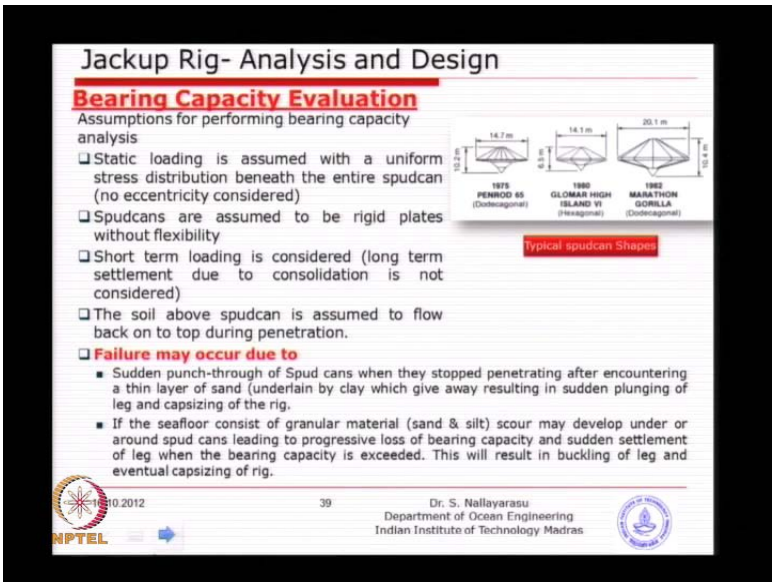
Design of Offshore Structures
Prof. Dr. S. Nallayarasu
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module - 5
Lecture - 4
Jackup RIGS-Analysis and design – 4

(Refer Slide Time: 00:12)



So, we will continue with bearing capacity evaluation for the spudcan as you can see it is a very similar to circular footing only thing is the shape and you know the penetration is too large unlike shallow footing normally most of the footing foundations are on the ground or may be one or two meter below whereas, in this particular case we just going to penetrate deeper into the soil.

So, you may get better bearing capacity, but we need to see the what type of soil that we can penetrate because if it is a hot soil you may not be able to achieve a penetration. So, it is balanced between the large size under soil which is slightly better than the surface soil and the size that is why you see that in this picture if you look at the right side you know typical spudpans used in the recent times you know this around 15 to 20 diameter 15 to 20 diameter when it is in number you might look very small, but actually if you look at the physical size its reasonably large and the the vertical size are.

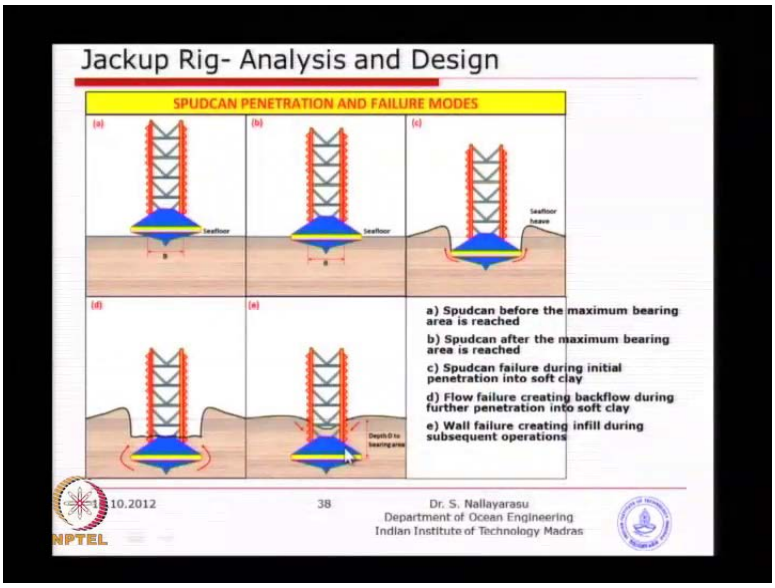
So, called the cone size on either bottom and top you can see around half of it you know if you look at the 20 meter diameter scan you have about 10 meter approximately. So, it is quite quite large in size typically made of steal stiff and plates inside. So, that during

the process of penetration it does not bent too much because you want to have a rigid foundation system. So, only bother about the soil behavior rather than a complex soil structure behavior. So, that is why we want to make this spud as rigid as possible. So, that you know you are only going to look at this geotechnical aspect rather than a complex behavior there is.

