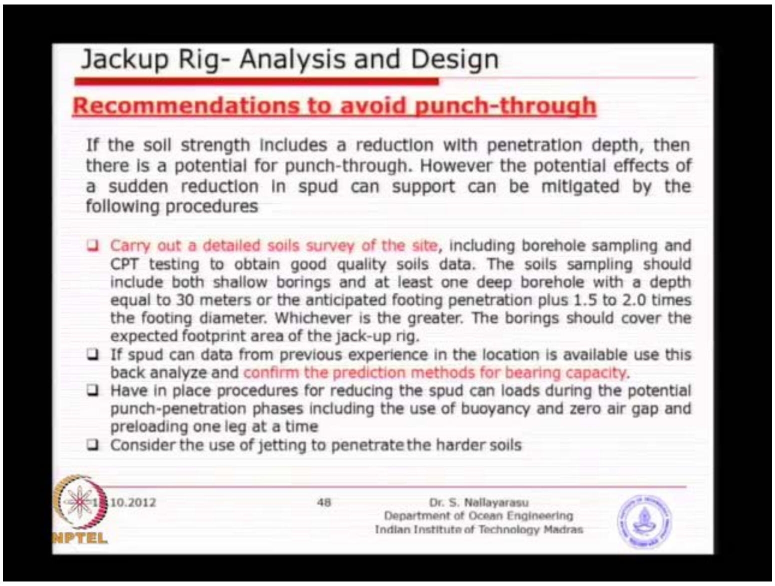
Design of Offshore Structures
Prof. Dr. S. Nallayarasu
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module - 05
Lecture - 05
Jackup RIGS-Analysis and Design 5

(Refer Slide Time: 00:13)



So, yesterday we were looking at the punch through as a major problem with installation. So, what can we do to avoid this basically you should do a proper soil investigation. That means more than one borehole and then deep enough to understand a soil behaviour. You know that is the main thing that you can primarily do it, in order to avoid any punch through. You know you have sufficient data and you do an analysis and all the possible mechanism of a layer. Now, the minimum soil borehole you go for minimum 30 metre or this seems to be not working, or one to two times the width of the footing.

Basically, you will know the reason why we need to do this, because when you look at the pressure bulb of the footing. When the vertical load is applied it will just deaminize as you go away from the footage. So, if you go far one to two times the diameter deeper then the ground surface. Then you will be able to see the minimum pressure at the bottom of the two times the width of the footing.

That's why we do it, at least for one and a half to 2 diameter or 30 meter, whichever is most of this spud can penetration in a 70 to 80 meter water depth jackup's not more than 30 meter. If it is 30 meter itself is substantially high, because if you look at a 70 meter water depth jackup 70 meter plus another 30 meter. So, 100 meter leg, when it is been towed 100 meter will be sticking above the hull.

So, when you are when you are bringing from one place to another place. The complete leg has to be above the surface of water or just little bit below water line, but most of the leg will be sticking above. So, imagine if you need another 70 meter leg penetration typically 70 plus 71, 40 meter, it will be sticking up. So, that is why the limitation not many of the jackup's will have penetration more than 30 meter typically.

So, that is why this 30 meter is a generic depth operation, but what happens is most of the time, when you are doing a jackup installation at one particular site, where the Jackup is already there. Or jackup is going to be installed there mostly we do a borehole of 100 meters, because for jackup type of structures we need deeper penetration. So, there you will do anyway. So, in such cases you can use that borehole plus additional borehole for the jackup, because when you look at jackup footprint is larger. So, you may do one or two.

So, the primary idea of doing more soil investigation is to understand the soil behaviour under such loading, then this bearing capacity. Sometimes, you use empirical methods using Terasaki or other methods, but then you can also do experimental studies come up with correlation for other particular site and difficult sites. We know sometimes we do this exercise of prediction methods of barring capacity to be confirmed by alternate methods. The best way of actually avoiding punch through is to sufficiently penetrate.

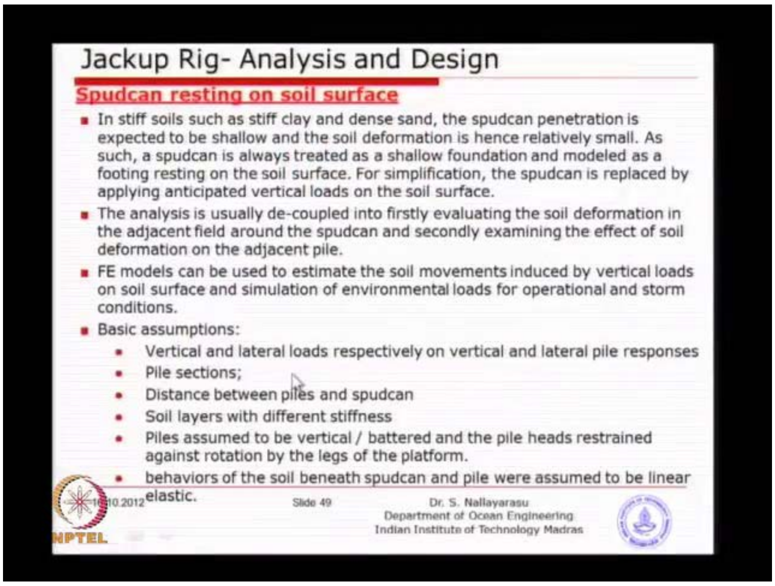
I think yesterday we were seeing one of the issues. You have a increased capacity at shallow depth and then going down you have lesser capacity. So, the best way is to go and break that particular layer you know by means of jetting. This is what I was normally we do not do jetting in case of penetration. We want to take it all because during jetting you know very well that the soil is getting disturbed too much.

Normally, we use the jetting for taking the leg up. So, in this case what we are trying to do is, basically when you have a soil layer either very shallow or may be mid depth. That it is not allowing the leg to penetrate. So, you can actually do a jetting to break through.

In fact this is true even for the jackup piles when we encounter a early penetration refusal, we try to do alternate methods of breaking. That layer trying to go down and then. So, sufficient penetration is there that means you may not encounter the punch through.

So, this are some of the ideas that you need to try and do this. Sometimes, when you have spud can resting on soil surface unable to go any further like a very hot soil. Basically, the capacity calculation will be very similar to spread footing. Basically, what we are trying to assume is the horizontal load is going to be taken by other means.

