Design of Offshore Structures
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Module - 5
Lecture - 3
Jack up RIGS-Analysis and Design 3

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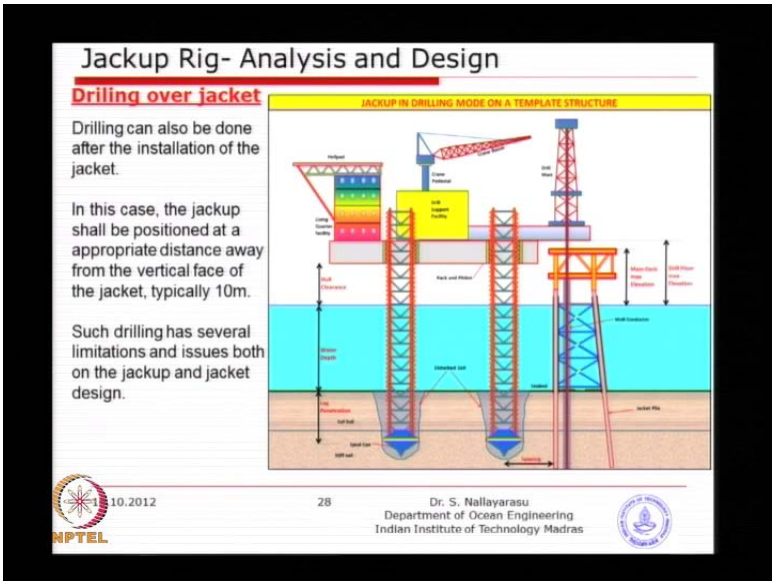

So, last week, we were looking at the drilling over the existing jacket. Basically we can see from the picture the cantilever rig is protruding outside the jack-up rig food print and then comes on to any of the wells. Normally each well platform we have you know it is a matrix of wells 3 by 3, 2 by 2 or just 1 row of 3, you know depending on the you know the reservoir capacity. At least I have seen maximum of 4 by 4 like 16 wells, 20 wells some of the biggest reservoirs, they may have 20 wells. Though the platforms you know basically if you look from this edge to this edge will keep on growing depending on what is the capability of jack-up; normally when you arrange a well bay, first thing what we need to look at is which particular jack-up rig we are going to plan to drill.

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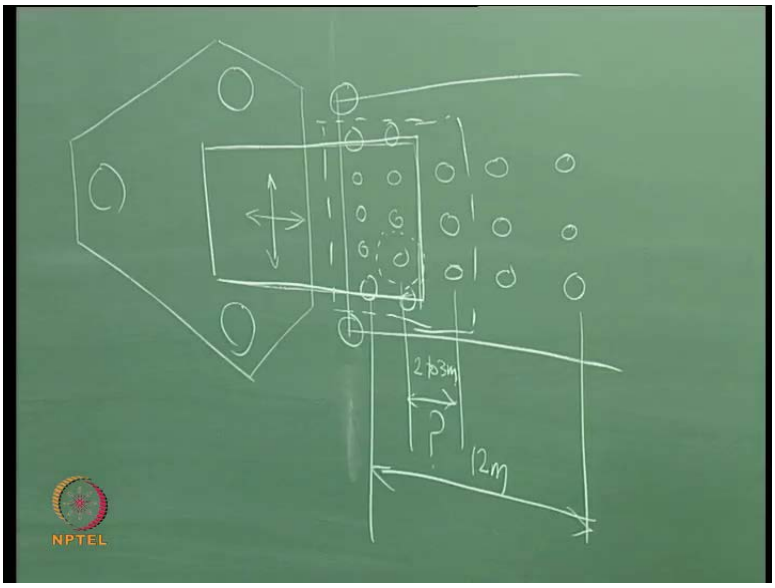

Typically I will make one sketch which I think depends on for example, this is your edge where jack-up rig going to come, maybe something like this. And the jack-up rig has a ability to trans travel in the direction of the length of the jack-up, and also can travel in the other direction. Now if this is your well platform depending on what is the transverse direction the platform can drill rig can move, because you are not going to relocate this jack-up rig, you are going to keep the jack-up rig at that same location, you are not moving. Only the the mobile platform, which is on the top of the jack-up is going to move forward, backward, laterally transverse in both directions.

Now if this is your jacket leg, what will happen is you try to arrange say for example, 3 by 3 matrixes of wells. Now the distance between each of the well is a biggest question, depends on the diameter of the well and also the other equipments attached to a well. I think, I was shown you a picture sometime back a instrument called Christmas tree which is mounted on top of the well which is basically a pressure and flow control regulation with so many wells and devises. So, if you draw a dotter line what are install and top of it, you will see that the diameter of the obstruction free space required can be calculated. Typically, this is 2 to 3 meter. Now imagine I want to have 20 wells, this will give you 15 wells. So, I cannot keep on growing, because by the time I reach this well the distance would have already become 1, 2, 3, 4 into 3 meters - 12 meters which we the jack-up rig cantilever cannot reach.

So, I decide to go for, for example, additional wells and the transverse direction provided what is the travel mode of the rig that it can travel, because on top of this, if I can travel this way, I can achieve maximum number of wells. So, before deciding the jacket design, you need to decide what jack-up which are the potential possible jack-up you can hire. Because you do not know, you will never know which you are not the owner of the jack-up; jack-up is going to be hired by the oil company, sometimes big oil company's do have their own jack-up's. So, once you know which jack-up you are going to do then you configure the number of wells and then design the jacket.