So, we will assume as a rigid foundation and that is how you need to make sure that you designed the spud as a rigid; that means, you have to steepen it inside with plates and primarily this is made of steel structure you donot make out of concrete because handling becomes every time you have to lift it of go over from one place to another place. So, you never think of making it out of concrete always it is made of steel plates and steep and sufficiently. So, that during the process of going down you get a the reverse soil pressure which needs to be designed form and most of time we try to do a static loading conditions because you remember when the leg is going down it is a forward process and at the achievement of the particular penetration it is going to, and almost it could consider the loading as a static, but during the process of penetration you could see that the load is slightly changing every time when it goes down and you do a So, at that time, but it the time variation is not very fast.

So, it could as well consider as a static loading that is the idea behind. So, you simplify the process of doing analysis and spudcans are assumed to be rigid this is what I was trying to do the reason is we do not want to create a further complication of flexible foundation and flexible soil interaction becomes too difficult to evaluate and also the behavior needs to be worried about because if we have such a complexity. So, the rigid foundation means sufficiently stiff and enough short term loading is considered only because most of our jackups are not going to be stationed for very long time. So, you just look at only the local and short term effects and not the long term effects like cyclic and otherwise soil above spudcan will be assumed to be flowing back when it is going forward and backward.

(Refer Slide Time: 03:54)



So, you can see here the failure may be due to various reasons, which I was showing here earlier what type of you know behavior. So, failure may be due to punch through this is one of the major problem of. So, many failures ninety percent of the failure of jackups are due to punch through we will just learn little bit more about what is punch through punch through is the phenomena either during installation or during operation the leg is suddenly experiencing large displacement in vertical direction due to insufficient capacity from the soil not from structure.

For example, you have installed already it is in operating condition you have estimated the operating loads may be several thousand tons and also estimated the loading could be few times higher than that and you have come up with design foundation is perfectly alright during operation suddenly a storm comes the storm condition slightly exceeding the design condition then the loads become slightly larger depending on the type of soil below you may see that whether it may punch through or not because if you have relied on a layer for example, if you have stopped your spudcan at a stand layer.

So, ten meter deep something like that at say twenty meter below and if the sand layer is that you are believing that can take all the load that is what you have decided that there is a very good sand layer. Suddenly the load requirements becomes larger than the capacity of the sand layer there will a punch through of a sand layer because the sand layer is not sufficiently thick if it is very large for example, thirty meter forty meter may be difficult to punch through, but if it is very less what happens you know that is why when you stop a foundation not only the jackup any type of foundation for structure you should make

sure that this punch through does not happen means the layer must be sufficiently bigger otherwise what you need to do is ignore the capacity of that thicker or stronger layer you know basically that is the idea.

So, this punch through is basically a problem in case of other foundation design we can ignore her e in spudcan we cannot ignore because even if I want to ignore I cannot take the spudcan below the stronger layer during the time of installation because it is too strong for me just now I cannot preload. So, much because, capacity is not available. So, I forcefully ended up in terminating the spudcan at the top of the sand layer and I could not achieve higher capacity at the time of installation, but during the storm condition I am exceeding because huge storm creates bigger reaction and leg punch through the jackup failure.

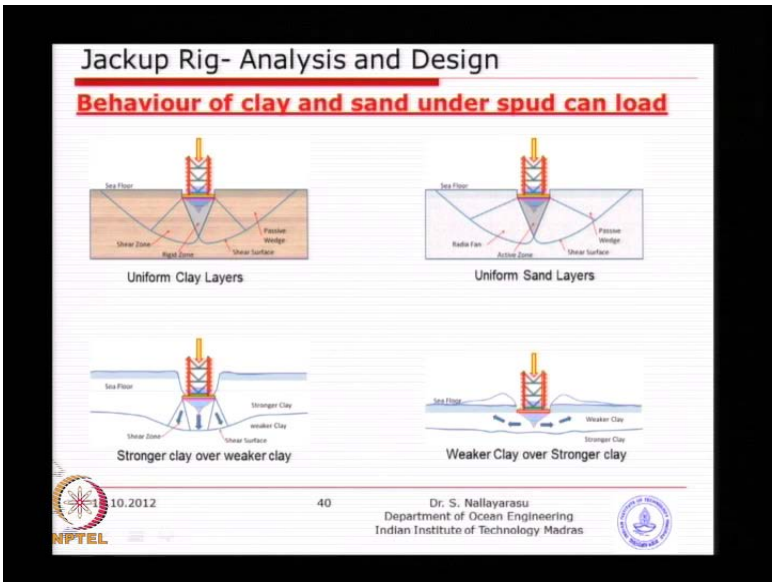
So, this is. So, basically irrespective of what you can achieve still you are having problem with punch through type of problem. So, we have to just make sure if it is not suitable do not bring this jackup to this particular site may be you have to come up with a bigger spudcan or bigger type of jackup. So, all those things needs to be. So, this punch through is basically a serious issue the department of energy in uk they have done a study and found that almost several jackups failed only because of punch through not because of any other design failures.