(Refer Slide Time: 05:02)



We need to look at how they can transfer because when it is laying on surface. So, that means only a frictional capacity can be available no lateral expression will be available, because it is not penetrating enough. So, in such case of basic in a spud cannot able to penetrate. Then we may have to look at various other aspects of introducing alternate mechanisms, one of such mechanism is basically provision of skirt on the spud can.

So, you have a circular part with an inclined surface, but also can provide a skirt. All around skirt is just a vertical surface, which will penetrate down to a slightly better distance. When it is trying to go horizontally the skirt will provide a passive resistance. That is where we are trying to come back. Calculate the passive and active resistances one side is passive and other side is active, because it is trying to slide away.

The horizontal resistance is going to be coming from weigh times the friction factor between the steel and the soil. Basically, the heavier that you create the vertical reaction more will be your horizontal resistance against moment, plus the passive and active resistances coming from the skirt foundation.

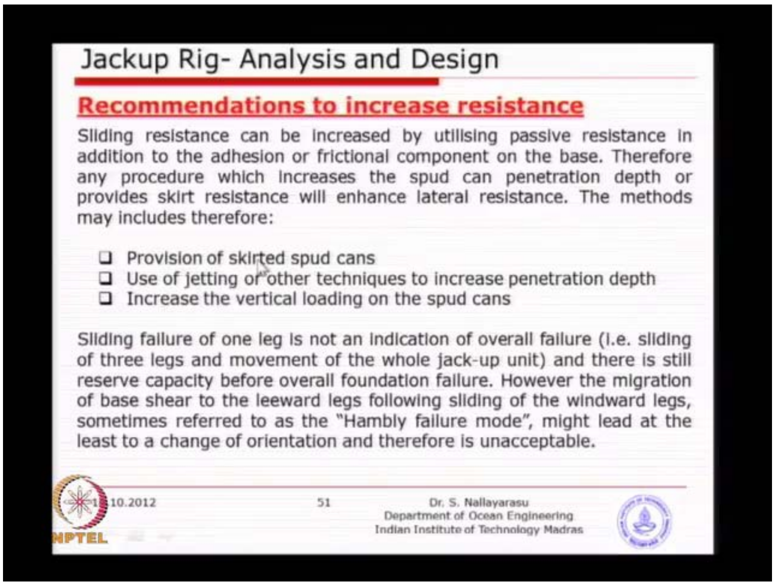
Basically when you have applied inserted into the soil. Whole system is trying to move there will be active pressure from the soil and up streamside and passive resistance, from the soil under down streamside. So, which active is active together with the load itself, because when you are actually system is defecting this way. Plus, some soil is acting as a active pressure, which is going to be part of the load itself. That is why we are deducting it and the passive one will be the resisting from the opposite direction.

So, basic stability equation is this the delta is basically the angle between the slope of the cone conical surface of it is not a flat surface. So, basically that will give you only the component the remainder will go as a vertical. So, the total horizontal resistance is obtained from friction between the steel pile, the steel soil interface plus the active plus the active minus the active. Some of this will give you the total resistance in case partial penetration of skirt the spud can or slightly on the surface with a skirt.

So, this sliding resistance whenever you are fully buried into the ground. For example, the spud can penetration is 15 meter. You will also get some amount of active passive resistance from the skeletal structure. You have the three legs you will have the braces which will be difficult to calculate, sometimes very difficult to calculate. So, you can actually do a equivalent surface calculation and add the active passive resistance from there, but normally they will be very small.

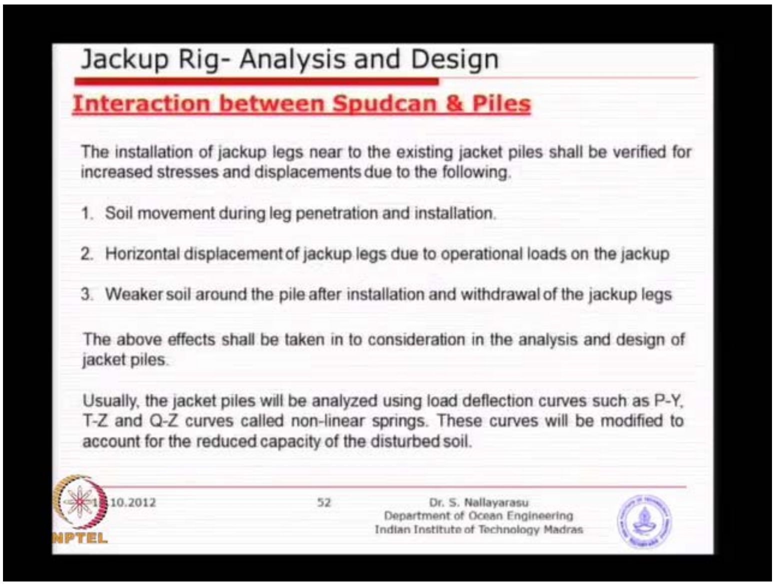
So, most of the design practice we ignore the resistance from the leg itself. What I mean the leg is just above the skirt the spud can. We only take into account a solid spud scan surfaces for active and passive resistances. As I mentioned earlier, you can increase the capacity by means of provision of skirt use water jetting to increase the depth of penetration and increase a vertical loading.

(Refer Slide Time: 08:24)



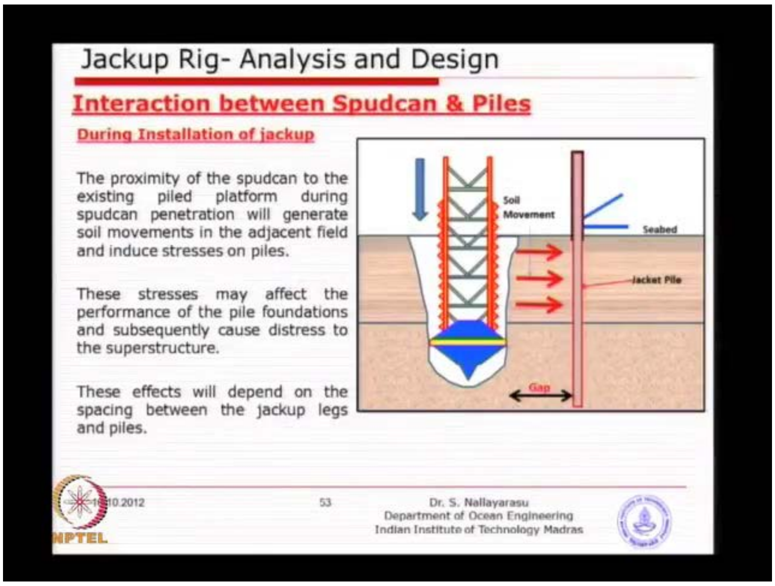
Spud can just to get additional, penetration into the better ground surface. So, that you will get the better capacity. So, all of them in a way is a well known practice .Most of the time we do this you know the increase the vertical loading by means of ballasting. So, as much penetration you can achieve, then you can have a modified spud can by means of a skirt, which is easy to do it, but the last technique of increasing the penetration by means of jetting, normally not practiced. Because, permanently it may change the characteristics of soil and you loosen the material, you may not get sufficient fixity.