So, you can see the linkage between design of jacket and the jack-up rig availability and suitability for that location. You may have a jack-up rig, but it may be not suitable for that location because spud can penetration is too much or maybe the design is not sufficient. So there are so many complexities in arriving at the well configuration. All depends on this so-called the movable drill floor forward and backward movement and the transverse moments. So, this is something that we need to keep in mind whenever you are looking at a jack-up for design of fixed platforms for drilling purposes, you must look at what is the capability of the drill floor movement, longitudinally and transversely.

And as I mentioned earlier on the other class, basically the height also matters. You know for example, if you go to Middle-East, Gulf countries, so many offshore platforms are there, as I mentioned the waves heights are very small, because is a sheltered area. May be maximum wave heights you will get maybe it 11, meters, 12 meters. So, the structure height need not be very high, because the wave crashed elevation is going to be smaller. So, no issues with jack-up, because jack-up can go up to 23 meters which 23, 24, 25 depending on whereas when you come to some other locations the wave height itself is 23 meter then the clear space requirements. So, the structure goes higher and higher, jack-up cannot get elevated so high because the availability of leg length. The same jack-up can work elsewhere, but cannot work in other location. So, you have to look at all these parameters, just not only a every jack-up can go anywhere and then drill which is not the realistic idea. Look at all the parameters related to that particular location starting from soil, sea state condition, type of drilling, well dimensions all those things needs to be evaluated for each and every location when you are planning to do a jack-up drilling activity.

Typically you know the cantilevers for most of the jack-ups, you know the vertical phase of the jack-up from here to the the distance between the jacket and jack-up typically about 9 meters, 10 meters depending on the design, because this really matters. The closer that you go interaction between the jacket and the jack-up is going to be more means the disturbed soil will be degrading the capacity of the jacket. So, we want to keep it more, but if you keep it more, we have a bigger issue with the actual purpose for which the jack-up is designed, because the drilling becomes very limited. We go too close your jacket becomes a problem, you may also get into problem with a jack-up, because there will be moment of the jacket itself. So, the interaction becomes quite substantial. So, we need to find the balance typical number is what I have given is about 9 to 10 meter, you know that is the kind of spacing, we are looking at for most of the shallow water jack-up's

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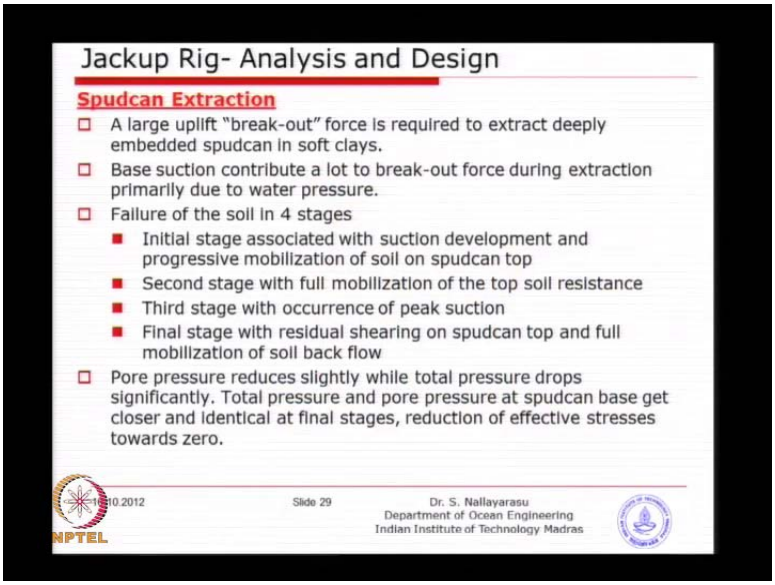

Now, after doing all that we have seen the animation, we have seen the process by which the jack-up is installed in the vicinity of a jacket. Now when we want to extract, how do we come up, you know basically again the reverse process. You can think, but it it is not a exactly reverse process, because we may not be able to pull out very easily because all the soil have already collapsed into the the pit created by the the movement of the spudcan during the installation. So, what happens is over a period of time, because if you have drilling for say 3 months, 6 months. Mostly not less than 3 months, because every time when you go for you do not want to go and mobilize a drilling jack-up for drilling

only one well, you will drill three wells, ten, you know more than three or something like that.

You may take several months during the process the conditions may change, wind conditions may change and the debris and the soil, which was actually coming out during the installation may actually go back. And also the sedimentation of material from brought from elsewhere, because of the subsea current can also get deposited into the also slowly it will get consolidated settle-down. So, what will happen is you have to pull this leg against the soil capacity which we call it the breakout force to get the soil failure in the vicinity. So, now, that capacity could be substantially more than… When you are installing you are not encountering this problem. So, what we need to do is how do we reduce this reduce this breakout force either loosen the soil, may be a process by which you can do a water jetting around the legs to loosen the soil. But potential problem of water jetting could actually damage the jacket, because your jacket is in the vicinity very close - 10 meter away. So, if the water jetting is not done properly, you may actually collapse the soil in the vicinity of the jacket legs, which make the pile to fail and which is not very good. So, water jetting is is a last sort if there leg is not able to come out and probably will be taken by the superintendent. But before that we need to make a design and the required uplift capacity of the the hydraulic and the motor winches required for may moving the leg up have to be arrived based on simple soil mechanics.

