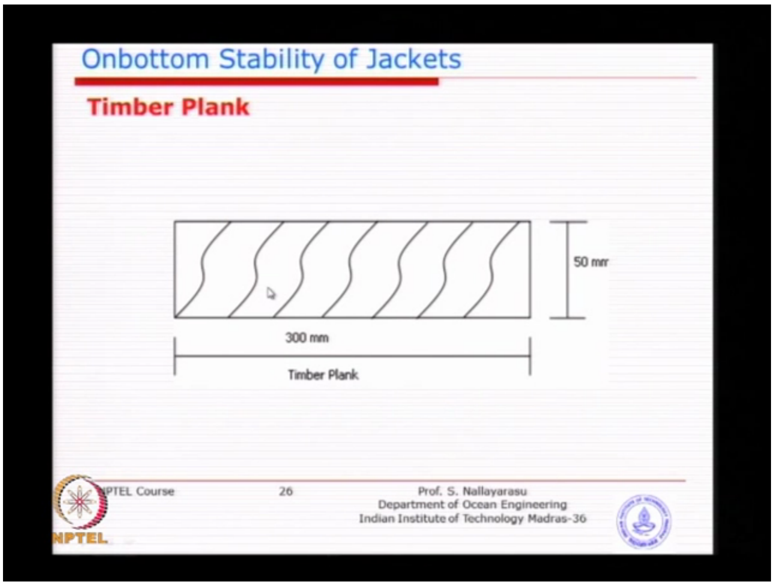

Or you can use timber panels which is cut from big logs of trees with typical thicknesses of 50 to 100mm and width normally not more than 300 because you will not get very big width so you can cut in something like this and place it in place of steel plate you just place your timber and bolt it normally bolted something like this.

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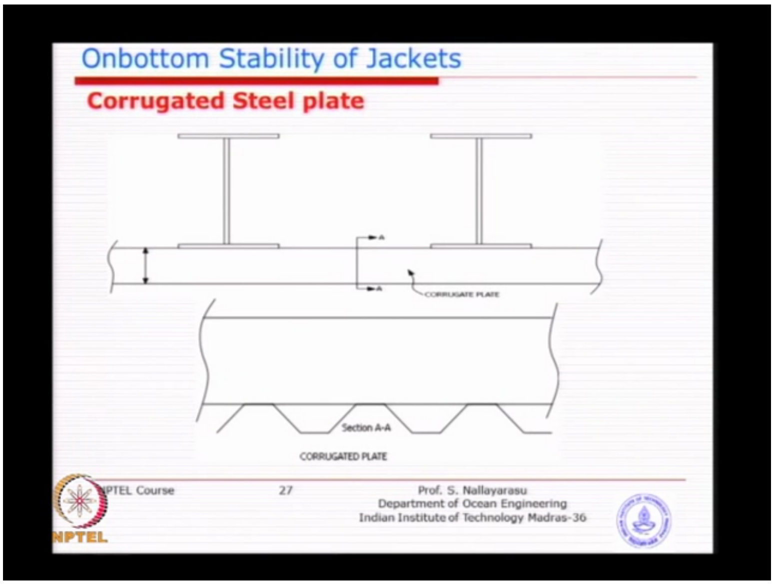

Or you can use a steel plate in a corrugated shapes very similar to propiled steel plates, this gives you additional strength instead of this kind of flat plate, you know the bending strength is very much small so you would require considerable support stiffening rather than we use a corrugated plate you know automatically we can span for a longer distance so that is something...

