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

Module - 2
Lecture - 1
Concepts of Fixed Offshore Platform Deck and Jacket I

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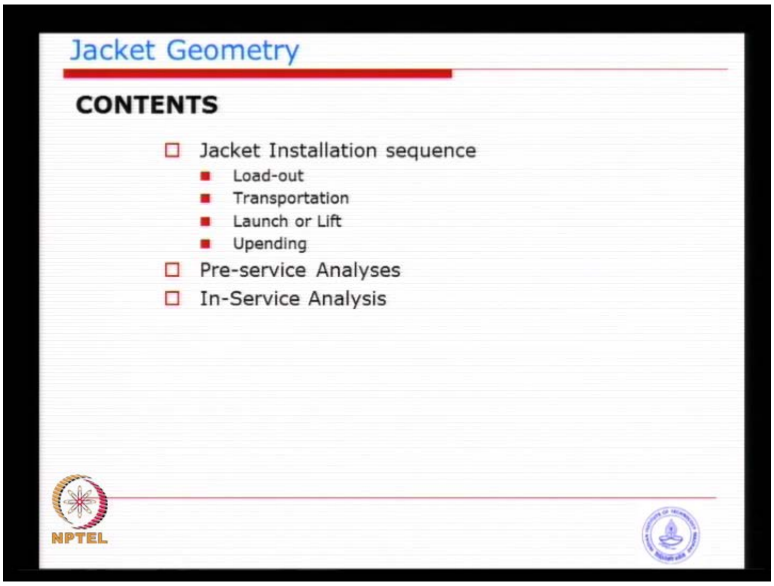

So, today what we are going to see is module two jacket concepts. You know basically the idea behind we have discussed in I think first session about how the framing or the necessity of the frame for piling, we discussed about a template. So, what we are going to see is the extension of that, and also today we will try to touch upon how these jackets are installed in offshore, and from the time that we fabricate the jackets on land or in the fabrication yard; and to the time that we install offshore what are the activities involved. So, we call it jacket installation, they are as important as the final design, because if any time during the process of transport or installation, if the jacket members are overstressed then you cannot use them.

Unlike onshore structures where the construction is actually done at the place of service, for example, you want to design a construct a building you do not construct the building elsewhere and bring it here unless you go for a hundred percent pre- fabrication in the process. But normally in onshore structures you fabricate only components of pre-fabrication for example, sometimes we do a pre-fabrication of a a beam and bring it to the final service; whereas, in this offshore concept we pre-fabricated the complete structure and bring to the final site and install.

So, what we are going to see, you will see the configuration of the structure is going to be a adapted based on what type of installation we are going to plan for the particular structure. That is where you will see the design is you know the design concept of the structure is going to be based on which type of installation you are going to use. So, we will see few of them just to introduce to you, so that you can appreciate the amount of expertise required in each of the discipline, you will involve many discipline in this including you know structural discipline which you are all studying hydrodynamics, naval architecture, foundation systems and then the machineries involved in installation. So, you will involve various discipline activities; some of you might actually learn all of them; some of you might learn one of them or two of them.

So, in here, we have got jacket installation sequence. You see there load-out, transportation, which I think is self-explanatory load-out is nothing but the transfer of cargo from land to the transportation vessel. It can be a barge or it can be ship or it can be any other form of floating object, where you can tow it to the final site. The transportation is basically movement of cargo from one place to other. So, you might have seen commercial cargo goes by ships is not it? Most of the container ships, oil cargo, tankers, transportation from one country to other country, one place to other place in the same country. In here what we are going to use most of the time, we use a barges which are cheaper because especially if you want to hire a barge for transportation of you know the oil and glass platforms will be cheaper than the ships that if you hire. Commercial ships are expensive and scheduled trips can cause higher. Here the unscheduled trip from one place to other that is all, and basically mostly we will use flat bottom barges. We will see what is the difference between a barge and a ship little later not right now.

And then we have after reaching the place, what you will do with the jacket. You either have to lift it and place it in water, because ultimately the structure has to be installed in the location where the oil and gas is available. So, you will have to make it fixed to the ground. So, this launch or lift is a simple idea devised to take the structure and put it into water somehow. So, lift means, you will use a heavy lift crane, take the jacket and put it in water; launch means basically we do not have a crane capacity of such large weight.

So, you just push the jacket slide the jacket into water, very similar to what you were doing for load-out, exactly opposite, from there from land to barge barge to water. So, that is the idea behind launch.

And then upending you will really appreciate what exactly is happening is the when the jacket is placed in water, it will float in some kind of you know position it can be inclined, it can be horizontal or it can be vertical depending on simple idea of buoyancy centre or centre of buoyancy. So, basically, we need to bring that to vertical position to make sure that your final service condition is achieved, because you have already designed a jacket for jacket to be in vertical position, so that the top side structure can be at the top. Whereas, here when you put it in water it may float horizontally, we do not know it all depends on our design of buoyancy and weight distribution.

So, ultimately, we need to make it up right sit on seabed stable condition, so that is called a upending. So, all these sequences what I have explained just now you you will see there require considerable effort to make sure that the structure is safe. As a structural engineer you want to make sure each and every element in the structure is not overstressed that is called pre-service design, pre-service analysis. It is nothing but every stage of this activity when you are performing on the structure, structure is safe that means, you need to analyze it, make a structural analysis and design the members, design the connections. Very similar, you know when you are actually doing any activity on land when you are lifting a beam that beam has to be safe during the operation of the lifting; otherwise what will happen, either the beam will fail or the crane if it is not checked for that specific activity, the crane will fail.

Many of the time, you see accidents happening in the one construction sites I think even in yesterday I think morning, there was a auditorium being built in one of the engineering college and collapsed during construction ten people died. Just because it was either not designed properly to take the loads at the time of construction or it was prematurely construction was going on sequence wise before the concrete was set. In fact, the news was that concrete was not allowed to set, before you go for a next stage of construction. So, the construction stage the whole thing collapsed ten people died. So, you could see that the consequences of not performing necessary design is very serious, because people are already working in the site.