So, you will see that the most of the jackups soil structure interaction is actually the basic study required for any jackup to be relocated from one location to other location other than mechanical or portion which is slightly a less difficult to do whereas, this one the site dependant seafloor consist of slightly granular material also can cause scoury because you know very well when you install a foundation next semester you will learn more about estimation of is a symbol phenomena when you put an abstraction in the flow conditions in the sea bed and if the material is ((Refer Time: 07:49)) granular material started to remove from the location.

Where the structure is is could easily a when you go to the beach once upon to a beach granular material starts to move away from the abstraction because of the turbulence and particles get the lifted up and then moved away due to the current. So, this exactly the phenomena will happened to the this is very large size and trying to go and settle down you have got a large size which you can make. So, due to this you could see that failure

could be happening. So, one of this problem is progressive loss capacity is keep on reducing because covering material can be…

(Refer Slide Time: 08:36)



So, typically what we want to understand in this ((Refer Time: 08:39)) two slides how the behavior can be. So, if you look at the first picture uniform clay layer uniform stand layer most of the will look very similar those we are studied soil mechanics then easily see the the idea of bearing capacity derived by you know basically four or five segments of soil behaving in a slightly different manner. So, if you see this the first one under the under the spud scan you see a portion of a soil becoming the part of foundation itself which is very similar when you drive a, you will be using that as the part of the foundation.

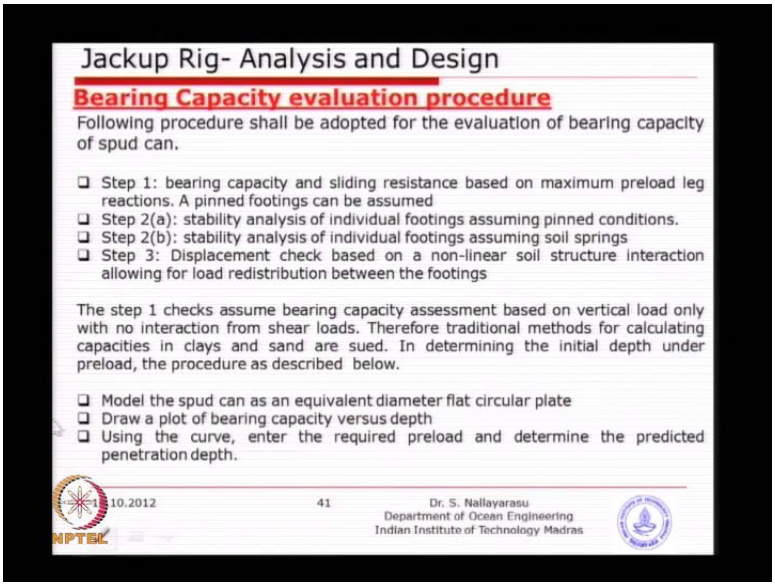
Similarly on the sand layer you will see the behavior it almost similar except whether its shear or you know depending on type of soil clay or sand the shape and size of this say mm the the the behavior of the soil will be slightly different depending on the soil type that is why when the deriving equation will see whether it is a c equal to zero or phi equal to zero type of soil basically sandy material or claying material will find out the equations whenever you have a layers soil then this became slightly complex problem you see here stronger clay over weaker clay or weaker clay over stronger clay.

