Elements of Ocean Engineering
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Lecture - 13
Introduction to Offshore Structures – I

Today, we will start Introduction to Offshore Structures with offshore platforms, the types of offshore platforms.

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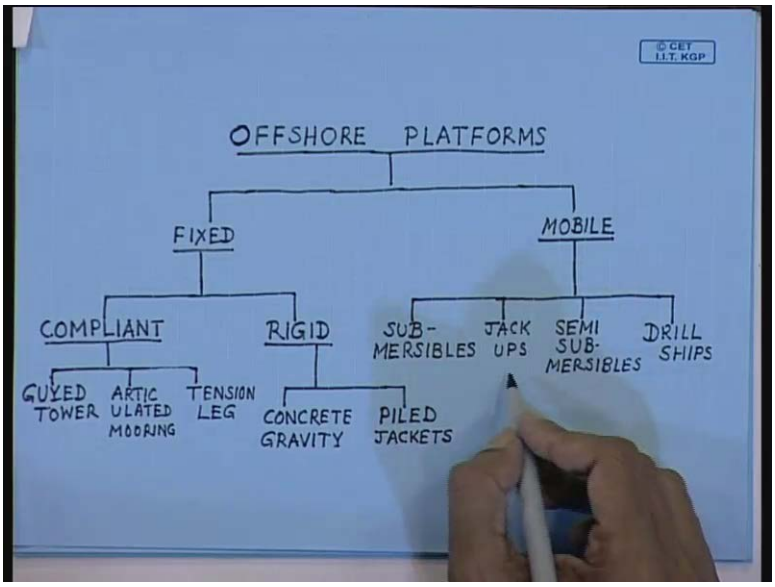

Now, there are various categories of offshore platforms, so it is better to subdivide them according to their functions. So, we will come across the design aspects later on, but first you know what are their basic functions. Now, you divide offshore platforms into two broad categories, the first one you call fixed, actually the dynamics of the platform is distinct for these two categories. So, the first one will be called fixed and the other one is mobile, now under these headings of fixed and mobile, you will again subdivide.

So, under the fixed categories, you have compliant and rigid, fixed is basically they have their base is connected with the sea bed. Now, we will discuss about the compliant category, compliant means the structure complies with the external load. So, the other one does not comply it is called rigid, now again under the mobile category that means, these types of structures, they do not have any connection with the sea bed, excepting of

course, jack ups to some extent in the drilling mode, they have their foundation on the sea bed, but most of them are floating.

So, these are first categories are submersibles, then you have jack ups, now these submersibles are different from what is your those ROE's, so these are, the other category is jack ups then you have semi submersibles. Now a days, actually the first category you have not many, so semi submersibles are more dominant. The last category is drill ships, now under the compliant head you have the major categories, but we will discuss all these in detail later on and most of them are used actually for moving wise.

So, first one is your guyed tower, then it is articulated mooring, the last category you have is TLP or simply you write tension leg. Another rigid category that means, platforms not having any motions, so here you have two types, first one is concrete gravity and the last category you have piled jackets. So, these are the various types of offshore platforms you come across, now actually these structures have evolved over the last say 50 years or so there has been rapid development in the offshore oil business.

So, with that, the structures have gone from shallow waters to deep waters, now here actually you will find to start with. Let us start with the fixed category, the more problematic varieties are with these categories, your jack up and the compliant category, so here you have to start with the jacket platforms.

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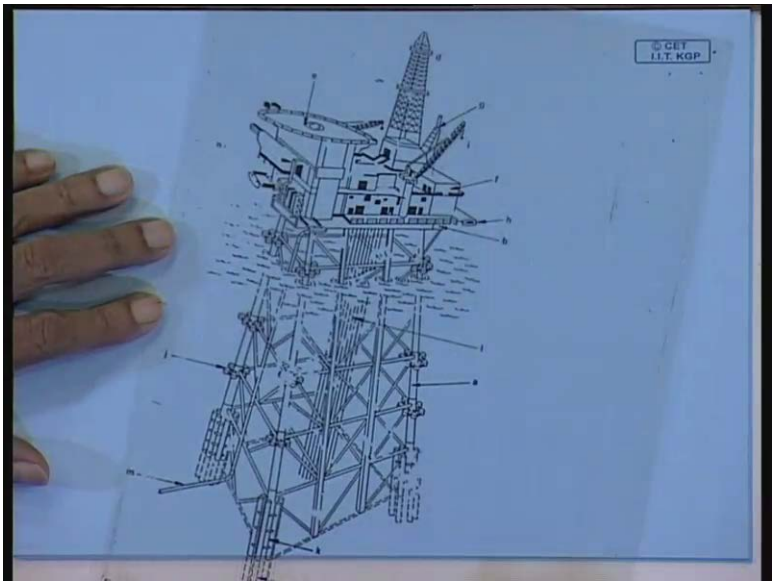

Now, here I think you can see this, here is the picture of a jacket platform, is of course you have taken a slide. Now, here you can see the various components that is, this is your deck and the helideck is here and this is your deck house and this is supported on a truss, this is a three dimensional truss. And here you can see that, there are a number of conductor piles that is, the marine risers, which take your oil from the sea beds to the platform top.