(Refer Slide Time: 09:14)



So, I think by now this time you have already got a idea of what is really happening. When you put spud can into the below mud line and then you install this spud can or a jackup near a existing jackup. We need to understand what is being done to the existing piles to the jackup, which you have already installed. So, what is going to happen is soil movement during leg penetration. When you are just pushing the leg down and down soil squeeze away and get compressed on the sides and trying to go. And push the jackup sideways when the pile is just few meters away 5 meters, 6 meters or 10 meters. So, this soil movement will introduce substantial horizontal pressure on to the existing jackup pile. So, which you could see in this picture this is what squid happened, the cause or the distance the soil is going to push and create additional stresses.

(Refer Slide Time: 10:00)



It could be possibly a large bending stress, we already have a actual stress coming from the jacket and wave loads and dead loads will create. So, this movement of the soil is going to affect the behaviour, the larger the distance this effect or introduced bending could be smaller. Because, by the time the soil dispersion will happen soil will already transfer the load to substantial distances away from the pile. Whereas, you can keep it closer then there will be good amount of movement. So, this is one thing that we need to look at very carefully, how much is that sensitivity of the soil if the soil is rocky material or a good material the effect will be less.

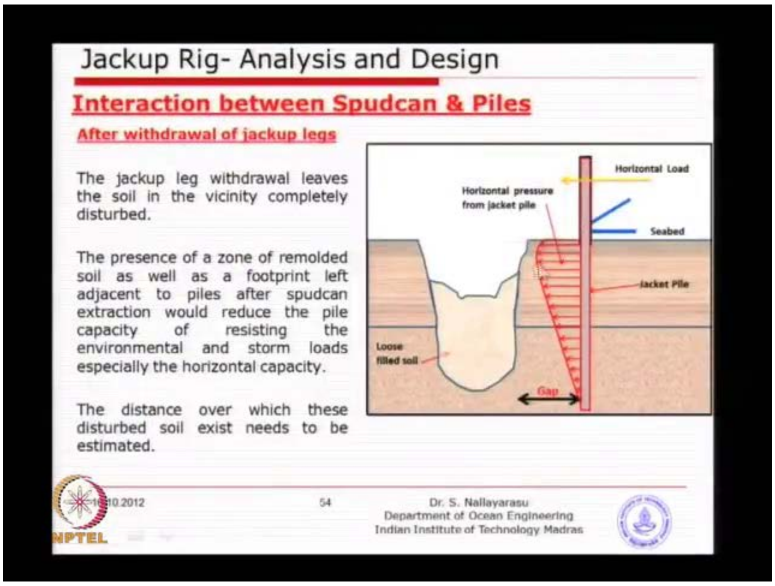
If it is a soft material it is trying to get displaced. That is why you will get a larger stresses. So, how do we evaluate this is biggest question until today there is no easy practise of doing this. It depends on the type of spud can, it depends on the type of soil depends on the location. Several research papers have been established, but it is all specific to one location is not possible to generalise.

So, every time we may have to evaluate number of experimental studies on this aspect is very limited. Because, of complexity of doing such an experiment is not available. In fact one of two experiments over last 30, 40 years. That means you have to go to the laboratory similar to understand the soil condition bigger challenge. You bring a soil sample and create a soil set up, which is going to be very difficult. That is why most of the studies on this particular idea is only empirical or probably finite element and that kind of simulation, horizontal displacement of jackup legs, due to operational loads under jackup. For example, when you have a jackup like this when the sea conditions are coming from the left side. For example, sea waves creating loads on jackup on this side.

If the jackup is not having sufficient fixity or it is flexible enough. It can actually move and create additional soil movement, which can be larger. Because, the jackup is about 60, 70 meter or 80 meter long and the leg penetration is only small. So, when it's trying to deflect like this I will show you deflection sea. Later on from an analysis you will see that at least half a meter, you know simple sea state. It can move left and right and that kind of movement can cause reasonable soil disturbance also can get loading from there.

Then the last the weaker soil around the pile after installation and withdrawal of Jackup legs. This is one of the major problem you install it and then leg is removed. So, by doing this what happens is you create a big crater. Something like this of course, is not going to stay empty all the time, but at least for one instant of time is going to be empty. When you remove the leg at that instant of time soil is not there. It will be just a opening and not small is about 5 to 10 meter 20 meter diameter. That amount of soil is completely removed of course, over a period of time. Then slowly the soil will collapse from the sides. When the soil is collapsing from the sides, then originally is 20 meter diameter.

(Refer Slide Time: 13:28)



Actually the diameter at the surface will increase, because soil is keeps on collapsing by doing this. What happens is that distance between the collapsed surface to the pile will slowly reducing because soil is trying to collapse. Of course, some amount of soil will get settled and then form better behaviour, but still near surface you will see a big opening kind of thing. This is a bigger story, because when you study the behaviour of the jackup pile. Next semester you will be going in more detail you will see that the soil need near the surface matters a lot, because if a soil near the sea bed surface is very weak. You will see that the whole jackup is going to deflect a lot and by deflection. You will see that a large bending movement will generate and stresses will be higher.

So, here we also need to worry about what is the soil and what is the characterises of this filled soil, which is not known because you have done the borehole before you bring the jackup you already have studied some taken the soil sample go to the laboratory and then investigated and then you got this trend , but after the jackup is gone nobody is doing the borehole investigation. We do not know what is the strength of this soil that you will be using for design of the pile, because already pile is installed now. That means you have to pre think about what could be the disturbed soil strength.