The behavior could be different. So, if you look at this second one we will easily understand you have a good material below, but there is a material on the top is trying to

just get depressed away when you are trying to press or increasing a loading because of the spud can Whereas in the case of stronger clay at the top, but the weaker clay at the bottom is trying to away on coming on the side to the top you know as much as possible because there is a very good cover layer So; that means, this might give you better bearing capacity then this one is it not? Because this unable to escape because you got a depends on the how much is thickness of the layer If the thickness of layer is smaller than the loose clay can come out. So, the behavior is going to be slightly complex many times we do not use equation because that is only applicable for single layer type of situation when you have multiple layers when you have multiple deeper and deeper those derivation may not be useful.

And now a days, in fact, that several years back we to use several empirical formulas inaccurate and because of that you might seen seventy's and eighty's several numbers of failed because of differential you know leg moment Now, a day's what we do is we have finite element softwares where you can model all layers of soil including the spud and try and evaluating them reasonably correct So, that is one of the advantage in the recent time we have computational devices like this there are several softwares available to do such kind of whereas, ten twenty years back you might even we not able to model using basic soil mechanics equation, and also enable to predict based on the empirical formula's available from research that is where you will…

(Refer Slide Time: 11:52)

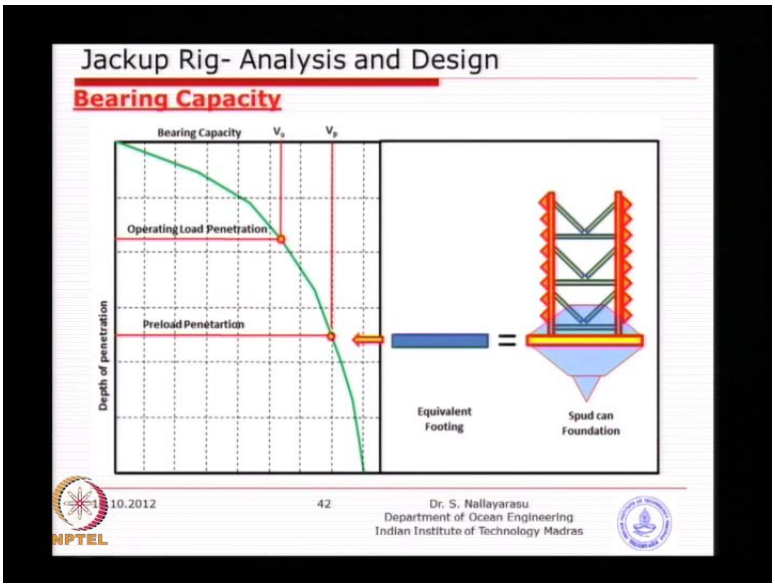


How we do the bearing capacity evaluation there are several ideas. So, one of them basically assuming pin condition spud can because if you look at the overall global behavior what is going to happening is the going to have lateral resistance only coming from the spud of the bottom with the reaction and also on the legs is a leg is not a circular pipe you know. So, the resistance will be where is small.

So, you will be almost looking like all the three legs are pined at the bottom and trying to rotate. So, the stability is going to coming from the distance between the legs the larger the distance what will happen The overturn stability will be better of Stability analysis of on individual footings can be assumed with also boundary condition called this and then displacement check based on non-linear soil structure interaction this is where we need to go and get the help of the computational softwares simplified method will be very difficult So, we normally do one of the software called we have got several other softwares which we can use the software we also have a license in our department there is a time.

So, the first step is getting the bearing capacity and sliding resistance is the important idea how do we get it? Model the spud can as an equivalent circular for plate; that means, we trying to approximate you can do that first exercise just equivalent circular disk evaluate using simplified formula as long as your layers are reasonably you know constant not varying to much and then you can draw bearing capacity chart something which I show in the next slide basically a variation of the capacity versus the depth penetration just like what we are doing for pipes I think next time we will be doing that and using the curve find out what is the required preload to achieve a particular depth penetration.