Now, one of the major advantages of this structures is that, you have the BOP essentially at the deck, you can service the blow out prevent out from the main deck. Now, you can see the piles, here actually you have to drive the piles through the sleeves, you can see the hollow rings at the periphery columns. So, these are the larger columns, you can see the one column here, 2 3 and this is slanted column, so this column is actually widening the base.

Now so these are risers and you can see the risers actually you are taking out oil from the well head or from the oil well down below and they are exports. So, N is called a export pipeline that means, the oil is carried through this pipeline into a tanker. So, there will be some small oil well out here, where it is fed to a tanker. Now, will you drive a pile, so the sleeves are there to drive the piles? The piles are driven through these sleeves through these guides, you can see the guides and on to the sea bed down below. So, actually this is a pile guide and this is a truss type of structure, you can see the bracings. Normally the bracings you will find, there are X or K bracings, so you do not have bracings in a random way like this in a jacket platform.

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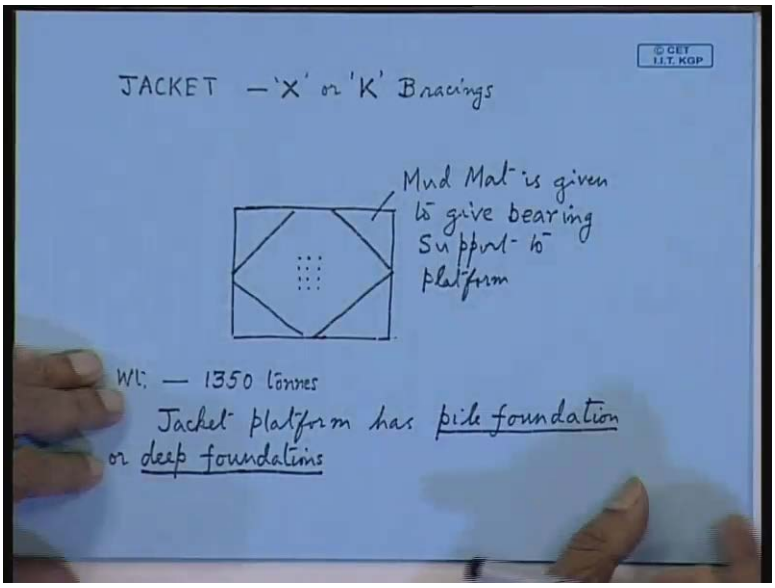

Jacket you go either for X type of bracings or K bracings, now these bracings have been designed after a lot of thought such that, there is no failure at the joints. So, here you can see, now what has not been shown out here is, at the base you will find a mud mat. Sometimes at the base you will find, this is a rectangular type of flat base and here you have a steel plate at the corners. Now, this has been given for the reason of, so this is called a mud mat, your conductor pipes actually will go somewhere here down below to the well.

So, conductor pipes will be here, this is your mud mat and these are your horizontal bracings of the platform. So, mud mat is given to give bearing support to the platform, the platform will be having tremendous weight. So, this jacket platform will be of the weight, I do not know this water depth has not been given, say around 100 meters. So, you can imagine the jacket, normally the mazagaon jacket that has been drilled for Bombay high, the weight is somewhere of the order of 1350 tones.

Now, all this weight has to be supported on the sea bed, so what you have to do is, first you have to build the truss and literally you have to pin this down to the sea bed by means of piles. Now, as I see here, I think this jacket does not have the long piles, which are driven through the columns. Now, sometimes they also drive piles through these columns, so those are called the main piles. And the other you can find around these circumference, there are shorter piles, these are called the skirt piles.

And here, you can see there are as near as 8 around, I think here it is less, around each of the main columns. So, these piles actually the function is, so this jacket is basically, jacket platform has pile foundation. In civil engineering, they are more comfortable with this term, they are called pile foundation or sometimes these pile foundations, they are also called deep foundations. A pile foundation is another term for a deep foundation why, because the piles are literally driven, say 20 30 meters into the sea bed, so that is why it is called a deep foundation.