Similar thing can happen in offshore when you are actually doing a lifting of a heavy lift jacket, and crane can fall down because the weight was not calculated properly, centre of gravity was off. In fact, a few months back, if you remember one of the site in Delhi they were doing, I think Delhi the crane actually failed, because the ((Refer Time: 07:51)) was incorrectly calculated for lifting of a very long bridge beam or something like this. So, you could see that these activities needs to be designed in accordance with the specification and make sure that they are all correct. So, this is called the idea of pre-service is nothing but before you place the structure at the site, you have several activities going on; each activity needs to be verified as a design activity.

Then the next one is the in-service; that means, the after the structure is placed at site fixed to the ground, superstructure is installed and then finally, starting to produce oil and gas that is what we are building the structure for that is called in-service condition or in-service analysis. All of you find a difference between this know, so basically that is where you have to differentiate the idea behind.

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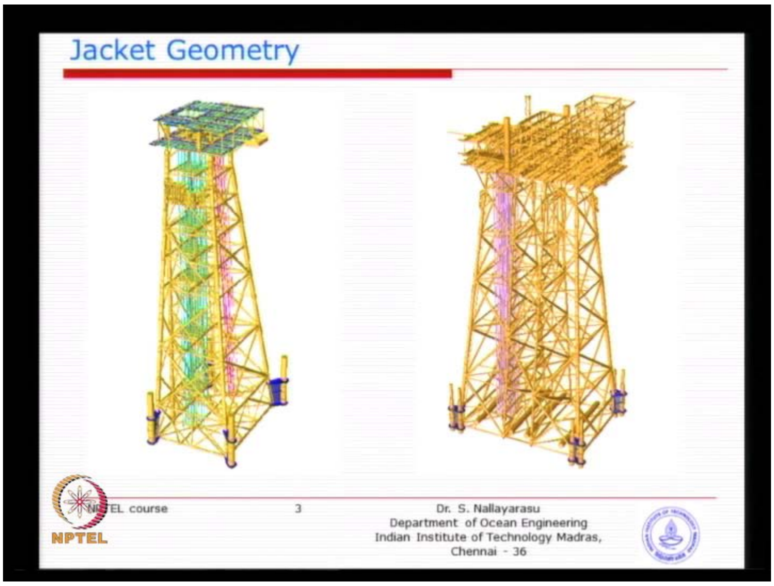

So, if you look at this structure, both the structures have you know foundations in terms of pile fixed to the ground. I think the previous class, we had discussed about a template through which the pile is going through. In this particular case you see here, the template is in a slightly different form because the water depth is larger. So, we did not want to have a pile going through the leg, instead we have a skirt at the bottom through which the pile is going through. Of course, there is a connection between this pile and the skirt and the leg, so that the load coming from the jacket structure can transfer to pile foundation through that plated connection. You see here there is a plated connection at this, basically a interface. By doing this what we have saved is the length of the pile above. So, much length instead of driving the pile through this, so now you have got only one pipe instead a pipe in pipe which we normally have for main pipe. So, this concepts have to be devised as early as when you are thinking about a idea about this platform at this location.

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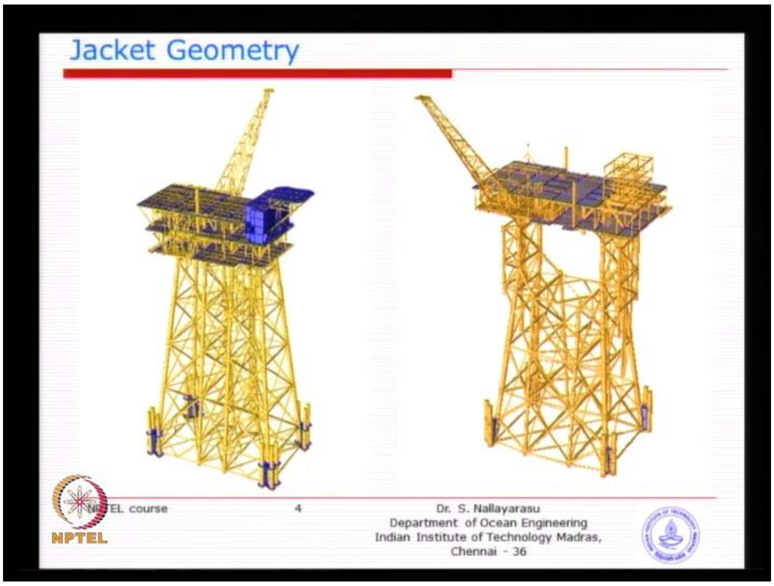

Similar structures, most of them deepwater structures about 150, 160-meter water depth, so that is why you see all of them are having skirt piles. But you could see here the number of skirt piles differ from platform to platform. You see here only two skirt piles whereas you see here three skirt piles. How did we come up with this idea, you want have to think. When you design a foundation system, some of you might already have gone through the basic civil engineering soil mechanics. When you design a foundation system as the load increases you got two choices, is not it? You can go for multiple, you know the point load transfer by making split up the loads, distribute the load to various points by making columns.

You know when you design a a simple building you normally try to put a four column you nobody wants to put a exactly at the centre of the room is not it, that will be not acceptable, you put four columns. If not enough or if the foundation system is very weak then you put additional columns in the periphery, try to do that. If not enough what will happen? You actually take the foundation deeper that is the concept of pile foundation. When you design a simple spread footing for buildings, you dig say two meter depth, three meter depth spread footing foundation. If still the loads are so high that the foundation is deforming excessively by in terms of settlement then you find a ground or underground where the soil is stronger is not it. So, you dig deeper and deeper while doing so, the concept of foundation changes from a spread foundation to a point load foundation which is basically the pile foundation.