(Refer Slide Time: 13:51)

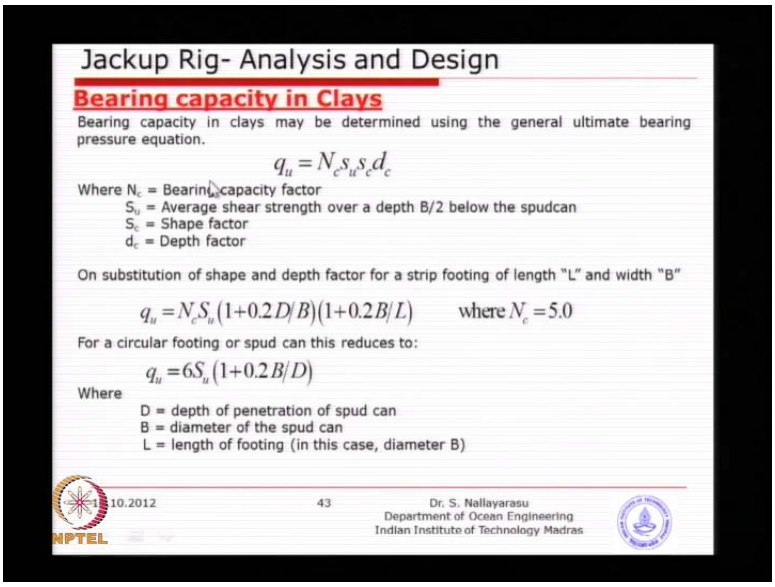


So, if you look at that basically something like this you know the green line is the capacity chart; that means, every meter of penetration of the spud can what will be capacity achieved because every time when you go down the soil slightly getting better and depth of penetration you get a over button pressure on the side So, the larger over button pressure you will discuss detail in the next course basically larger the soil pressure you will get better capacity because it is not a living the soil to move way and move out. So, what we are achieving from this graph is basically trying to find out what it is load at the time of operation.

If the relationship between the bearing capacity and depth is slightly like this we should very happy Because it comes increasing in a on linear there is no big zig jack Now, if you have a load we need to find out what is the preload require for achieving this penetration from this graph then you go back to your jack up and that you know the thanks to get the preload and you will achieve the penetration So, basically these two will be the most important numbers to remember one is the operating load and the other one is preload. So, at both condition s you should achieve a whatever required by the code when we were designing foundation systems we normally design of the at least two or two and half is not it. So, similarly here we need to find out what is the capacity and then design it here.

So, basically this V p is the preload V naught is the load at the time of normal operations like drilling and positioning. So, basically that is the idea. So, the approximations what we have done is is made equivalent as a circular disk which is penetration into the ground to the depth of x meters t that depth what could be the capacity.

(Refer Slide Time: 15:51)

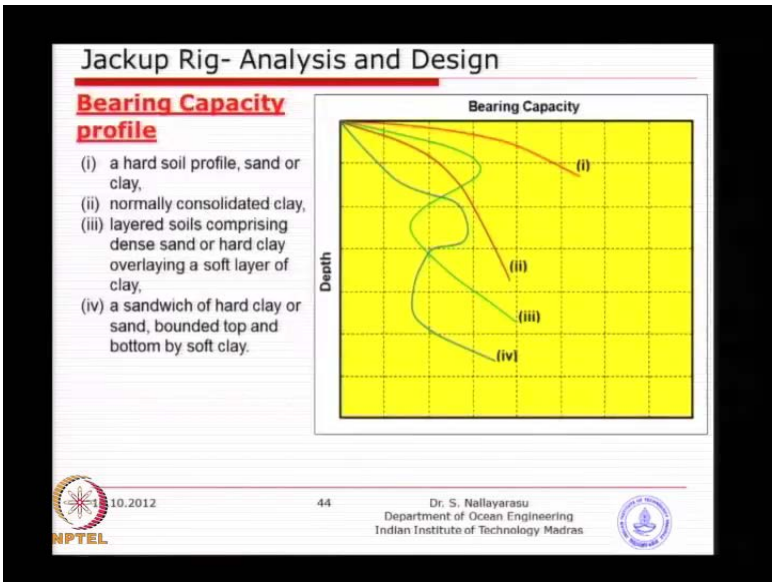


So, what we need is every penetration we try to evaluate the capacity by this equation basically I think those who have studied soil mechanics will be able to understand the idea is basically if it is a clayey type of soil is related to undrained shear strength and bearing capacity factors which could be easily derived this equations hardly takes five minutes to derives by based on the this type of analysis which we will be doing it later in the next course. So, basically the ultimate bearing capacity at the time of failure can be computed and we could prorate it to working capacity by means of a factor of safety.