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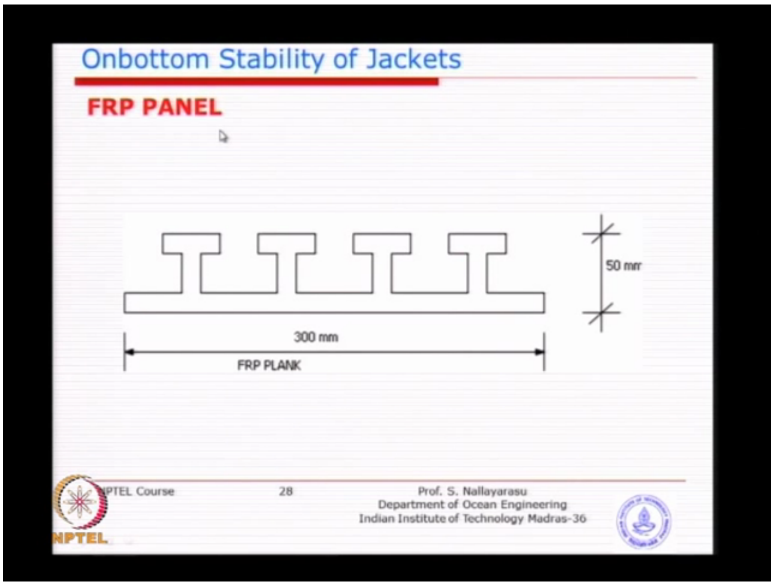

Or propiled FRP panels, this is what normally used in many industries including aircraft industries you will see that this kind of propiles are being used for bending. So you can see here this is actually moulded shapes they are not fabricated they are moulded shapes, width you could have 300-400 depending on the capability of the manufacturer with a 50mm with T shaped propiles for stiffening effect could produce as much as several times higher bending strength than typical steel plate of 10-15mm.

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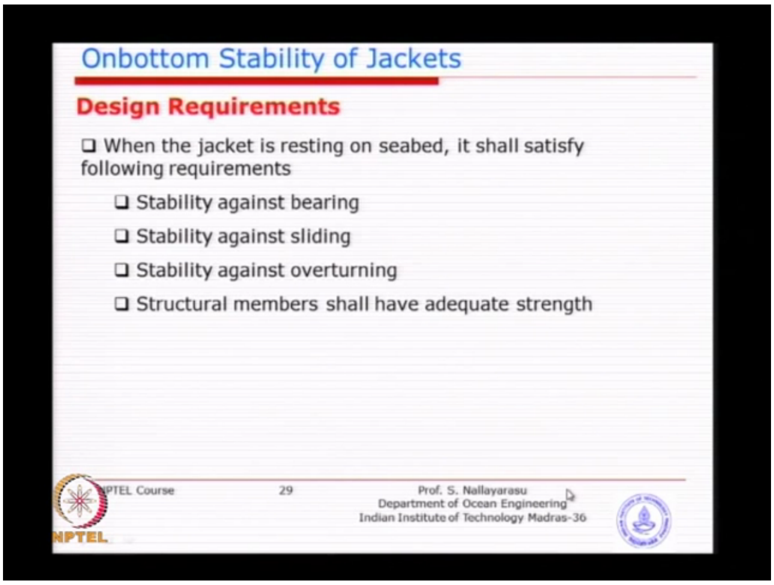

So the stability requirements if you look at overall, we have sliding and bearing and overturning and then the strength of the structure to take and transfer the load from the jacket to the seabed or the soil, so the mud mat itself should have sufficient strength, before the soil fails the mud mat should not fail so that is something that we need to make sure that means the structural strength of the member resting on the seabed also should have sufficient capacity otherwise, soil will be stronger, mud mat will fail before the soil starts to deform. So always we need to design in such a way that the capacity of the structural members are higher than the soil, soil can fail but not the structural members.

So while doing so will also look at what is the design bearing capacity based on our soil mechanics principle and then compare it with the computed bearing pressure provide sufficient bearing capacity as we normally do fall pile design bearing capacity factor or the safety factor is 2 and 1 and a half which is what we were discussing. Similar bearing capacity factor needs to be provided depending on the type of loading situation.