So, that is why you see here in this particular case, we have two piles which are adequate to transfer the load safely. Whereas, in this particular case, we have got three, because the loads are excessive. I could not increase the diameter larger, because constraints you will be given several constraints that that this diameter I cannot handle. Contractor will say too big, of course, you can make one big diameter five-meter diameter instead of three numbers of piles good idea, but the idea cannot be implemented because they cannot install. So, we decided to go for three piles of smaller diameter.

One could ask a question why not I go for one kilometer deep is not it. Instead of three piles of 100 meter deep, I will go for 300 meters of one pile - this is also good idea, but driving a three hundred meter depth pile may not be feasible you may not have a equipment to drive, bigger equipment is required. So, you can see that the design is influenced by external constraints that you will be given at the time of a conceptualization this is what we have you cannot ask for more. So, that is how the configuration of a jacket is going to be influenced by many of these external constraints, which will be available at the time and it depends on location. For example, 300 meter pile driving may be possible somewhere else, they may be having a equipment to do that; whereas, we do not have, and that is why depending on the situation which project which location, who is the contractor where is it happening, all those external factors needs to be taken into account while configuring a jacket.

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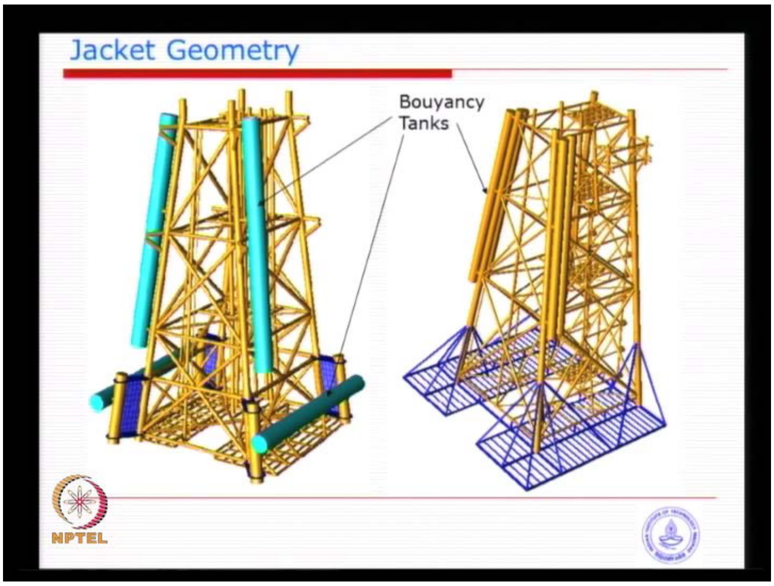

So, you see this picture at the bottom, when you place a jacket in upright condition. You could see that it has to rest prior to the piling is done inside. So, for example, these are the legs, you are going to do piling by driving the pile, but before that the jacket has to rest on the seabed, when you transport it to the final location, you place it in the seabed. It has got its own weight, if the weight is too heavy what will happen? Even before the piling is done the jacket will start sinking below ground, which is not acceptable. So, in order to do that we have got a temporary foundation in terms of a spread mat foundation, so that is called mudmat.

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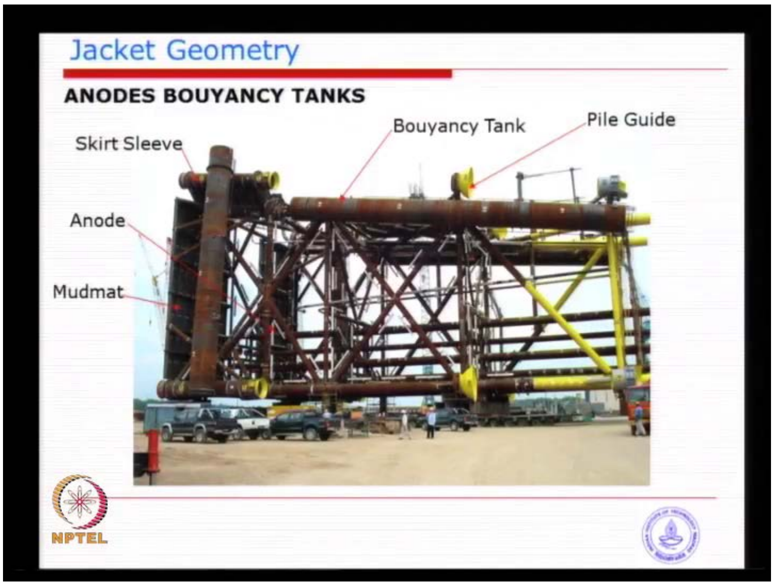

In fact, it is given in the next slide, if you see here at the bottom, it is not little dark there you see a plate kind of arrangement at the bottom, so that plate is nothing but a steel plate arranged, and fixed to the structure. So, that when you place a jacket it takes the pressure due to its own weight, because it will take few days before you start doing the piling through the skirt sleeve maybe two days later. So, the idea of these the mudmat is very similar to any simple foundation designed for onshore structures. Simply what we need is spread the load in such a way that the deformation vertically is lower.

At the same time when you place a jacket in sea, it should also be stable, it should not slide number one it should not overturn; I think you might have studied simple overturning stability, sliding stability, vertical and horizontal equilibrium due to wave and external forces. So, all those things needs to be done to arrive at what is the size of this foundation, because after all if this is not safe you cannot do piling because it will just already overturn.

A typical picture showing the fabricated jacket you could see that large diameter tanks are placed together with the jacket basically when you place it in water, these tanks prevent the jacket from sinking. Of course, when you design a jacket members each member will have its own buoyancy and the weight must be lower than the buoyancy; otherwise, you will require additional tanks very similar to your survival suit. You know I think your if you have travelled by boat, you will be given life jacket, any of you have travelled like this. You will see that if you definitely need life jacket if you do not know swimming self-stabilization.