So, this is the generic formula for the footing of size b and l whereas, if it is a circular footing we could substitute the shape parameter and the depth parameter and ultimately we will get a equation which is six times s u with a depth parameter the deeper you go you are going to get a better capacity because the soil will be better. So, this is just for the idea of how the bearing capacity can be related to soil parameter the importance what i wanted to conclude here is it all depends on the the shear strength of the soil here which is basically the clay characteristic if it is a sandy material it would be slightly different formula which you do not want disposing this particular course. So, basically soil

parameter and depth of the foundation size of the foundation shape of the foundation all are important to evaluate the bearing capacity using this you could derive a graph something like this basically the relationship between capacity and the depth of penetration of the soil of the soil.

(Refer Slide Time: 17:35)

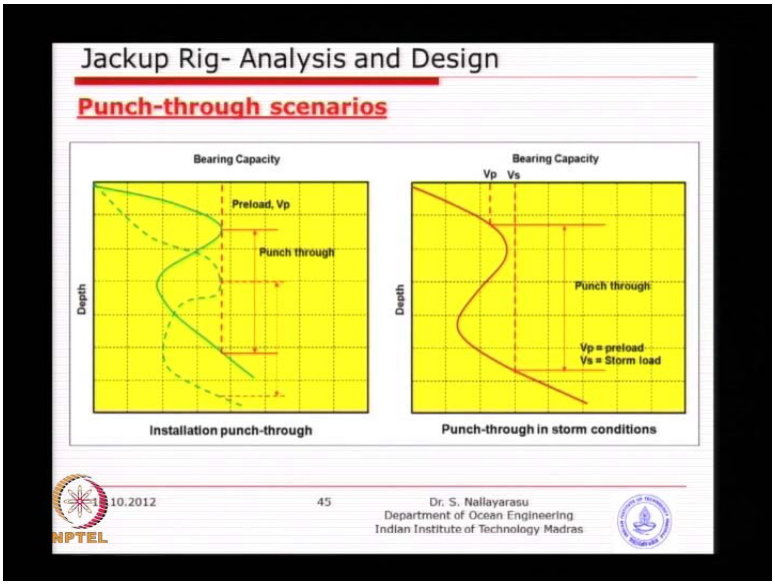


If you do the same thing for different different you know locations for example, just a typical case what I drawn here you see there are four four relationships bearing capacity versus depth the first one the red one is good is basically capacity is increasing reasonably high as you achieve a depth of says several meters, but it is going linear almost linear slightly non-linear whereas, if you look at bearing capacity is increasing and then suddenly start to decrease because this increase is local because of the strong layer it could be a sand or it could be a better clay, but then below layer you have a soft material this type of ah sand layers are very often to the encounter in the offshore you will have sub material good material and then you might have a material which is having least strength and this is where the problem the problem because you will be finding it.

So, difficult to penetrate that better material during the course of installation because this spudcan penetration is purely based on weight and the weight that we are going to into unless do you like for example, when you are having a pile foundation you do not you actually have a hammer which can we drive to whatever penetration required whereas, in the case of jackup, we cannot do it we cannot bring a big hammer and drop on top of the

jackup jackup will be gone case. So, that is exactly the problem the problem is during installation you will find it difficult to penetrate this. So, you will end up this stopping your spudcan at the top of this which may not be sufficient later on in the case of storm that is where the issue. So, we need to find out the shape of this bearing capacity graph that is why I started with this nice graph where is gradually increasing there is no sudden increase and decrease of capacities which is a good place to whereas, if you look at this comparison first one and two may be good all depends on the soil profiles I have just given a hypothetical soil description the layer descriptions you may not exactly get it, but situations are going to be similar like this three and four. In fact, three is not at all suitable. You get a very large capacity at the very shallow depth, which is going to be a big problem, because the zone you get the capacity exceeding this, this point, suddenly it is going, go down to several times deeper. For example, if you if you have a capacity, which is not enough, you need a capacity more. If you want to get this one, you need to come from here to here to achieve this is capacity. So, you will see that the depth of the penetration going to be substantially larger which you might find it not suitable, because leg length is not there. At least the fourth category is good as long as you can make sure that you are going to exceed this capacity of the operating condition as well as the maximum during the sump condition.