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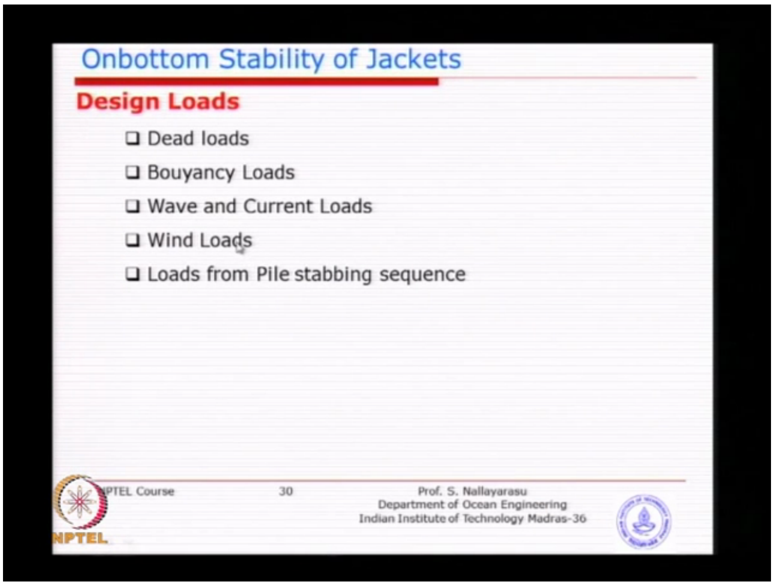

So what are the loads arising from you know the system definition is that dead load and the buoyancy for sure you will use to nullify in fact, several cases if your bearing capacity is a problem, we actually keep the buoyancy tank not flooded so that after the pile is driven then you can flood the buoyancy tank because in any case it will help you in reducing the bearing pressure. Wave and current load at the time of driving or at the time of jacket placed in the seabed, wind loads not very much predominant except little bit of the piles sticking on top of the jacket and then the loads arising from pile stabbing sequence including weight of the hammer.

For sure you will not place the hammer unless the pile is touchdown to the seabed, you understand the difference because if you actually place the pile, pile is fully supported on the jacket, you will never ever plays the hammer on the top because that will be most dangerous because the total weight of the hammer will come on top of the jacket. So always after cutting this so-called this stiffener or the projecting steel from the pile then the pile is allowed to enter into the soil then only will place the hammer because you do not want the total hammer weight to be supported by the jacket itself, but in some cases if you have to do a smaller hammer like this you can do so, but bigger hammer will not be able to sustain.

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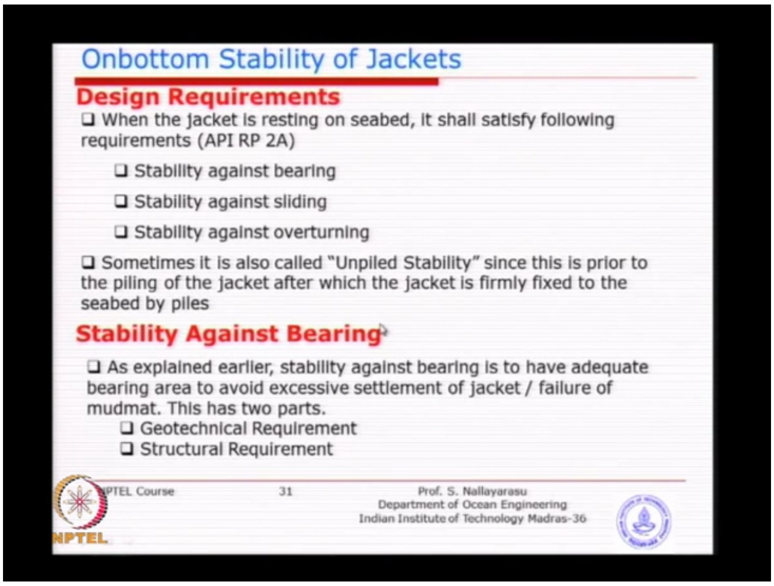

So design requirements this bearing, sliding, overturning is a must, of course bearing capacity comparison is very easy; one is geotechnical, the other one is the structural requirement. API has mandatory bearing capacity factors given in the code which will follow, so the factor safety against bearing is simply calculated as the bearing capacity calculated based on soil mechanics principle divided by the applied bearing pressure. So bearing pressure can be calculated by decoupling the vertical loads and the horizontal loads and I am trying to combine them and compared that with the ultimate bearing capacity that you calculated based on the shape of the footing, it can be Triangle, Circle or rectangle whichever.