So, here basic idea is these buoyancy tanks are providing additional buoyancy to make sure that the jacket is floating in a position that we wanted, you see here there are two buoyancy tanks one at the bottom, one at the vertical or the horizontal level. Now you see here the weight of the jacket is going to be heavier at the bottom, you can see from the shape itself the left side is heavier and the right side is lighter. So, you could see one of the tank is placed at the bottom, because you know very well that you want the jacket to be floating horizontally, so that can do the upending later on. So, all these manipulations are arrangement of centre of gravity and centre of buoyancy needs to be worked out and to make sure that it is stable all the time.

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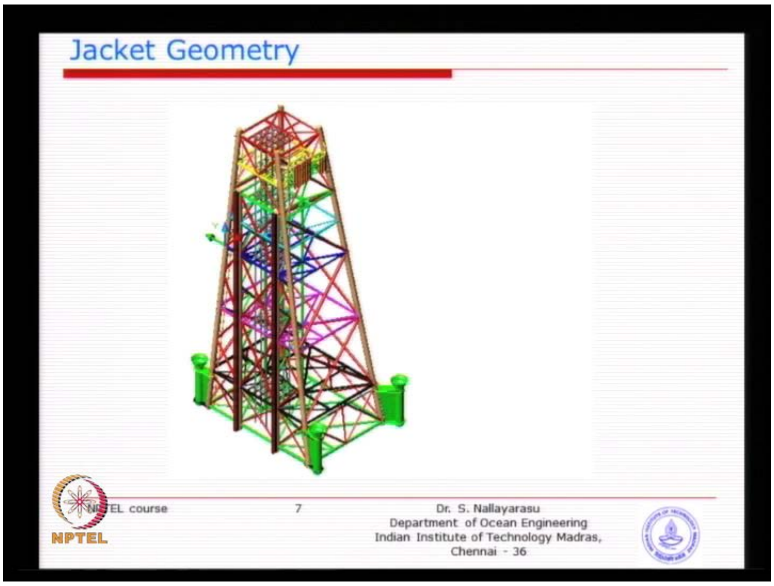

A typical installed jacket in vertical position after you transport and all that, so it is basically prior to piling it is resting under seabed. So, you imagine, if you have a horizontal load coming from wave and current, it should be stable. So, one of the predominant parameter is the width of that jacket at the bottom from here to here or from to here to here, the larger the width is better is not it, you can easily imagine. Stability will be easy to get, if you narrow the width, then the stability will be potential problem. So, that is also to be kept in mind when you design a structure for final service condition you also need to take a look at what is the dimensions minimum required that I will be able to achieve the stability.

Because if you cannot achieve this stability, because this is unpiled condition, the piling is not done yet, but before that it has to rest on the seabed should not fall down. So, if you have not taken this into account, what will happen? It will fall down. Many of the jackets actually fall down this way. Even every year we have several accidents happening, last year also two jackets fall down like this, because of inadequate design carried out or there could be a potential problem with assumptions made like a soil conditions, like sea conditions you do assumption of sea condition of this much it exceeds some cases. So, all our design has to take into such variations.

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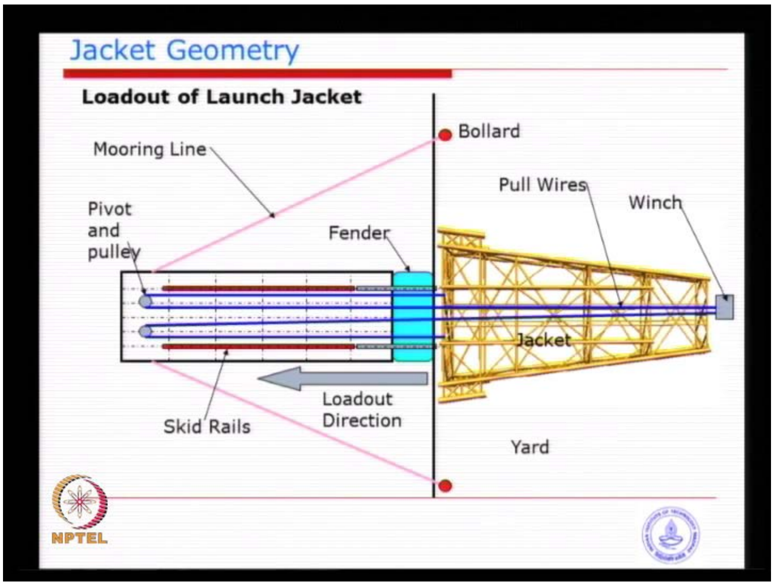

So, we are going to go and look at one by one. What is load-out? So, you see this jacket on the right-hand side is a yard; and left hand side, you see the barge floating in water; and in between the yard and the barge, we have a flexible element, because you do not want the barge to be rigidly sitting the yard foundation. So, basically you have got a fender system, normally we use it in most of the port and harbor, it is a circular cells placed, so that when the barge is trying to move it is not getting damaged against the wall, so that is the idea behind. So, you see here the jacket has to move forward to get onto the barge, somebody have to pull know. So, basically the idea behind, if you keep a winch here can you pull it, we cannot pull, because the barge is a floating object you may not get a reaction point.

So, the idea is very simple; keep the winch on the ground and have a sleeve and pulley block in such a way that when the winch is pulling forward, the jacket will move backwards. You see the the reverse arrangement normally done this way to avoid. At the same time, the barge is always kept towards the land, so that during load-out if the barge moves away what will happen, jacket will go into water. So, by doing this arrangement, this load-out basically allows the load-out to happen in a safe manner. Now you see here this barge is a floating condition right, it is not a stable like a quite water calm water in a even in a calm water in inland water body, you can see some slight moment due to wind and locally generated sea disturbances. So, if this one is going to be done in a not a open sea sheltered water, but still you will have sea conditions not as good as you wanted to be you may have barge is moving up and down rolling and pitching.