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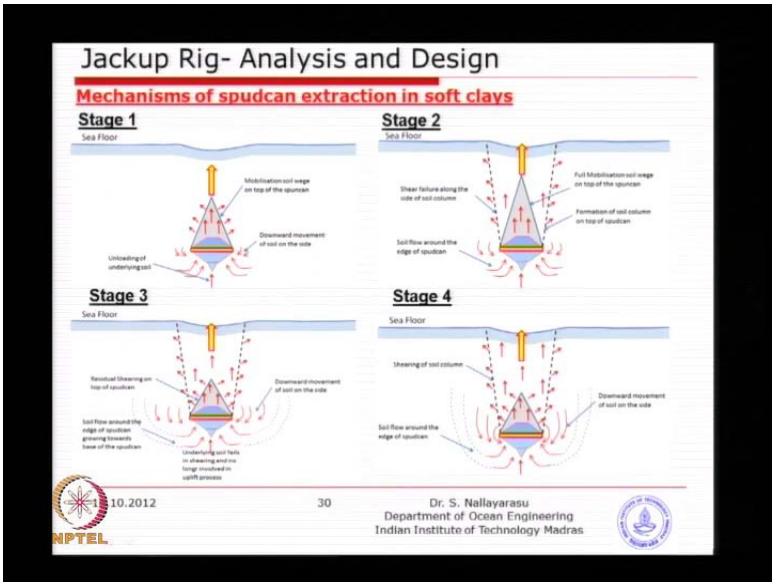

So, the basic idea is I was just prepared few sketches to show what really can happen, because we have the spudcan prepared in a way that it has to go down easily during the installation, because we got a down size cone with a very sharp edge which facilitates going down. But at the same time, we also have to have upside cone, so that when it trying to come out also can come easily. Imagine, if you have a flat surface what will happen is very very tough, because then you actually going to lift of the whole soil which will take larger effort and bringing out. So you just make a slightly reverse tapery and arrange. So, these calculation needs to be made depending on type of soil, because not all the soil is going to flow; if it is a sub clay, probably it will flow downwards when you are trying to move up. But if it is a stiff clay, it may actually get stuck to it, so depending on the type of soil material.

So, the various stages you could easily understand how the failure is going to really happen, basically if you look at the stage one is very deep below into the mud line and when it is trying to plough a cone of soil becomes part of the the lift process. The leg is trying to come out and it carries that much of soil from this picture, and the breakout are so called the failure plane could be potentially the conical frustum. You know, basically the conical surface you know around the spudcan boundary. And stage two, as you come closer and closer the mud line, you know then what happens is to cone is there and also the failure is not going to be there. Because it has to come out, there could be potentially a failure surface elsewhere slightly away from the cone, which is shown in the a dotter line you can see here.

So, this could be a possible failure plane which you have to breakout, so that the whole soil can come out and just come outside the seabed. And basically as you come closer and closer variety of things will happen, the soil will try to collapse because by the time when you have come to this stage, almost the plane has been defined, the failure plane has been defined by the process of movement. And the soil will try to collapse and come to the underside. And if this process happens very fast, there could be potentially a section pressure at the bottom, you know basically because of the hydrostatic pressure is say 100 meters and you are trying to pull of and that pressure could be acting against. So, these are the things that we need to take into account when you are trying to pull of the leg.

And of course, if you do not have this soil at the top, movement becomes easier; and if the soil is like disturbed clay probably easier, but if it is a sandy soil imagine breaking this failure plane could prove to be potentially difficult. So, we need to see what is the material that is going to be filled after you erect jack-up, so limit for 3 months, 6 months. If there is a lot of sand transport, I think you might be doing in your hydrodynamic course, sediment transport along shore, if it is a coastal area and lot of sand material can get transported from one location to other location can get deposited then is what normally happens. You do not have that kind of prediction, when you try to common remove your unable to remove because your winch capacity is already predefined you cannot change at that time, so that is the problem when you may encounter. So, that is a situation, you will resolved to water jetting, because you already have a jack-up bar, you need to come out of it and unable to come, then you have the auxiliary messes where you can jet water loosen the soil or just bring out little bit of soil from the the mud below mud line and then try to remove.

So, these reason why we need to know how the spudcan extraction is happening, this is going to affect the the neighboring structures. Because when you remove like this, for example, you may actually form a crater like this most of them we call it a jack-up leg mark, you know basically the mark left by the leg after the removal. So, this will be permanently there of course, over a period of time, this soil might collapse slowly from the sides and may become a slightly depression at three locations. But over a period of time, it will get filled and then may come to the natural state, but still the soil becomes quite lose, and that is what we need to know because we need to understand what is going to be done to the jacket because of this loosened soil.