(Refer Slide Time: 20:58)

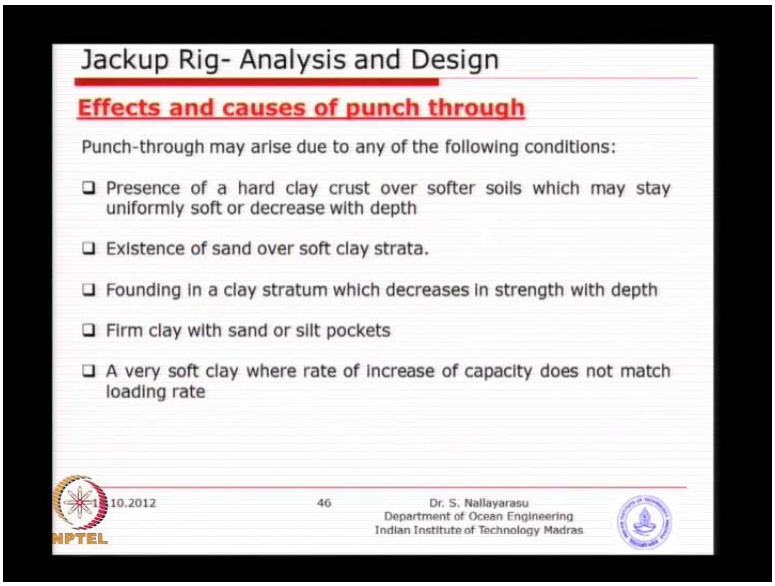


Despite doing this you still can do a evaluation, for example, you will look at the first one installation punch through, you were trying to actually go and get a capacity of

something like this, whether we should stop here or we should stop here, it is judicial decision. Example is, you need twenty mega newton capacity, you get exactly twenty mega Newton capacity at this point,, but then can we stop there. If you stop there later there is slight increase what will happen, the leg will just failed. So, at that time itself, we were decided to stop the spot can here, by somehow penetrate it put more preload and that will be more safer than stopping it at this particular point because it is only a local capacity, and that soil thickness or the layer thickness are. So, small. There is more chances of leg being penetrated there.

So, if we come to the right side, if you only consider the operating load, I think this V s is the basically the preload that you have which is going to be stopping there and during the storm condition if the load becomes higher than the preload then what will happen, you will get a punch-through. So, depending on situations you will have to decide,, but in this particular case, this is the type of soil we have to be careful just change the spud or change the rig itself. So, this punch-through is one of the primary aspect, most of the codes that ask you evaluate this prior to finalizing a jack up or that particular location.

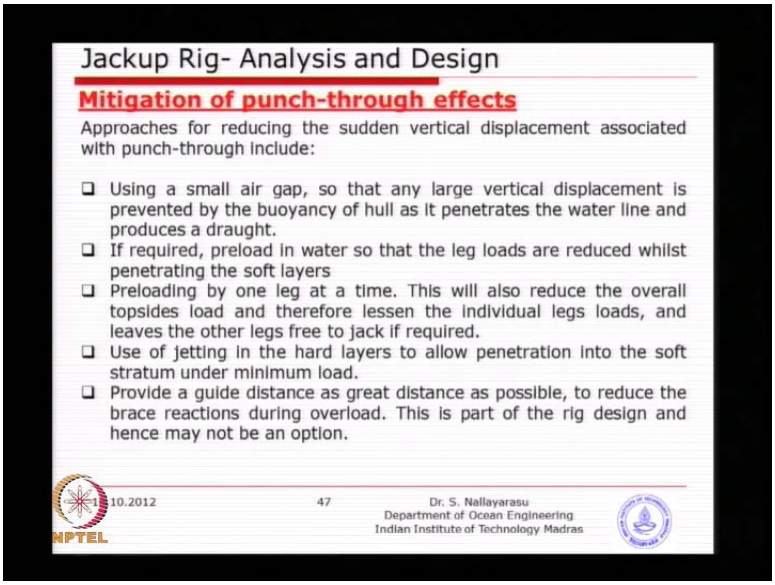
(Refer Slide Time: 22:40)



By this, I think by this you will have a clear idea of what is the cause and the effects. The effects is very clear, the jack up does not have much of, you know basically the redundancy in the system. One of the leg fails is almost the jack up is gone. So, the effect is very easy to understand,, but the causes are multifold. It could be due to differential

settlement, which I think some of the failure mechanism we saw yesterday also. You know it could be a small displacement at one location,, but subsequently the jack up starts tilting, because of the large moment generated by that effect because the leg reaction changes. And then there will be a overall over turning stability, which could cause more reaction to the soil on one side which then becomes higher than the original capacity and gets penetrated then punch-through can happen. So, it basically a sequential operation of one problem can cumulatively add and create a final punch-through. Several reason which I have mentioned basically, we have seen this one in the picture hard layer, soft layer, existence of sand over soft clay strata which is one of the scenario there. Firm clay with sand and silt pockets, you know basically can punch-through very soft clay where the rate of increase of capacity does not correspond to the loading rate, basically the along the depth.