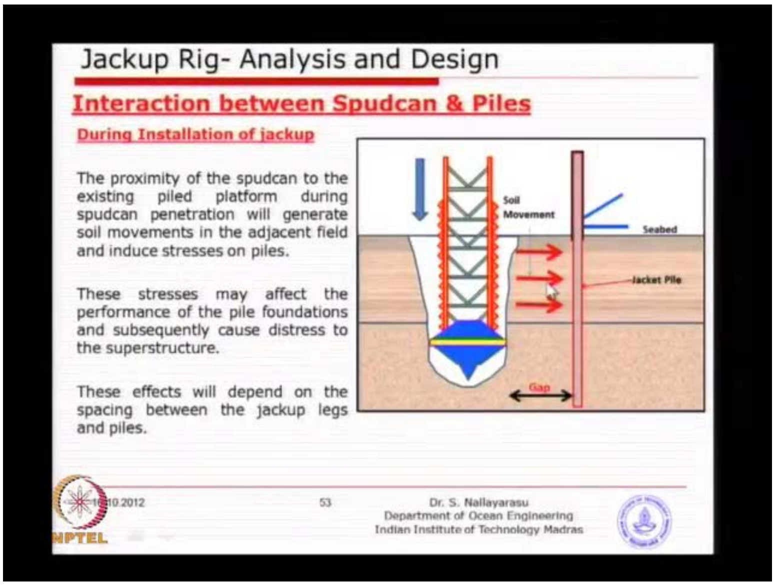
If you want to use the strength of the soil at the time of design of jackup, which is unknown, because you will never know what type of disturbance will happen. The best think what we can assume is the soil is not present there. Because, then you can assume that is the worst case scenario, that the soil presence is not there complete hole.

Only the soil is available between this point and this point and smaller the distance the effectiveness of the soil against, the pile movement will be smaller or larger depending on the thickness. So, basic idea is the assumption of no soil is the worst case scenario. Partly filled soil with some kind of characteristics, which can be assumed depending on for example, if it is sand almost in few days, time this will get filled. Then get into a may be fifty percent characteristics.

If it is a clear soil it will take a longer time to achieve any strength characteristics. So, quite a number of studies theoretical studies with laboratory as experimental verification. We call it sensitivity of the filled soil. After how long it gets back to original strength? So, if you know that characteristic the relationship you can use after ten days. You will get only ten percent 15 percent of the original strength. So, you can use that characteristic to design the jackup pile

So, basically the interaction between this spud can and the pile is nothing but how the spudcan installation. The removal is going to influence the design of pilem, which is not known at the time of design of pile, because we have not done that. So, we have to assume certain characteristics they have to assume certain distances. Then design the one of the important thing is to develop the load deflection characteristics for the soil, which I think is a full course you will be doing in next semester of developing this. So, called the non-linear soil pile displacement characteristics, which will be used to design these piles. Basically, what we are looking at is vertical displacement associated with the particular load. Horizontal displacement associated with the unit load for the soil, in and around this pile. So, you will have certain soil.

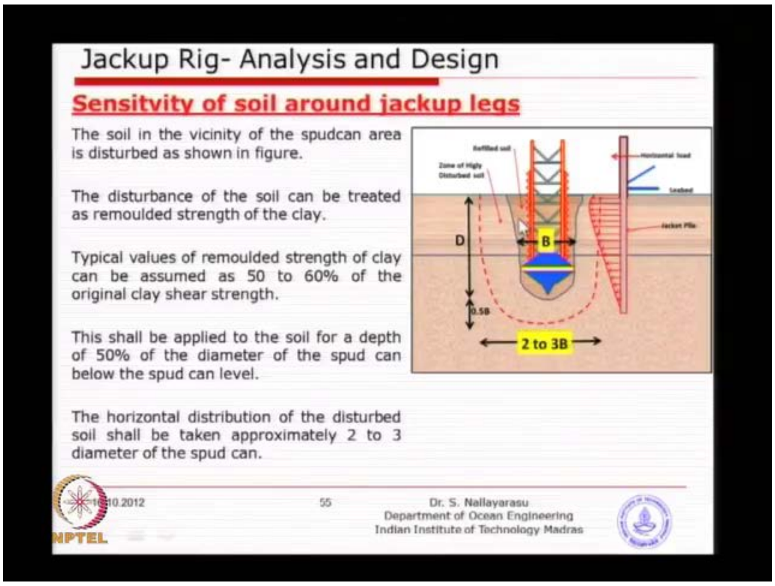
(Refer Slide Time: 17:24)



For example, you will have this opening is not there then this soil is infinitely available for resisting the pile. So, then you can take a soil testing and relate that to displacement and then come up with a relationship. So, here we can use linear springs non-linear springs will talk about it in the course. So, that is the idea behind why we need to know is the type of soil and the disturbance created to the soil. Then develop a low deflection characteristic, which will be used for design of jackup piles

That is a is a exercise that requires large time, because you may not be do it by empirical methods. Number one, experiments is not feasible, because it involves too much of money and time. So, what we will do is some code guidance is available from A P I and some other course. So, we will try to follow that if you look at the sensitivity around the filled soil. Of course, after several weeks of time the soil is filled before, we start up the removal. You will see that the soil is available to some extent may be not full slightly smaller, but the characteristics will be definitely different from characteristics of soil in the near vicinity.

(Refer Slide Time: 18:42)



Now, if you want to develop a low displacement graph for the this particular location. If the soil is same in nature for continuous say several meters of distance from the pile. Then you will take that characteristics and develop using whatever the existing methods, but you see here on this picture slightly few meters away you have a different characteristics soil, which is shown here. Now, what we need to do is very similar to layered soil horizontal layering. You have got different soil at different distances.

So, you need to calculate the combined behaviour of the soil near the pile. Slightly away of course, if this soil is very far the effect of that may not be much important. So, typically from various literatures. Of course, I have take this one from guidance from H S C notes. As long as the location of the spud can and the pile spacing is away from one and a half to two times the diameter. For example, the pressure bulb if you look at the pressure bulb or the disturbed soil is so much.

So, it is almost like two to three times the diameter of the spud can. So, if you look at distance of centre from here to here. If you limit somewhere around more than one and a half diameter of the spud. So, if you have a ten meter spud can you go for 15 meter. What we are trying to conclude is the effect of the soil disturbance will be slightly smaller not completely removed, but 15 meter is a lot of distance. Because, if you want to keep from here to here 15 meter you look at all other parameters go up.