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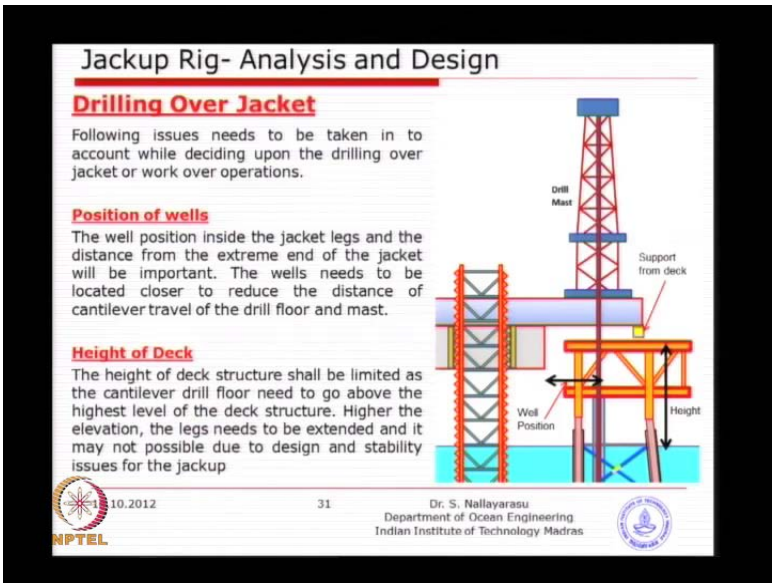

So, typically the drilling over the jacket, I think we have discussed most of the parameters. Position of wells, height of the deck I have just mentioned about each of this parameter needs to be considered a before arriving at which jack-up is for this particular site.

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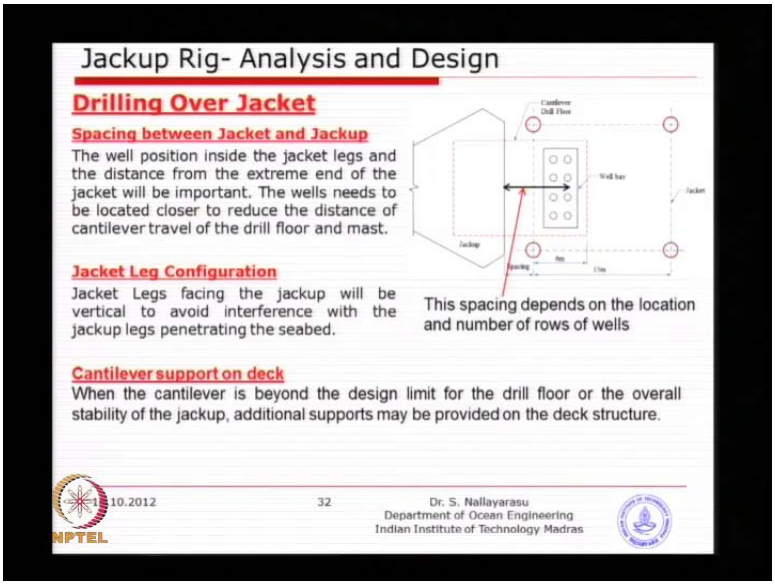

This is a picture I was trying to draw in the blackboard basically the position and the number of wells and the array of wells suppose to be decided by the jack-up dimensions of the the movable drill rig. Jacket legs configuration, I think I did explained early when

we were talking about jacket configurations for well platform, process platform. Always well platform one of the phase we keep it vertical, just to make sure that the jack-up can come closer. So, if you go back to this picture, maybe this picture, you see here this particular jack-up leg is inclined; whereas, the front leg to phase the jack-up we have made it purposely vertical. Otherwise, what will happen, this leg will go in this passion to close to the the jack-up leg penetration location, which will be potentially not good because soil is already disturbed. So, and also the distance between the jack-up leg and the jacket leg will become too small.

So, always the leg whenever you are designing a jacket for drilling by jack-up then you need to keep the vertical phase one side, you know. But if the jacket is not going to come and drill, you do not need that then you can make a jacket of symmetric configuration of all the legs are four directional inclination, because anyway jack-up is not going to come because your having a drilling rig on top of the platform itself. So, basically the jacket legs configuration, we cannot have any protrusion outside the leg. The meaning is if you have this is the leg location, we do not want to have any structure projecting outside the vertical phase of the jacket itself, so that is the very important thing that we need to note down, especially below water, because below water only your jack-up legs are going and then penetrating.

Cantilever support on the deck, basically how much we can you know the design of the drill floor is done by the jack-up people. Sometimes what happens, you have a jack-up the owner has the jack-up, but your well configuration whatever I have drawn on the board is such that I have to go little bit beyond. So, what can be done either I modify the jacket design or modify the jack-up design. So, the simplest idea is we could go and provide additional support to the cantilever rig; many times we do this. You know instead of see the drill floor is not possible to extend beyond 10 meter, why not we give a support from the jacket; that means, we can go little bit for because instead of cantilever it becomes supported conditions.

So, many many times we do this exercise; that means, we need to find out what is the load transfer from the jack-up drill floor to the jacket, so that you know we could consider that the loading in the design of the jacket structure. So, this also is sometimes done it, because you already have the jack-up you do not want to modify too much and

you will still want to approach see another row of wells, so that you can maximize your production.