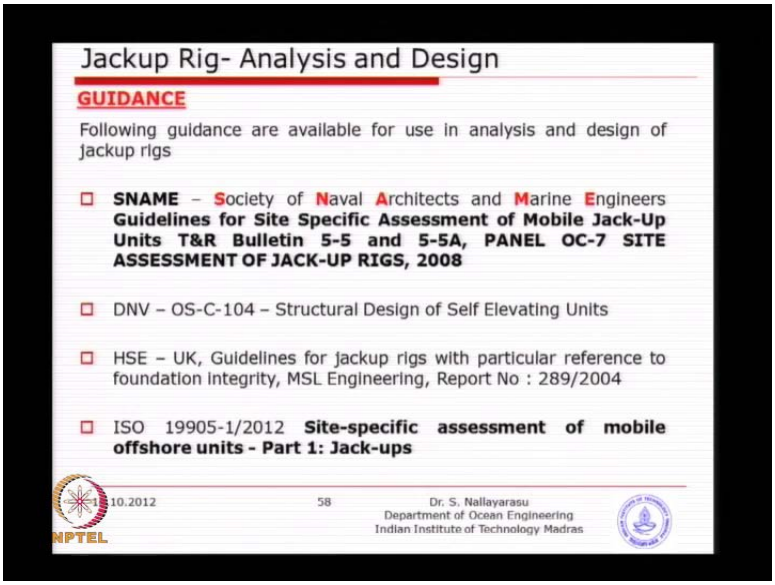
(Refer Slide Time: 24:13)



What the mitigation measure we can do is basic idea is, evaluate during the pre installation process. You know, if required the preload water, the legs are reduced while penetrating through the soft layers, basically you just make sure that able to control the preloading process. Even if it is going to happen during the installation stage,; that means, during the process of lowering the legs and penetration you are able to pump out and pump in water. So, that in case of problems, you can remove some water from one side. So, that you can slow down the process of the punch-through, if you are not having control, just you can only see and watch, this is going to just keep on sinking. So, there

are several activities that we need to keep in our mind that we can prevent the punch-through and follow several guidelines like distance great from the disturbed soil, to reduce the brace reactions during overload, basically the punch-through locations.

(Refer Slide Time: 25:29)



I have given some of the guidelines, which I will just show you. These are four guidelines, which I have taken some of the information. I have I think most of them are available in our library – three of them are available in library only this is not available, because this is recent one. The first one is you know the Society of Naval Architects and Marine Engineers, which is downloadable, I think you can download, it is free, so which gives reasonable guidelines on engineering and installation of Jack-ups.

The second one is basically only the structural part which is a similar to any fixtures offshore structures, Structural Design of Self Elevating Units, which is like Jack-ups and other systems. The third one is only a guidance, it is not mandatory, it has got reasonable information regarding all the hazards like what I have discussed for last three-four classes. Possible hazards, possible mitigation methods which is basically a health and safety executive of UK department of energy, which is give us a guidance only. And the last one is compiling all the information together is a very good document, which I am trying to get a copy, old version I have – Site-specific assessment of mobile offshore units, this is basically including the floating as well as fixtures.

You know in case of semisubmersible or drill ships, you have moiré system and their safety, whereas, in case of jack-ups is basically the jack-up legs penetration and associated. Here you will not find anything related to the hull, whereas, in this you will find lot of information and the design and the process regarding hull itself. So, you can see the distinctive paths, this DNV will not talk about hull or soil, it will talk about the structural design of the legs and structural design of the hull as the plated structure. Whereas the HSE-UK department of the energy guidance will give you all the possible the ideas what can happen during installation and operations. So, it is actually a comprehensive collection which you could use it for the purpose of learning more. I think will stop now.