Then look at it you drilling may become problem. Most of the time you get about typically one diameter you know not one and a half, but that is true for smaller spudcan like 10 meter. Suppose, if you have 20 meter spud can, what will happen that, becomes very large, which may not be feasible to operate a jackup brick. That is the time that we need to look at many of the platforms that we are designing.

We assume that the soil is completely removed and design it. So, you are paying additional cost to this piles, because you are going to make pile diameter bigger wall thickness. So, that even with no soil the pile is able to survive, because you have to design it If that happens the jackup will fail. So, the sensitivity is basically what is the kind of disturbances and to what extent. So, the horizontally about two to three times diameter vertically about half diameter is a kind of reference, that you can refer without doing specific study.

You know why we need to know about this vertical distance. Sometimes, what happens you may have a pile going inclined like this instead of vertical pile. If you have pile battered in the front phase. Also, you know you come across or go across this line what will happen there will be a vertical loading transfer into the pile itself. Because, the pile is just on the line of spud can. You want to go away from it. So, that is that is one of the area, where we need to make sure that sufficient distance is available between the pile surface and to the vertical line of intersection.

So, the next one is pontoon design I think we need to just quickly look into naval architecture part of it, which I think most of you may be doing in another course called design of floating systems. I think in the next semester or may be on the third semester. So, what we need to look at is the hulls trend the buoyancy requirement stability. So, three aspects of course, structural design pontoon is simple. Just designing a steel structural system to resist vertical loading, which is coming from your super structure, and the buoyancy loads.

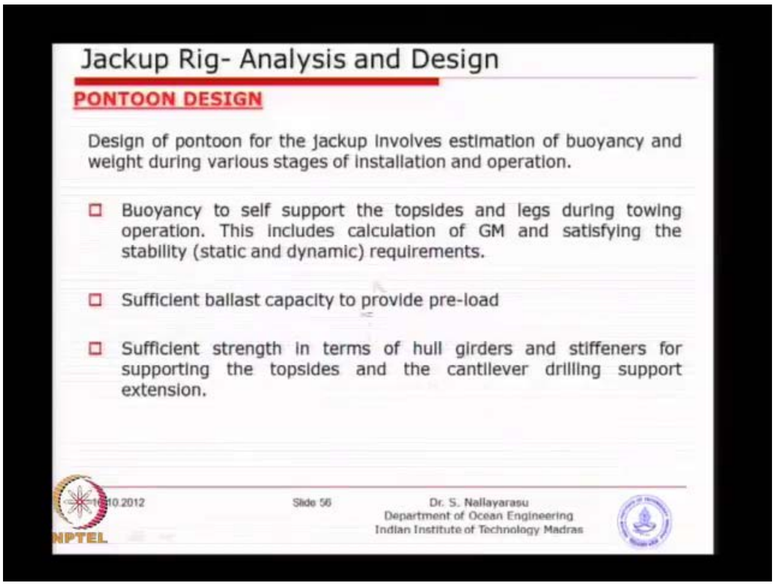
Basically, steel design I think what we have not learned in this course is the plated structures. We have learned about tubular numbers, which is I think most of you predominantly able to solve given the bending moments forces. You are able to come up with diameter wall thickness. Now, the plated structures behaviour is slightly different. You know it’s going to be thin plates. So, stiff end versus un stiff end plate theory. You have to learn, which will be coming in one of the course. I think we will be teaching you. So, plated structures versus non tubular structures like beans channels, which I think one or two classes. Next week we will try to cover.

So, design of most of the hull structures for either ship or for this kind of pontoons or any other floating systems heavily involved plated stiff end plated structures. The reason being you know tumulus can be used, but of course, for columns we may use some of the semi submersible circular or semi circular shapes, but for ships and this type of pontoons. We normally use a plated structures. So, sufficient buoyancy how much is a sufficient buoyancy. So, basically we need to have buoyancy higher than weight what will be that percentage of higher all depends on, you know what will be in your freeboard.

Normally, we talk about 10 to 15 percent reserve buoyancy. So, what is reserve buoyancy is basically the reserve buoyancy percentage in terms of weight buoyancy. So, total buoyancy minus weight divided by original weight. So, you see the buoyancy about 10 percent is more than enough, but most of the sea going vessels and ship, we keep slightly higher. Because, we should be able to adjust the freeboard depending on the type of conditions you are in operation, but most of the temporary situation.

For example, like floating structures temporary, we keep about 15 percent. We may keep more than that like 20 percent 25 percent depending on the design, but not 100 percent. So, most of the time creating reserve buoyancy is also going to add weight, because you need to make the pontoon size bigger. So, that the buoyancy will be larger. So, this buoyancy calculation is very simple volume times submerged volume times here sea water density.

(Refer Slide Time: 25:22)



So, you can here calculate easily as long as you know what is the weight of hull, which is you require a design. So, is not a single step exercise, first you need to do a few iterations come up with the plan, area of the rig required come up with dimensions. As soon as draft freeboard assume thumb rule exercise of estimating weight. So, you may have from history, so this type of jackups may be two thousand tons take that verify the buoyancy required. Go back do a preliminary plated structure design for vertical gravity load buoyancy. Then come up with weight re calculate the buoyancy and then go back again recheck the design. So, it’s just a few times iterations, once you do this you already have the geometry. We already have the structural design plate thicknesses size everything is available re verify the buoyancy. So, that when you put this system it will float definitely float.

Then you can go on to calculation of G M and stability parameters, which is purely you know, which you never will be learning in the floating systems design. I think most of you might be knowing G M calculation centre of buoyancy centre of gravity. I think in your full mechanics you normally do it, but other than that you need to look at the static and dynamic stability, due to external forces and come up with positive G M. If the G M is positive the system will be stable. So, that is exactly you need to look at static stability. Then disturbed or dynamic stability you need to look at, so that the that the hull will be not capsized.