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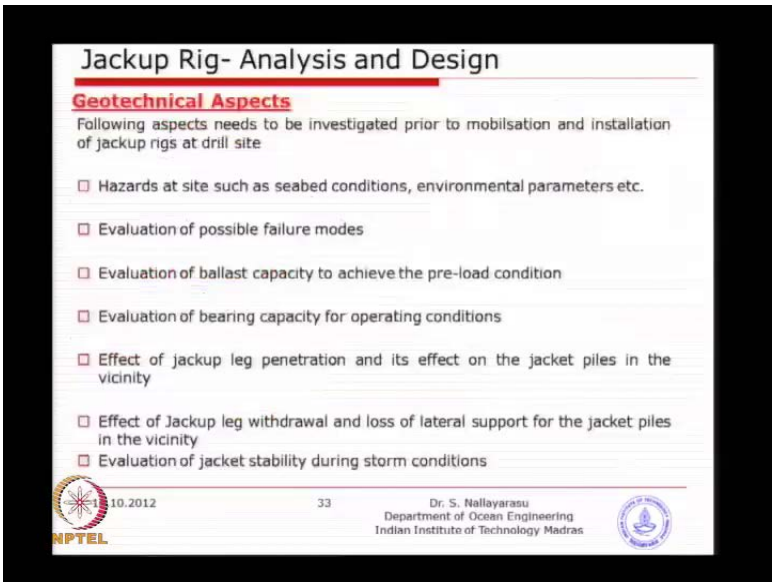

What are the other aspects that we need to look at when you are installing at a jack-up at a particular location is a you know listed down, especially the geotechnical aspects. First of all, we need to look at the hazards, which we are going to see in some scenario which can happen. Basically, the seabed conditions which is most important that the flat seabed condition exist, there is no big problem because you will be able to install the jack-up very easily. Suppose undulations whether we should do a leveling before they bringing a jack-up or if that undulation is within the limits of acceptability then you do not need because every time when you want to go do a leveling it is a easy exercise especially underwater removal of debris becomes expensive. So, that is why we need to evaluate that type of situations, which may come.

Sometime what happened actually you might do the leveling, but by the time you bring the jack-up, there may be a gap of see one month, two months, three months; something else might have happen you know some of material transported from elsewhere you see conditions you cannot predict. So, there may be a small amount of material deposited which has occurred between your leveling time and the jack-up coming in which is unknown condition you might have thought that is already leveled perfectly rise, but when you are installing your jack-up at that time there is a little of...

So, those kind of unforeseen scenarios, what happens to the jack-up we need to evaluate. Environmental conditions for shore before bringing your jack-up to any site, you must make sure that during the period, you do not see a environmental condition, see exceeding the design limit. And we look at possible failure, most I think few of the pictures will give you an idea how they can and potentially get into failure modes.

Evaluation of ballast capacity to achieve preload condition which during the installation process we did evaluate or we need how much weight to make the leg penetrate x amount of depth, because we need to increase the weight. So, as long as you have the volume of ballast available then it is possible. Suppose your ballast tanks are too small, you may need higher than the ballast tank capacity then you cannot do the ballasting. So, mostly we do ballasting using water, for example, if you go for ion ore ballast then the volume required will be smaller, but who will bring the ion ore to this dislocation very difficult.

Every time you have to keep one transport bar to transport the iron ore which is not very good, so that is why mostly jack-ups do not use heavy ballast material use only seawater ballasting. And that means, the volume required needs to pre-calculated for a particular site. You may have the jack-up, it may be not suitable for a particular site because that particular location soil is too good, and you need a bigger ballasting capacity which your jack-up does not have, you may not be saying you know you may not be using that jack-up for that site, because is not suitable. So, the evaluation the ballast capacity evaluation has to be done for site to site; that means, depending on the soil capacity, depending on the soil at each location, you will decide whether that particular jack-up is suitable or not suitable. And that will depend on the geometric configuration.

Bearing capacity of that particular site for a given jack-up for operating conditions; that means, at final drilling time what would be the capacity required for the the spudcan. Effect of jack-up legs penetration and its effects on the jacket or other structures in the vicinity which is very important. So, you could see substantial amount of work especially on the geotechnical aspects which I think most of you will be attending our course on foundations next semester I think. So, basically these are the aspects we need to relook at every time.

And effect of jack-up leg withdrawal, because you saw just know how it is being withdrawn, and what is being done is created disturbance to the soil in the vicinity and how much effect we should try consider in the original design of jacket. Because you are not going to do evaluate the jacket after you withdraw the jacket, jack-up leg, you need to precondition. That means, you need to understand what jack-up is going to come here, you have to preplan and for that jack-up what would be the disturbance created by the jack-up leg and that needs to be taken into account in the design of jacket.

So, you can see how much of front you have to have your thinking preplanned, it is not that after you installed the jacket I will come and the evaluate, I will put one more piles you cannot do installation of pile after the jacket is install. So that means, for a particular location, if you have planned x, y, z type of rig for drilling, only those things can be used, you cannot bring a new rig; unless it is very similar in behavior to that previously designated rigs. And then evaluation of jacket stability during storm conditions, basically because of the changes in soil behavior.