And the minimum factor of safety of 2 set be provided only for weight of the jacket that means the gravity loads. And including if you have a pile hammer but with deadweight of the jacket + pile plus the environmental load a slightly reduced factor of safety of 1.5 is acceptable that means this is not storm load, you should not get confused with what we were doing last time. For main pile design we have 2 for operational wave conditions and 1.5 for storm extreme storm conditions. In here, this 2 is for purely gravity loads and 1 and half for gravity load + the wave loads or wind loads jointly together.

So what is the meaning is, in case of slight environmental conditions are existing at the side during pile driving, we do take little bit more risk whereas purely due to weight of the jacket alone we want to have a higher factor of safety this is required by the code so we have to follow. So when you are equating the bearing pressure weight of the jacket divided by the area of the mud mat, will give you the bearing pressure due to self weight which you will need to compare with the ultimate bearing pressure or ultimate capacity based on the soil type and provide a factor of safety of 2.

When you are actually doing the same thing with environmental load that means you will have horizontal load then you can calculate by simple combination of vertical plus horizontal that means P by A + M by Z either you might have studied in your mechanics course, so you can combine the vertical load and horizontal load, you can find out what is the bearing pressure and that will be replaced here and then the factor of safety required is 1 and a half.

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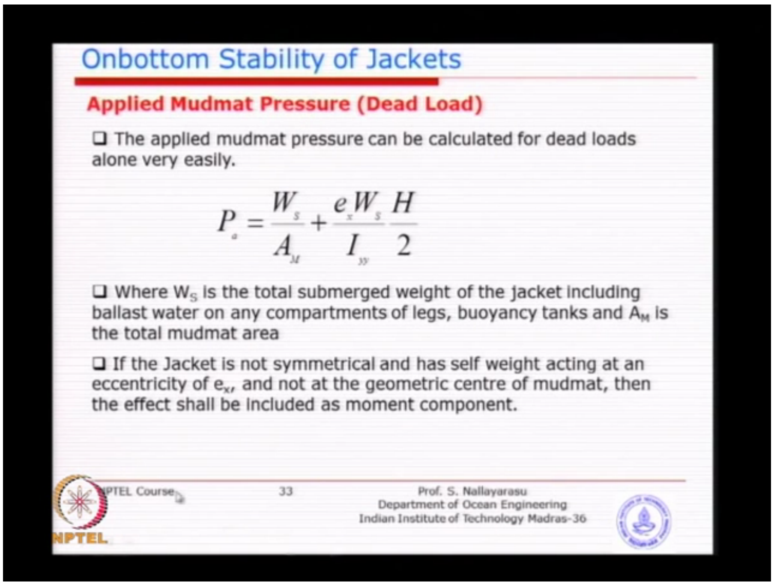

So that is what you see here, the applied mud mat pressure when the jacket centre of gravity is not exactly at the Centre. If you have this jacket centre of gravity is exactly at the Centre, the second component will not be there is not it? Because the there is no eccentricity of the loading so W divided by area of mud mat will be the bearing pressure. When the centre of gravity is moving toward somewhere either in X direction or Y direction, in this particular formula I have just provided X direction so e into W will provide you the moment, moment divided by section modulus which is just nothing but I by H by 2.

So this I is nothing but thus if you look at the rectangular area the moment of inertia of the rectangular shape of the mud mat at the mud line, so if you have eccentricity in Y direction like what the picture I have shown you diagonal direction you will calculate the similar. So the reason why I multiplied by H by 2 I want to find out the maximum pressure, if you come inside the pressure will definitely be lesser than the pressure at the extreme corners. So for a rectangular mud mat you will see that the 4 corners you need to monitor, not the inside because you are very sure that the bearing pressure will be definitely smaller than the edge.