So, what you will see that the jacket as it moves partly onto the barge; at that time if the barge moves up and down, what will happen, you may actually damage the barge or damage the structure. So, this condition needs to be accessed carefully and designed. The idea behind is you cannot prevent the activity from happening, sea conditions you cannot change, you cannot stop load-out; stop load-out means the project is not there. So, activities have to go on, what precautions we have to take is forecast or predict such issues upfront design the jacket, design the barge. So, that is where we need to think about what can happen, what cannot happen. What can happen and what is the probability of that happening. If it is only very low probability, you might say this I will take a risk, because this may be happening or not happening. But if the probability of occurrence is higher you better take that as a design activity and perform that to make sure that at the time of load-out, you do not think anything else. You can still go on because that was part of the design. So, this load-out simulation, we have to think about it.

Load-out can be done by skidding or loadout can be done by machineries, basically trailers which carries them. So, what is the difference when the weight becomes too heavy for example, 5000 tons. Can we find a trailer to take them off, may be difficult that is the time we decide to do skidding, because the trailer capacity is limited by a number of axles and the capacity of the tire pressure basically that is. So, typically about 2000, 3000 tons you can do that, but as the weight increases to 5000, 10000 tons, we have no other choice other than simply skidding. So, you could see that idea.

So, what is the advantages and disadvantages advantage. As you can see any weight can be skidded out whereas, the trailers have got very good advantage of stabilizing the levels. Here if there is a level difference in the ground it will actually make a structure to fail whereas, the trailers nowadays come up with computer-controlled suspension, I think most of you might have might remember, each and every mechanical device or vehicle like for example, car is got a spring device to adjust the levels to some extent. But they they are not computer-controlled, they are just a mechanical spring.

Whereas, if you have seen that picture each of the axle is supported by a hydraulic jack which is controlled by a centralized computer. So, if there is a unevenness in the ground the hydraulic jack will come and activate and push the pressure down to make contact, because there will be loss of load. So, the next tire will get it more load if one of them is not contacting because it is a continuous support know. So, such manipulation can be done by these hydraulic jacks. So, basically that is the advantage of the trailers and mostly used for fenders structures; structures not very strong then use the trailers whereas, the jacket type of structure is well braced and very strong and you can use a skidding method.

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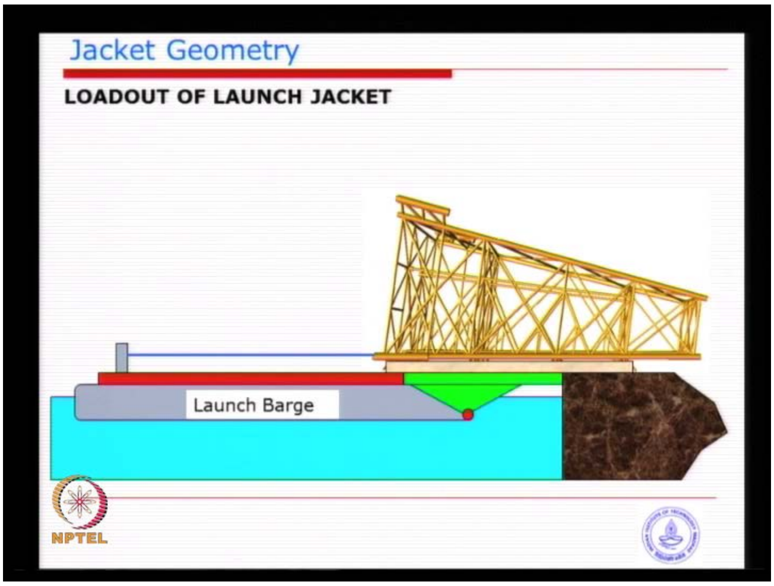

Now, you see here the next picture you could easily understand the jacket is being pulled from ground towards the barge. And you see in the green color are basically the kind of pivot point because the next time when we want to launch it, we will go in the opposite direction. For example, we loadout in this direction forward moment, in this way, when you want to launch it we will go exactly opposite. So, that is why you see a prearranged setup which we have a pivot there. So, when the jacket is going forward, we will be able to dive into the water without damage. Normally you you might see, if you have gone to swimming pool, dive board is little bit cantilever from the edge of the swimming pool you understand the idea know, and also should be little flexible not very hard. So, exactly a diving board, but allows the tilting of the jacket as well strong enough to carry the loads. So, that is called a rocker beam or rocker arm.

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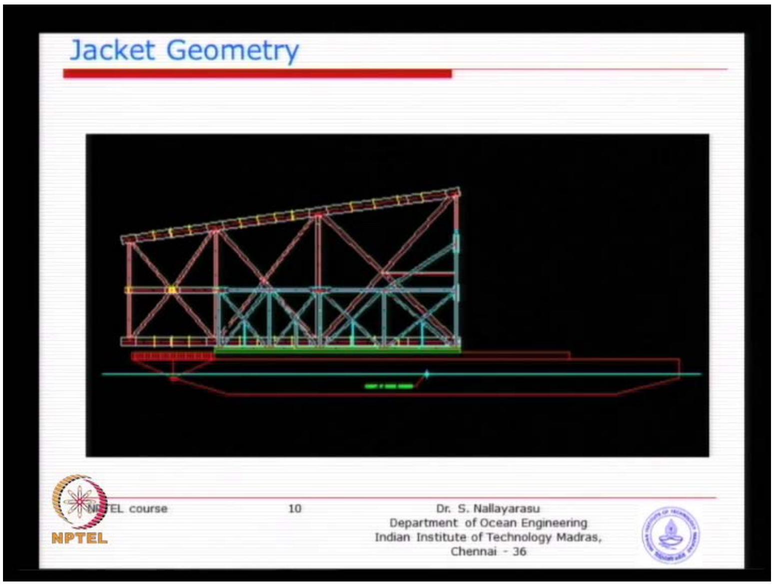

Picture showing the transportation time, how it is placed.