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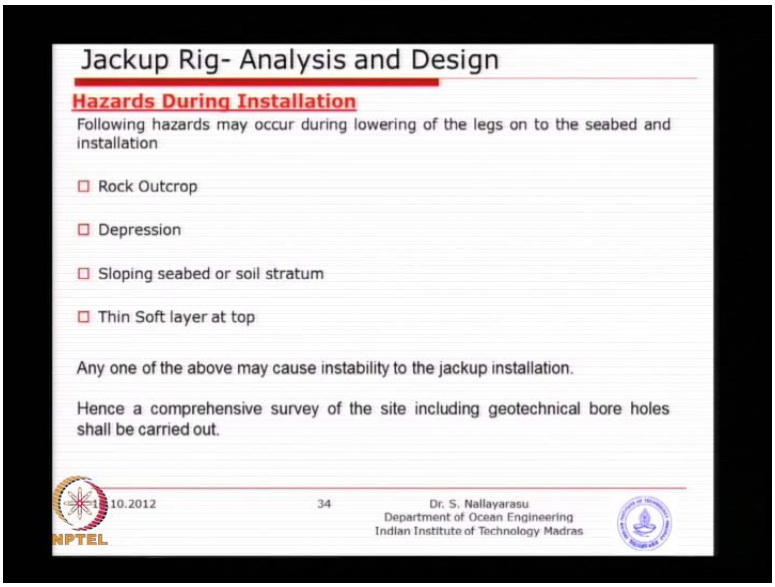

What are the hazards, basically one is the easy to understand is the harder material, but of course, rock outcrop very rarely experienced, because you may not have even installed a jacket there. Because there is a rocky material at that site throughout the area, you may have planned for a different type of offshore structure, because you may not able to drive the jacket piles, because rock out crop will not allow. But sometimes what happens is

rock boulders jacket is in one location, when you are bringing in a larger footprint required for jack-up, you may find one of the leg is encountering big boulder material which was not removed, because is little bit away from the jacket, because people might consider why I should remove if it is for away.

Or there may be a material scrap material dropped from several barges going around like pipes or like other base material simply dropped, many times people do this because bringing back is expensive then just throwing their any scrap material, so that could be potentially problem. Big depression either naturally occurring or previously previously made leg marked by the jack-up concern going. And the sloping seabed, soft layer at the top, so these are some of the scenarios which might occur are more than this. So, each time, we need to evaluate these.

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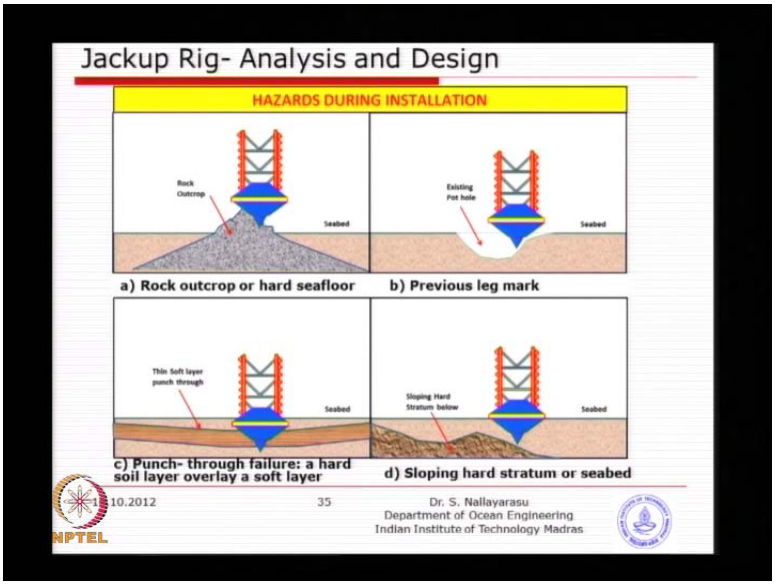

So, what will happen when you have a rocky material or a hard material and the jack-up is trying to go down only one leg and other two legs are try to go down. So, what will happen this is not going further penetration, because material is very hard. So you will see a tilting of the jack-up. Depression, a basically again a similar idea except that it might go faster than the other legs, and basically not getting adequate support to try to tilt exactly opposite way. Soft material at the particular location three legs are there about fifty meters apart; you know one scenario I want to explain how soil profile changes especially in subsea conditions, there last time we were trying to install a jacket four legs

the footprint of the leg spacing is about 50 meter by 50 meter. So that means, the diagonal distance could be about slightly higher than 50 meter and one bore hole was done at the centre; that means, the soil investigation reveal that there is a particular profile of soil, and then design the pile and install it. But that site three of the piles, there was no issues in driving, one of the pile was not going through means about 15 to 20 meters sort unable to drive within the short distance. So, you could see the variability by our assuming a central bore hole by drilling a hole and taking a soil sample that is not reveal the variations within that fifty mete radiation. So, you could see that there could be a local pocket of a variable material which could cause this kind of trouble for us.

So, if we look at one of the leg fifty meter away, local pocket of soft material thin-layer which maybe not there in other two locations. So, one of the location is punching through, the other location is supported very well. If all three of them hunching through is no problem, because it is going down uniformly, stability not be an issue. Whereas, the one of the leg trying to tilt, you will see that the jack-up will become unstable and collapse. Also sometime sloping subsea strata, seabed is very good, but the strata is inclined which was normally happened even in the case of conventional pile driving, everything seems to be perfect. When you are driving against the sloping surface the pile goes at buckle at the edge, and then you will see that pile is go easy impact. One of the project what as happened is the pile was being driven exactly like this, there was the sloping stone at sixty, seventy meter below, and when it was trying to hit the surface the material is so strong that is not allowing any penetration to go vertically.

So what has happened is pile is trying to buckle against this inclined surface and going very easy. So, there was a resistance in a basically encountered by the pile driving, it could be noticed from the number of blows required, but later it was going very easy. So, the contract was thinking something, it was broken that this it has broken the hard material and going down. But without realizing the pile was buckling and there was a club of material of piles as you know assembled or a cumulated together and which is why it was going to be very easily.