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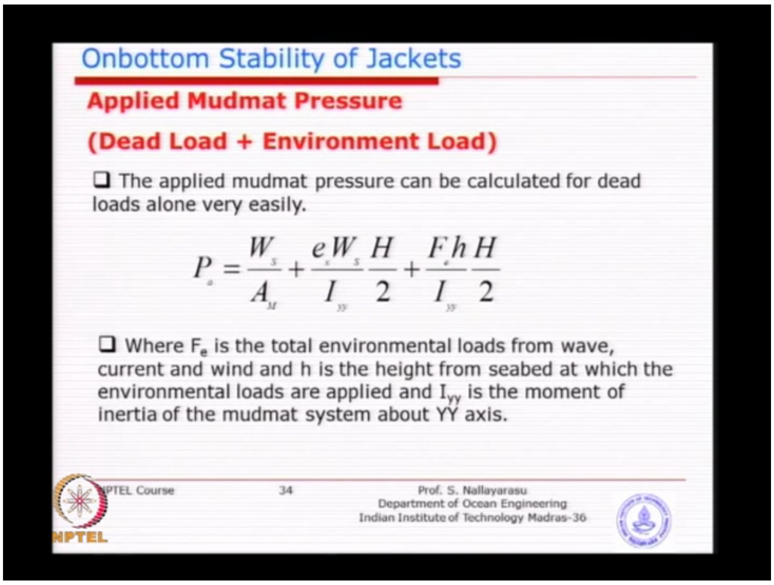

So that is including the environmental load so the next term is added, F is the horizontal load due to wind wave and current multiplied by the height of the application of the load from the mud or mud line will produce the moment divided by corresponding section modulus, so basically this is cumulative effect of eccentricity due to its own weight, eccentricity due to placement of pile or hammer and then the moment arising from horizontal loads induced by wave current and wind, so all these together to try to calculate the...

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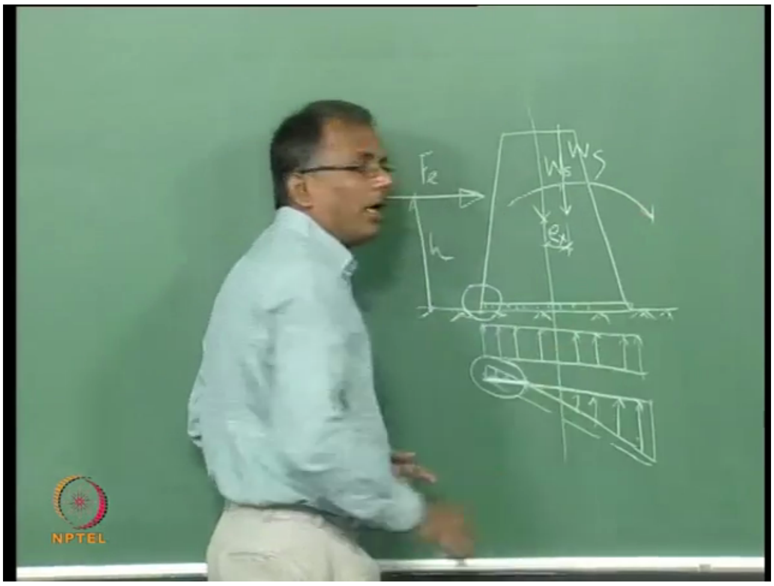

So if you look at bearing pressure distribution for a typical mud mat, if you have jacket like this, if you have decided to provide a mud mat like that throughout for example, the bearing pressure due to self weight alone supposed to be uniform something like this, if you have weight is acting exactly at the centre. And if the weight is having a centre of gravity change like this then you may actually, depending on the position of the centre of gravity for example this is e x, you can see here certain portion is in negative that means this COG is shifting towards one side quite a bit.