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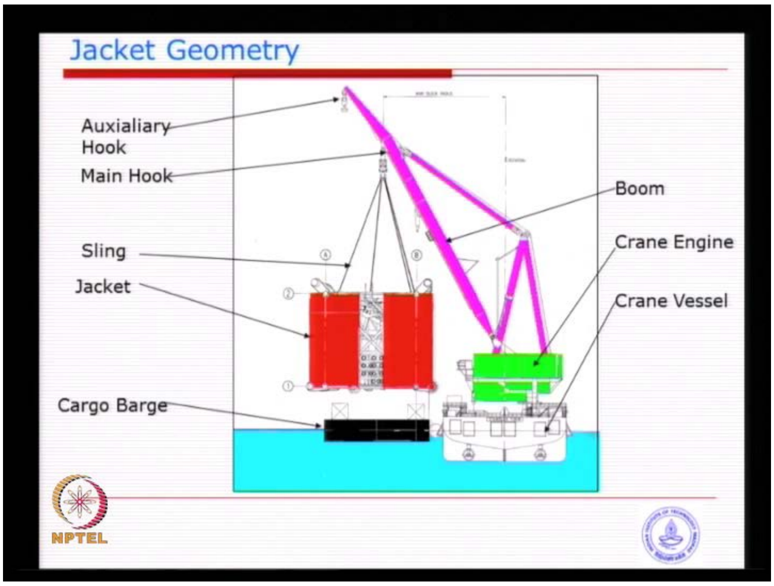

So, now we see a arrangement, where the jacket is being lifted off instead of launch, we can also do the lifting of a jacket. So, what we need is a crane and imagine we need a crane capacity of few thousand tons. So, how do we get such capacity, because over the time, now you see many contactors are having large capacities like 10000 tons capacities. Whereas, if you see the cranes on land, you might see 50 tons crane, 100 tons crane like that why we could not get a 5000 tons crane on land have you seen 5000 tons crane? Anybody building the full building and then shifting it off, mainly the problem is the counterweight. You will see every crane on land, you will see a counterweight at the back. If you want to lift 20 tons, you will have a counterweight at the back some amount of weight to manipulate, so that the crane is stable; otherwise, it will become unstable.

Whereas, in this offshore cranes we do not need that counterweight, so how do we manipulate. The counterweight is easy to achieve by means of ballasting water on the one end. So, if you have a crane locator on one end, the other end you full ballast with seawater, and because the structure is floating, it can get a easy way of… Whereas, in case of land-based structures physically, you need a if you need to lift 5000 tons you need a more than 5000 tons counterweight, where do we get the counterweight where is the space. So, the crane will become too big.

So, in this picture, what you see here is a various components. This is the barge which was actually used for transportation, which brought the jacket to the location. And this is the barge carrying the crane which we call it HLV - Heavy lift crane vessel or sometimes lift vessel. And you can see, this structure is prearranged with arrangement, where you can tie the ropes lift point, connect to the crane by the boom and then start lifting. So, you could see that this activity involve design of the structure, design of lifting here, the cable and cable attachments and design review of the boom, and the crane itself. The crane has to be safe. Some of the accident involves failure of sling. Sling is nothing but a cable; it is just a technical name given there. It is a cable where of steel and the boom is also a steel frame.

You will have different design and the crane base itself has to have sufficient capacity to handle, and ultimately the crane vessel must be stable during lift if not it can capsize because of the… So, you see here it is actually a eccentric lift across the beam we are trying to do the lifting this is quite vulnerable. Because to get the stability for this ship need to have sufficient amount of ballasting on the right-hand side is not it; otherwise, you will not be able to keep it in stationary condition. So, you could see that it is potentially dangerous.

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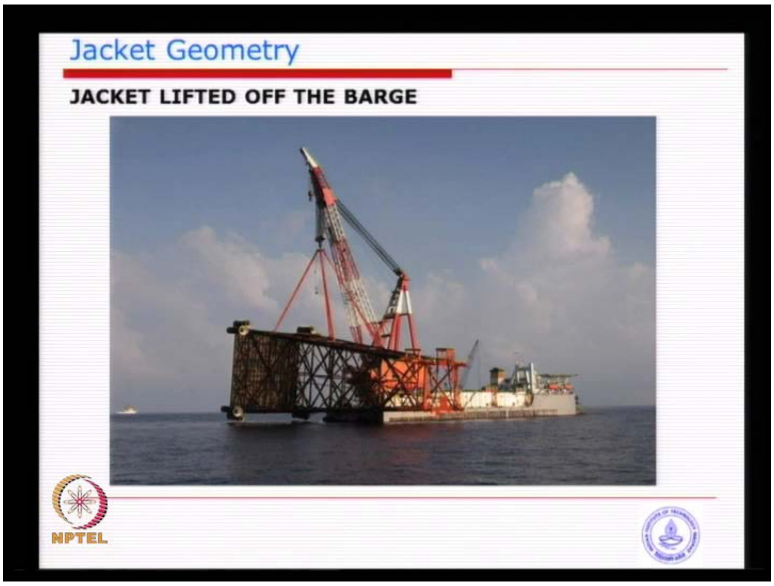

Instead, if you do the lifting anyway, we will see that longitudinal lift in another picture. So, this is a picture showing one of the jacket which was involved there in the design and installation you could see that the jacket is just lifted off, the barge has been removed you know. From this barge at the bottom has been immediately removed, because the reason is there could be potential movement of the lifted objects because of the sea waves could come and hit. So, that is why barge has been immediately withdrawn and now we will place this jackets just slowly into water. As long as the jacket has got sufficient buoyancy, it will float; if not, it will sink. So, basically that evaluation has to be made before we lift off and you should have sufficient buoyancy.

So, what should be the requirement of buoyancy, we need to find out what is the cordial requirements, minimum 10 percent. Normally we allow for 10 to 15 percent; that means, if the weight of the jacket is 1000 tons, you need to have 150 tons excess buoyancy, so that means, when you are designing it, you need to provide adequately. If you do not have buoyancy then you attach additional buoyancy chambers specially fabricate for that purpose. Sometimes we actually have commercially available buoyancy chambers, you can just buy and attach or you can make a steel fabrication attach to the structure.