But it was not able to be noticed until such time you know the blow go into where so small, but one blow it was going very fast. Then they decided to investigate found that the pile already have collapsed, because there was a boulder just below so many meters into the ground. So, you can see this type of conditions would also potentially a problem

to the jack-up, because this leg will go at stuck and other two legs may keep penetrating, because they load is going there and try to collapse there. So this process of installation and monitoring of all the legs and positions is vital to the the safety of the jack-up.

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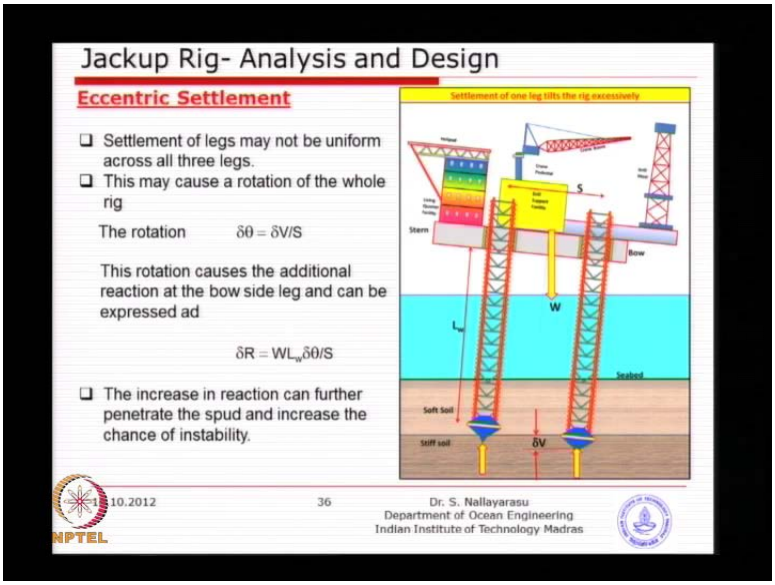

The other thing what may happen is basically a small rotation causing a large moment in a basically, because this is being in non-redundant system, it could cause complete failure depending on the differential settlement of the legs. Even everything is perfect, we have seen just only four cases of possible scenarios. But even if they are all not there, a slight change in centre of gravity, for example, three legs are there, and if the COG of the system is extending to one side increased loads increased the formation of the legs can cause differential settlement, now it go backwards.

So, you can see the design of superstructure facility for the jack-up, the COG of the system should be kept in mind, because you have to keep within a centre area, so that you do not have too much of loads between three legs. Normally when the design fixed structures, we do not worry about this. You know, you can have as much load as much penetration as much foundation design; whereas, this kind of mobiles systems, you must make sure that many are designing the jack-up the COG of the system has to be kept as close possible to the centers of gravity of the triangle. So that the loading between the three legs is not too much of difference; to avoid this kind of rotational failure, which is very important.

That means, when you are configuring the leg, when you are configuring the hull, the part location and the superstructure. For example, you come up with the superstructure gravity is not exactly at the centre of the triangle. So, what can we do, we can do you a ballistic exactly opposite side, so that you can bring the centre of gravity. So, you have a manipulation methodology just to make sure that COGs, but despite all these still, if you have differential basically, the settlement of the leg. It could be very small, but can cause tremendous effect because of length of the leg and the movement created at the top can simply collapse. Several locations this has happen basically the jack-up collapse against existing jackets. 1980s at least several of them collapse against existing well platform, because of simple stability issues; though the soil is good, verified, but unable to stabilize because this kind of disturbance can cause rotation of the structure.

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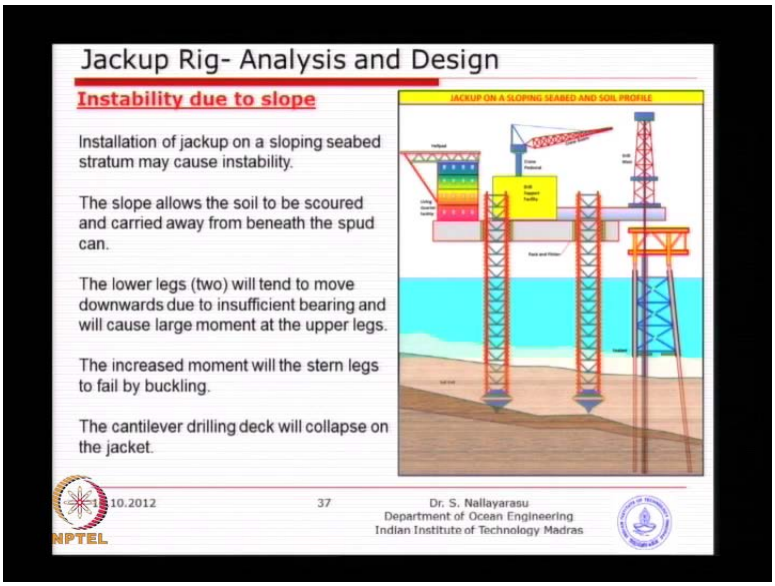

The other instability, which we just now discussed is basically installation on a sloping under bed strata, you know basically one of them is getting full bearing, the other one is not getting bearing. So, what will happen is trying to destabilize the system and then collapse against the jacket. This also is cause for worry so that is why when you design a jacket, we do one bore hole, but when we do a installation of a jack-up we always look for more bore hole maybe two or may be three. So, that you also look at the variation of the profile substrate below, so that whether is safe to install or unsafe to locate there. So, basically that the idea; if there is a such a situation, what can we do we have to preplan it. So, increase the weight here before it goes here. So, basically, the penetration will

become more uniform. So, you do a ballistic on that side, so that you control your... So, all this calculation is to be made depending on the situation there.