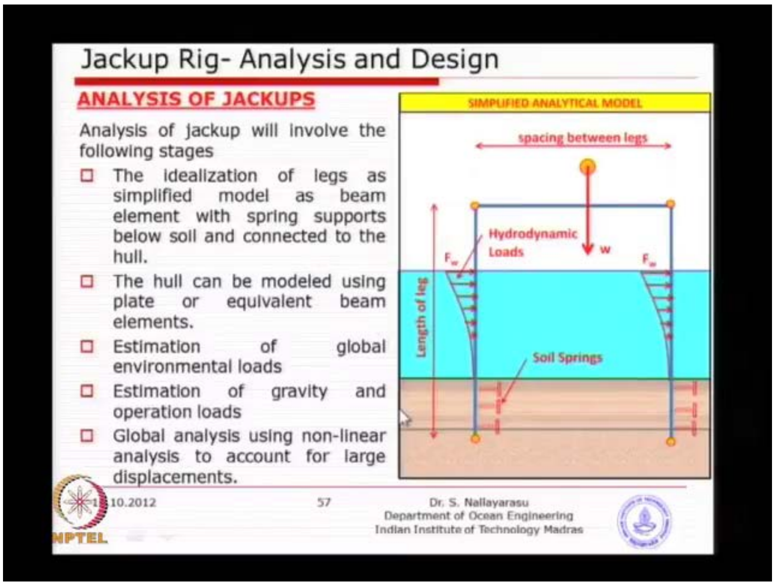
So, basically it will fall up right with minimum disturbances to the systems, that is installed up there. Then next one is sufficient ballast capacity this is up front. We have to calculate you already need some amount of ballasting for stable system. For example, you already have a geometry all the tanks are empty, because you divided the compartments. I think I might have some pictures later on you already divide this whole compartment whole pontoon into several sub compartments.

You might feel little bit to get stability because you have to bring the C O G and centre of buoyancy for hours. It is stable G M will be calculated, but in addition you need a temporary ballast at the time of leg penetration. So, you may need another half a meter filling.

So, you need to make sure that you have sufficient depth in the hull. So, that when you flood water that amount is available. So, that is basically the provision that you have to make it though, it is not required during operating time. That means you will increase that. So, the larger you keep it the more chances of good leg penetration, because you cannot go beyond. Once you calculate particular amount of water can be filled you cannot go beyond. Because, the hull will fail because you are loading more than what is possible. Then sufficient strength in the hull basically design of a plate guarder plated structures to carry this weight of water weight of structures, installed in top either in fourteen condition or in supported condition.

So this pontoon design to some extent it involves various disciplines structural design hydro dynamics and then naval arc portion so you need expertise in all three aspects so that you can come up with a design, but as a structural engineer what you will be involved is trying to calculate the structural plated structures. As part of it you also can do a buoyancy system design. Whereas, when you come down to the static dynamic stability and see going characteristics. May be you might be not able to do unless you have that side of the knowledge. Analysis of jackup, there are several techniques available basically simplified versus detailed.

(Refer Slide Time: 29:47)

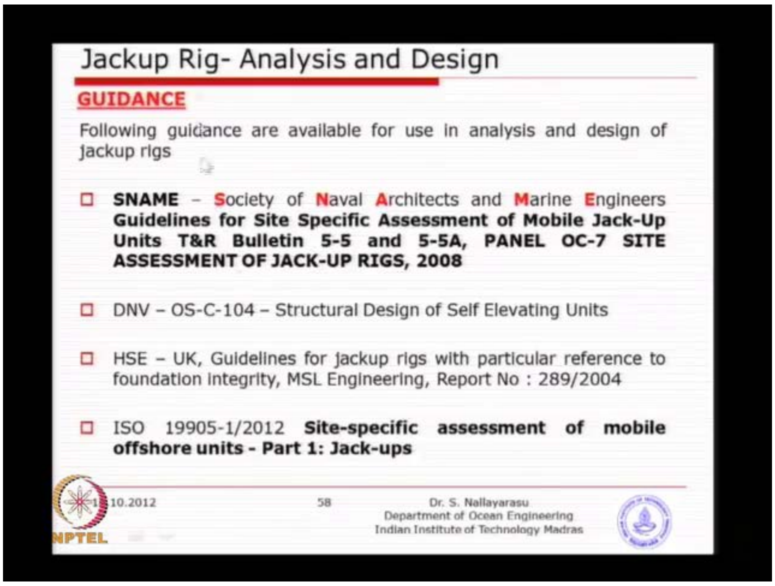


Simplified is initial stage, we try to do a simple pontoon frame analysis, not of course two dimensional or three dimensional. You can see here what we are looking at is equivalent leg diameter. You have a lattice structure, if you can come up with a equivalent diameter, because you want to look at the behaviour quickly instead of modelling so complicated structure.

If you can come up with equivalent diameter by means of equivalent you know the drag area and inertia volume. Then you can find what will be the equivalent diameter and apply that to this kind of model. You can find out what could be the maximum base year depending on base year come up with, whether the leg diameter have to be increased or the leg dimensions has to be increased. So, that quick study can be made and then later you can go into a detailed analysis

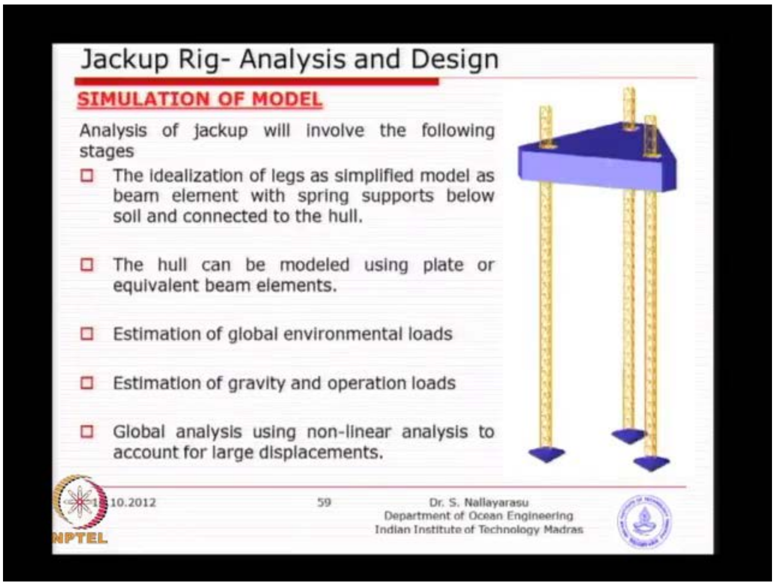
So, basically many times in the preliminary studies we do this type of simple analysis hull can be modelled using a simple plate element, one leg or one plate elements structure. So, that the analysis can be understood easily and behaviour can be predicted estimation of global loads in a simplified manner. Simple Morison equation on one single beam element you can calculate in five minutes. Gravity loads of course, you do not know in the starting. When you are designing a rig you have to collect information and apply and global analysis using non-linear. Because, the displacement of the Jackup is going to be quite large, is not a redundant structure. So, you may use a software, which has got a capability of non-linear load displacement characteristics.