You will see that this area very simple stress distribution we can understand that there may be a negative stress which is what something that we need to investigate because the mud mat nobody is holding the mud mat to the seabed because there is only a contact, so this portion of the mud and will not be effective. So as long as if you have stress distribution something like this, 0 here and all are compression there is no issue but as long as when you calculated because of the COG is shifting towards one side if you find that the negative pressure is there that means that much of the area of the mud mat is not effective because there is nobody is holding the mud mat and the soil together.

So this is something that you will get from whenever you have a very large horizontal force applied at the height of h, you will see that this corner of the mud mat is trying to lift up and if that moment is very large, the jacket will actually topple that is something that they are interrelated. As soon as you get very high compressive pressure on one side, you will see that there will be a negative pressure and if the negative pressure is larger enough the jacket will for sure it topple. So the bearing pressure and the overturning they are actually interrelated so in this particular case you can see here this h plays a major role.

If you actually have a pile sticking out for example, I have a pile something like this placed on top you will see that wind load is going to play a major role because the height at which it is applied though the magnitude is smaller, the height at which it is applied can cause potential overturning can create more trouble.

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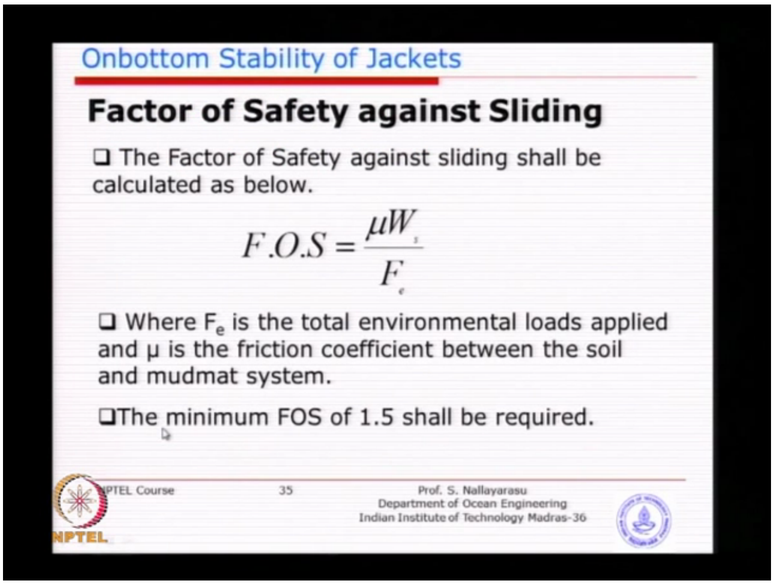

Factor of safety against sliding basically today we will look at only the sliding due to drain condition. So sliding is proportional to this weight, the heavier the structure, sliding will be easily prevented, the F e is the total environmental load applied and Mu times W s is the resisting effect of the system. So the heavier the structure it is better, it cannot move you know so the factor of safety is required is minimum 1 and a half. So this is the resisting force at the interface between the mud mat and the seabed and F e is the applied horizontal load which is in the forward direction and factor of safety required is 1 and a half. Most of the time we do not find sliding stability is that critical unless you make the jacket so lightweight that it is going to just move around without much. But most of the time when you place the jacket you already have sufficient weight that it will prevent it from moving.

The factor of safety against overturning is also as I mentioned is interlinked with the previous one, the bearing because the negative pressure sets of that mean it is going to overturn. So overturning stability is calculated as weight times the distance from the the consideration basically one of the corner there. So if you look at this is the distance x, I think there may be some diagram because you take moment about this point if W times x is divided by F e times h is the applied moment, restoring moment will be W times so you take moment about this point you will get, the factor of safety is not specifically mentioned in the code but in any case in the industry we normally use factor of safety of 1.2 to 1.5.

1.5 is good but 1.5 is very very hard to achieve so in many cases we actually accept factor of safety of 1.2, in some cases 1.1 because overturning will ever happen if W times x is higher than F time h.