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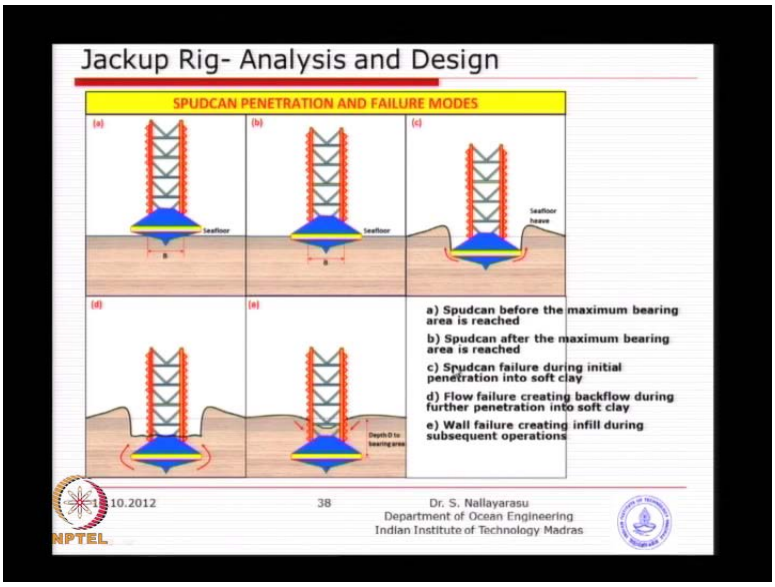

What are the failure modes basically this is by this time I think you would have understood, what type of failures are expected depending on type of soil and mostly sings jack-up legs cannot penetrate tool rocky bottom or sandy materials. So, predominantly clay type of material is only used. So, only matter is whether the clay is uniform or several layers of different strength, but typically what was expected out of a clay is basically a squeezing effect, basically if we have a jack-up going down. So, you seem picture a, if is good soiled, very good clay what is very good clay is basically your shear strength is higher. So, we will talk about in the next semester what is a type of number five k p a, ten k p a untrained, most of you are civil engineers will be able to understand. So, if it is a good soil when the spot has goes down the lower bottom cone has just penetrate, but then you get a full bearing of the circular mat foundation.

You know so if substantially good soil, you may not even penetrate, it is getting enough bearing capacity or if it is a soft clay like this like very soft clay. Very soft clay means when you step into that kind of muddy area, you know your leg goes down, I think you might practice if you go into several places in the coastal zone less than five k p a kilo newton per square meters; that means, 500 kg loading, it will just simply sink. So, that is the kind of soil we are talking about. Then when you have such scenario the soil will just

the clay will try to squeeze and just bulge away on the circumference of the spudcan. So, you could see here depending on the type of soil, the behavior is going to be different, but after all what happens as the leg moves substantially down this is not going to stay like this, it is going to collapse and come on top of the the spud itself.

So, this behavior will depends on whether it is a single layer or multiple layers or very soft clay, medium. So, you will require numerical models; simplified calculations using foundation design maybe not going to work for us. So, most of the times for this type of study, we use a three dimensional finite element programs to stimulate the behavior under varying strata conditions. That means, more than picture structural system, here every time you are going to do this. You know, basically, every time when you are planning for jack-up to be mobilized particular site, the amount of work done is a enormous.

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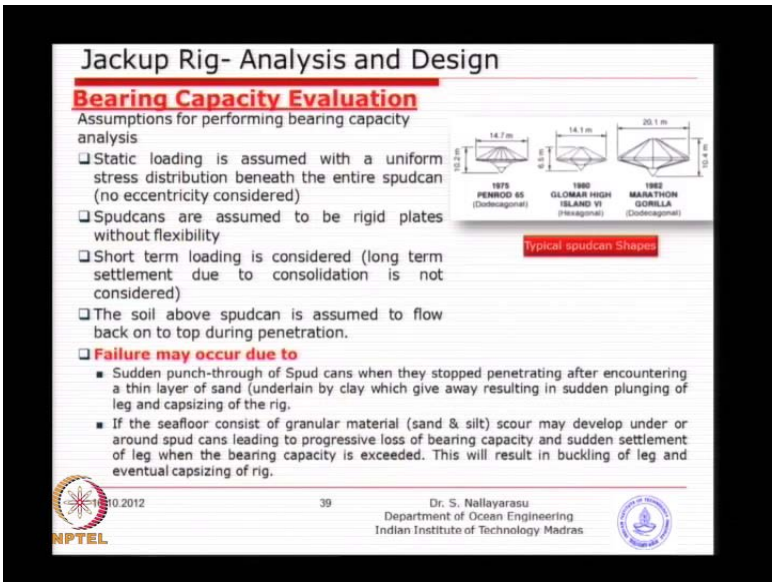

How do we evaluate the bearing capacity, basically since we are introducing this subject in the next semester, we may not want to go into full details of this particular aspect now. But I think most of you are civil engineers I think must have studied soil mechanics, basic soil mechanics in your course, just we will introduce this and spend maybe tomorrow one hour.