(Refer Slide Time: 31:28)



These are yesterday this few guidance available, I think most of the information is available and one and four. Sometimes, you will use the other two also, the information on most of the sea going characteristics. The jackup rig leg up and down characteristics all available in the same guidance. And sight specific assessment, how you do a leg penetration leg removal is available in I S O, including little bit of structural design. Here, you will see that primarily structural design like plated structures. Then U K guidance is primarily on soil or geo techniqual aspects.

(Refer Slide Time: 32:20)

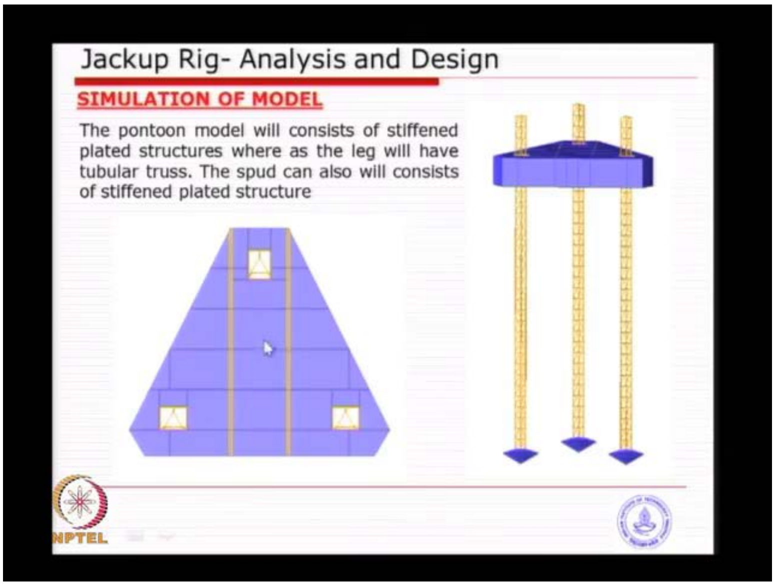


A typical one of the recent project is shown in here is 70 meter water tub Jackup. Basically, nearly 30 meter by 30 meter square, but not exactly square the distance. From here to here is about 36 meter and other dimension is 30 meter. Basically, 6 meter is the depth of the hull this is one of the rig trying to modify for. It was used in several several years 30 years. Now, it's not feasible, because most of the 70 meter locations are already drilled. Now, most of them are either shallow, shallow means the sea conditions are so high, we are unable to use this. So, we are going to use this one for production operation in a separate place, where sea conditions are possible.

So, it's not going to use for drilling is going to be used for. So, it's a conversion exercise is going on just now. So, basically typical computer model with hull is modelled using plated structures. Leg is modelled using you know skeletal frame structure with spudcan model using plated structures with stiffened elements. So, this the simple procedure is to look at during detailed design is to model completed structure. Only problem is you need to make sure that the interface between the leg and the hull modelled appropriately for the low transfer. It's not a fixed connection, because you got there combining arrangement. The load is transferred through the toots of the recombinant.

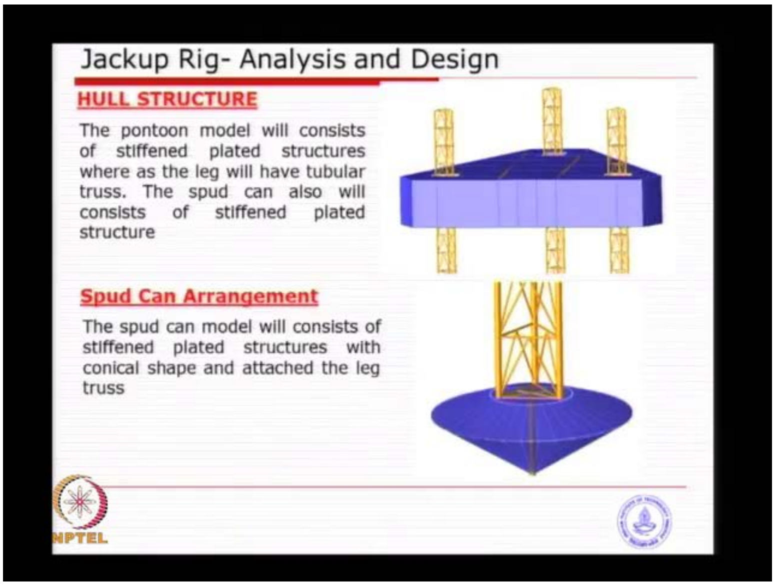
So, you have to make sure that some kind of modelling is possible, because this is very important. Otherwise you will simulate a big moment connection, which is not realistically true here. So, you need to simulate that exercise by releasing only possible to transfer vertical loading and cannot transfer the moment. Typical arrangement in that particular jackup was in this manner, hull compartments. This is what I was trying to talk about, each one is the compartment.

(Refer Slide Time: 34:30)



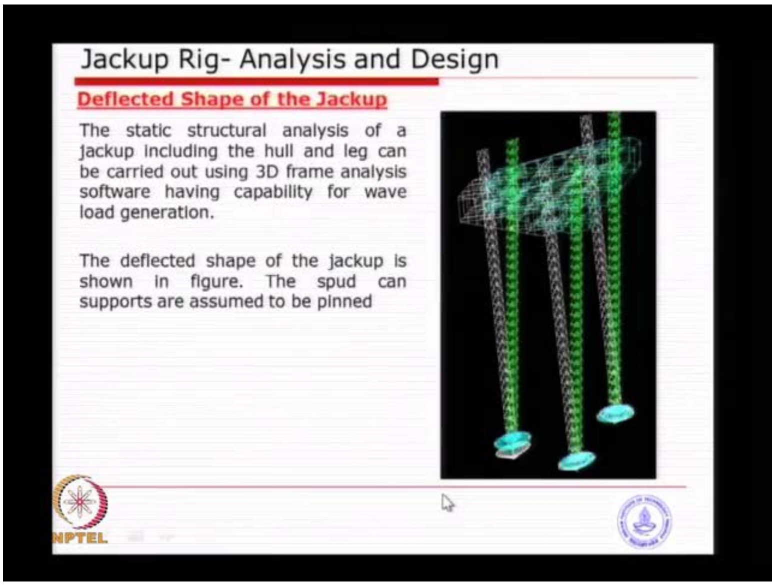
The primary the guarder you see in the yellow colour is a guarder supporting the drill mobile floor, which is parallel going. That will be coming all the way from the bottom of the hull to the top of the hull with a raised skid. The left side right side you see compartments, each one is one compartment allowed for flooding. You see on the three corners the legs are going through opening. Of course that opening will have provisions for all your hydraulic and winched devices, which can raise up and down.