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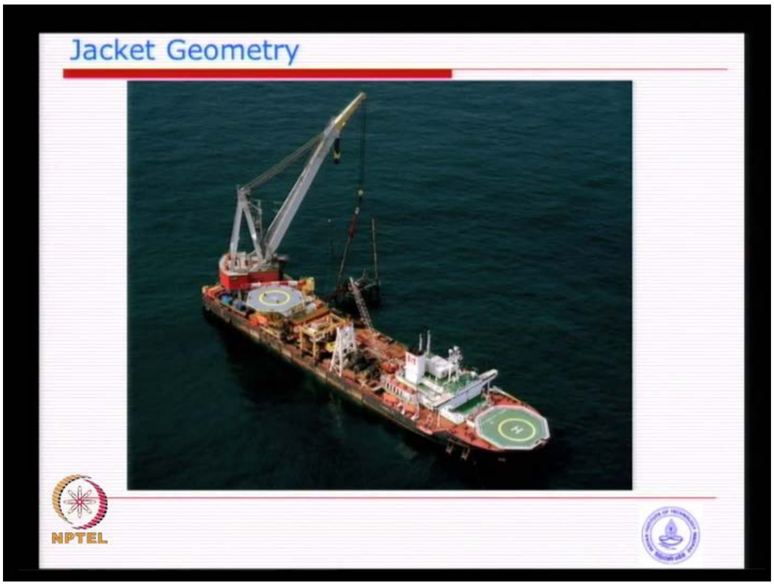

Typical crane vessel, so this is what I wanted to show you. See the crane is on one end; if you are doing a heavy lift on using this crane, you can do ballasting of the hull on the right side, so that is the idea behind. All the offshore cranes have a huge capacity ranging from few thousand tons to thousand tons to typically about 10000 tons, 15000 tons crane is also available in some part of the you know North-Sea; some of the contactors have such capability.

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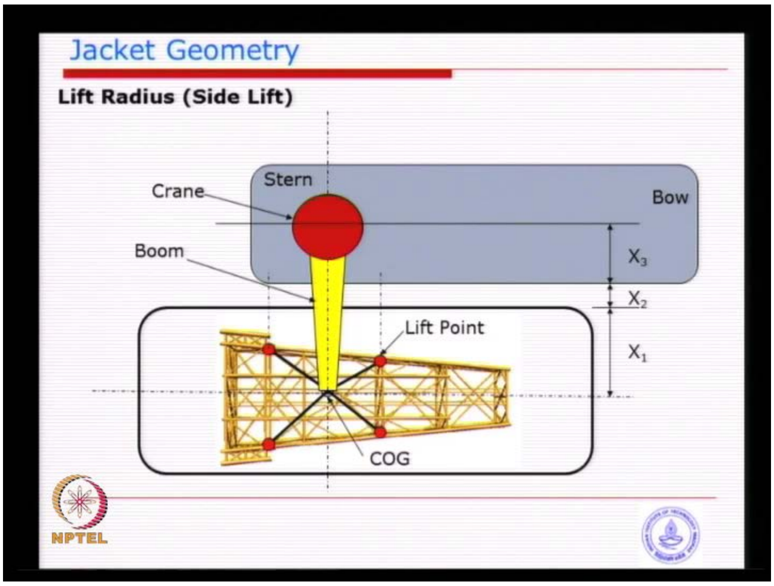

The side lift this is called the side lift, this is what you saw from the picture. The larger this distance X 3, X 2, X 1 the more trouble for the barge, so we need to design for it. As long as you can achieve this condition by means of ballasting by means of design it is fine; otherwise, we need to look for lifting in this fashion.

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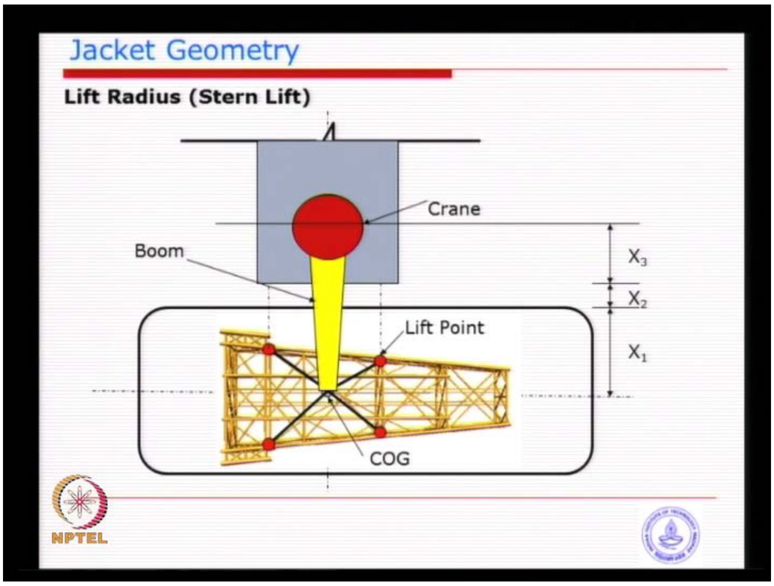

This is the safe lift because, the ballasting becomes easier to achieve. The other part of the barge is not shown here because, it is too long. But you can see this is basically a stern lift, I think the terminology the bow and stern. The bow is the front side of the barge or ship, and stern is the backend. Normally most of the cranes are located on the stern end and you can see here this is a side lift. And what you see in this rectangular picture which is the transportation barge, which brought the jacket to the final location. And basically that gives an idea why the the lifting is always done in the stern manner, because of the stability of the system.

And you can see also this picture is the the lift points selected in such a way that the structure is safe. So, what we need to see is where is the centre of gravity of the structure and arrange the lift points in such a way that when you do the lifting, it is also the stable configuration. Because otherwise if you have a lift point somewhere else you imagine you take one of this object and try to lift something like this, it is always the centre of gravity will pull the structure down. So, if you try to do elsewhere, it becomes unstable. So, basically that is the idea behind, any lifted object should have the centre of gravity below the lift point. So, the crane is coming and that lift point can be located accordingly that is again to be selected by the designer.