(Refer Slide Time: 35:16)



Just a close up picture of the hull and the spud can. Spud can is little complicated fabrication itself in this particular one. We had a large diameter pipe going all the way. The stiff end plates inside in some cases you may not have the central tube. This is one of the analysis for survival condition, you could see the top displacement is two and half meter during a storm condition.

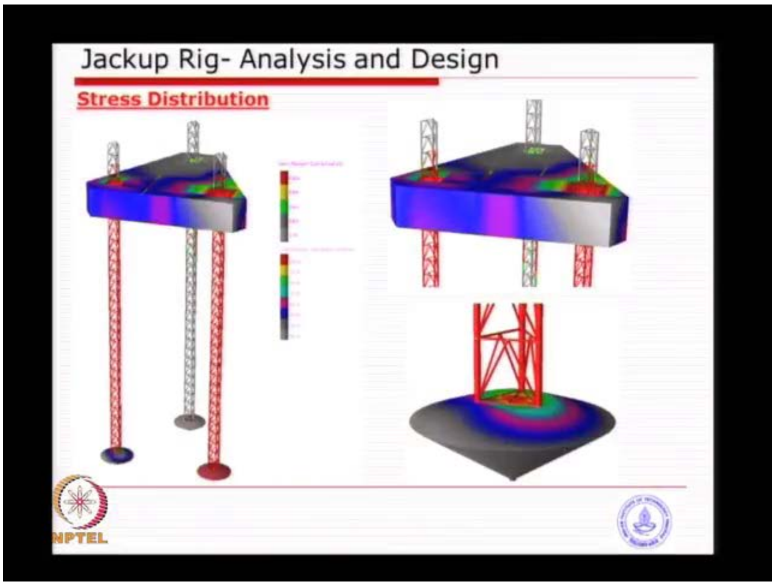
(Refer Slide Time: 35:42)



The jackup hull is getting displaced by two and a half meter, which is substantially larger and can introduce in this particular location, the sea bed could be a meter displacement.

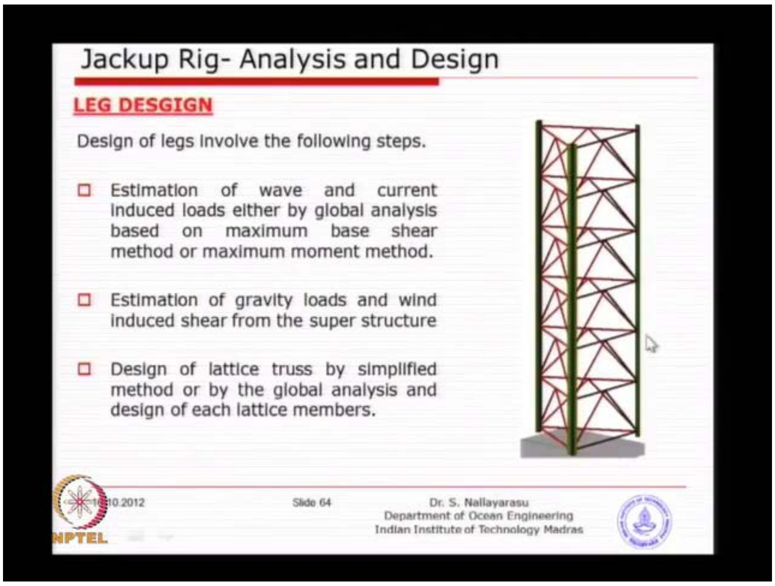
So, then the jackup is displacing by 1 meter. The leg dimension is about 6 to 7 meter. You can see this reasonable amount of soil is trying to swage towards the jackup side. Also, the plated structures you need to design either by manual methods or by means of finite element analysis. This particular case when we were trying to convert these original bulkheads and the plate structures.

(Refer Slide Time: 36:28)



Quite a number of location you can see red colour all of them is overstressed. So, what we need is we need to strengthen the structure, because over stressing is due to additional loads introduced. because we are converting drilling rig to production rig. So, you even see here most of the leg portion is almost over stressed. So, you need to substantially strengthen the structure to accommodate the new loads. Also, the spud can connection is heavily stressed.

(Refer Slide Time: 37:07)



Leg design, I think most of you have able to do a design by means of your tubular number design. So, when you do such an analysis we have done this analysis, you will be able to extract number of sources from each either the leg or brace. Then come back and then do the design. Suppose, if you want to do a preliminary design you can also come back. Because, when you are starting a jackup leg or jackup design starting, you do not know what dimension of leg you want to assume. Unless, you have somebody previous design you want to copy and modify. If you are starting a fresh design first you need to find out what is the geometric shape and size.

So, that is the time you may actually do a simplified analysis by computation of forces computation of leg dimensions and all that, but detailed design I think it becomes a routine exercise. You do a 3 D analysis wave loads automatically taken by the global analysis by computer software. Then gravity loads already anyway available from the super structure in the hull weight. Then the design of lattice stress either by simplified method simplified method means. You will no need to design each one of them.

You provide each of the member by looking at the dimension. You need to avoid buckling for sure. So, you will find diameter which will avoid buckling. Suppose, if you have spacing between this leg to this leg is 6 meter. You will automatically find out what should be the diameter of the connecting member to avoid buckling. So, you will look at T by t and you look at K l by r. Arrange in such a way that these this stresses will come automatically the proper angle. So, all this by experience after few cycles of design. You will be able to come up so lattice stress either you can design by simplified method or by global analysis, like what you have done here.

All the design will come out using a that as long as you know where to start because you need to find out what is the dimensions. Arrange it into three dimension analysis, but to do that you need to first of all do this exercise by simple idea. Separate leg get the dimensions arrange it and then complete the design. So, overall I think the design activity is involving several aspects of you know structural design hydro dynamics and then the naval arc portion.