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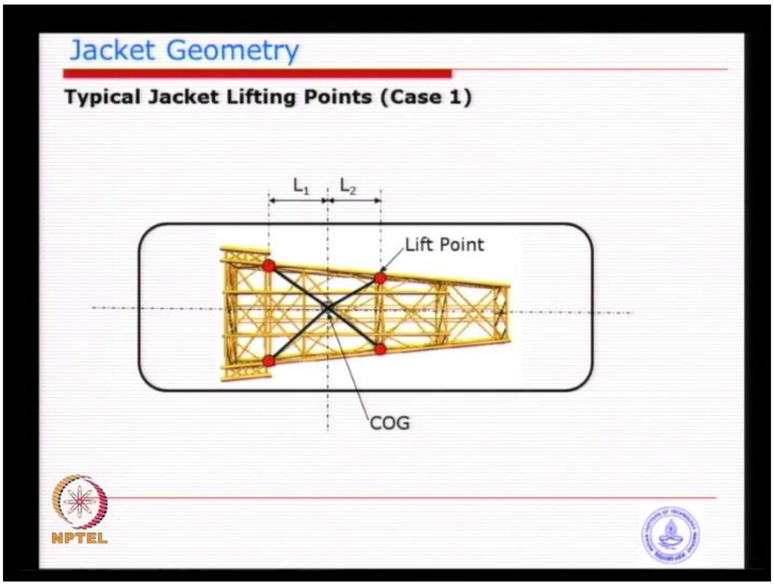

So, you see here the left side and right side distances between the lift point and the centre of gravity if it is equal, it is good is not it, because fifty-fifty distribution. If it is one-sided, it is not very good. Sometimes we actually do it, for example, if the centre of gravity has shifted towards the bottom of the jacket, you shift the lift points then only it will be stable; otherwise, what will happen starts swinging, and that swing can damage the structure, it can also damage the barge.

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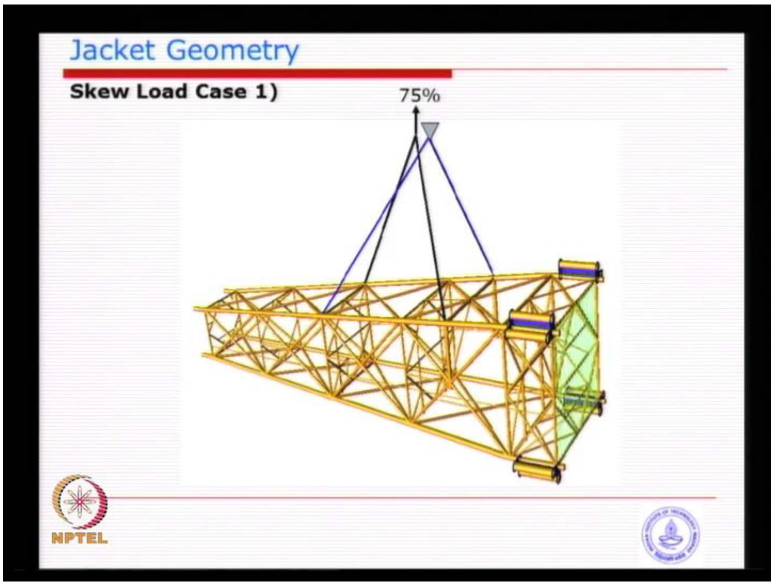

A typical simulation of trying to design the structure; sometimes this kind of conditions skew load, because the cables are not cut exactly to the… Imagine you have four cables, two of the cables are longer than the actual length required, theoretically by say 50 mm what will happen the two cables will not take the load, the all other two cables will take the full load, so that is a kind of simulation you need to… It can happen because cutting a cable of say 200 mm diameter to exact length and bring it and manufacture could be potentially proved to be difficult. So, eventually it may happen or it may not happen, but the probability is very hard to establish and by experience, the designers will be required to do such kind of assumption, because there is a high probability of happening, because manufacturing a cable is not just only a machine, it is personal intervention is required. So, this kind of condition also needs to be simulated.

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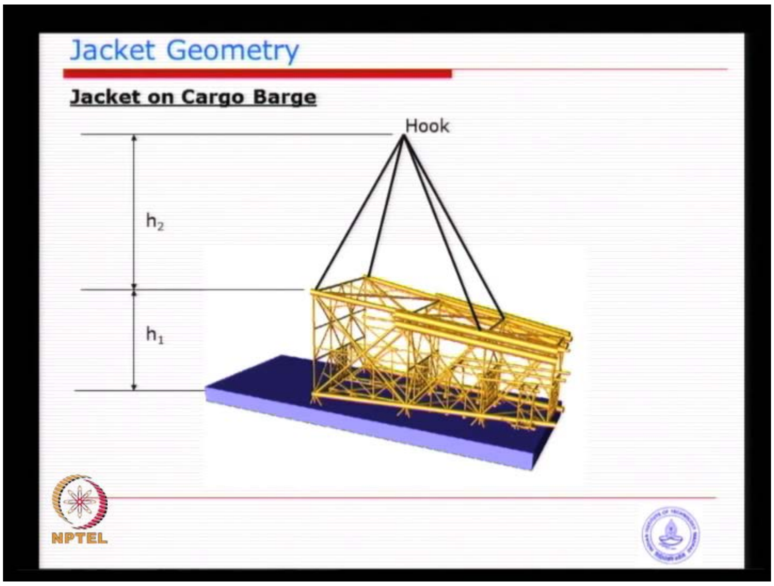

The third thing is the height by which you actually attach the crane, because if you the higher the elevation, you go it is better is not it, you get a larger angle between the horizontal and the sling. Imagine, if the cables are vertical, it is better is not it. There is no horizontal force coming in compressive force, but the higher you go, the crane may not be able to reach it. See here after this angle, the crane cannot go any further up is not it, so it is limited by the crane height, so we cannot do that.

We will stop here.