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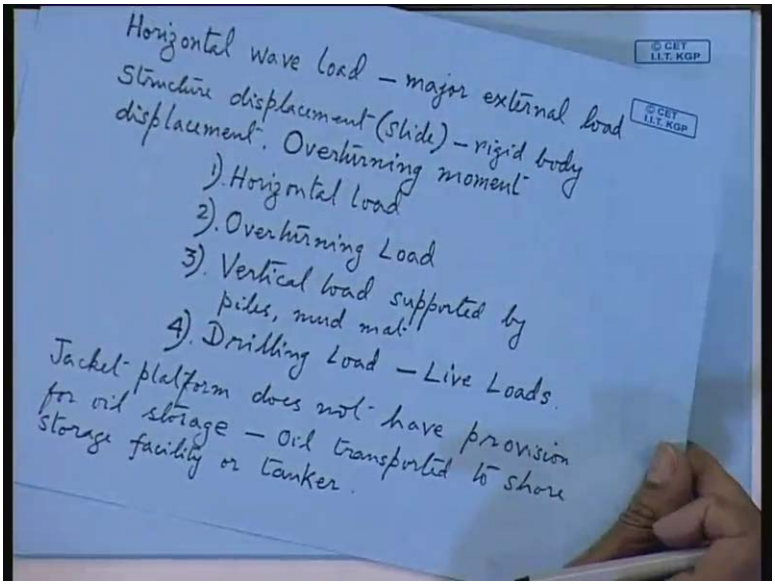

Now, here the major environmental force that is coming to this platform is horizontal wave load, so this is your major force, now this causes, there are two types, so major external load you write. So, as I have said, this will cause structure displacement, now sometimes this is called slide. There is rigid body, the structure is going to be bodily shifted around the direction of the wave. And the other is, so slide this is rigid body displacement and the other is the more important one, that is called the overturning moment.

Now, we have to build the structure that is, your pile foundation has to resist these two types of loads, basically horizontal load and overturning moment. What about the weight of the structure, so these are the two types of loads which is coming from the environment. Now, in the structure that you see, there will be major weight coming from

deck. So, all these deck modules will be of the order of weight, let us say 1350 tones and jacket weigh something of 1000 tones.

So now, 1000 tones of weight has to be supported on the sea bed, so that is done primarily through these piles. Piles are giving you the end supports that is, the corner support to these huge weights and also some of the weight will be supported by the mud mat. So, here the other is vertical load, vertical load supported by piles, mud mat, also these are some of the loads. The other loads, that you will face is your drilling load, now these are called live loads, drilling is an important function of the platform.

So, these are the four types of loads that you will come across in a jacket platform, now coming to the, main purpose of the jacket is to, now your jacket does not have any provision for oil storage. You can see the structure, the jacket platform does not have provision for oil storage. So, that is why, you have to have an export pipeline, does not have provision for oil storage. So that means, you will have to take the oil to a storage facility, so oil transported to shore storage facility or tanker.

So, the jacket has to be positioned in such a way such that, a nearby tanker can berth, you have to have a sufficient water depth or you have these export pipelines, you can leave you them to the shore facility. So, wherever you find all these jacket platforms, you find the sea bed to be literally criss crossed with pipelines. So, pipeline is another important aspect of your any platform, now here actually, the jackets actually have to be built.

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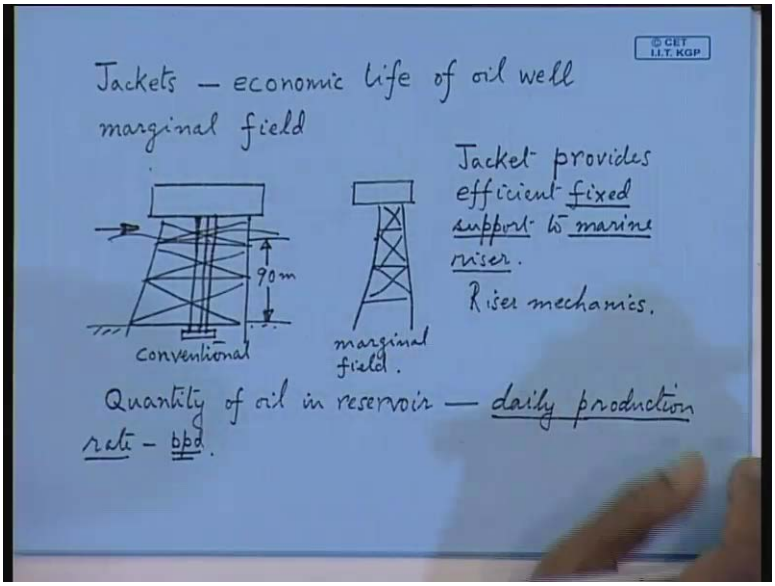

Now, jackets, whenever you build an offshore structure, you think about the economic life of the field, economic life of oil well. Now, it is no point wasting too much of money where you have, what is called a marginal field that is, sufficient oil reserve is not there, but only small amount of oil reserve. Now, in that way, in that case actually the design of the jacket platform you have to change. Now, here the figure that I have given you, your jacket basically is of this type that is, you have the larger columns in a slanted way, here are vertical columns and here, you have the bracings.

So, either you have the X bracings or the K bracings, so this is your jacket, now in a marginal filed, sometimes they do not go for all these large structures, they have a smaller platform. So, you can have smaller platforms like this, so this is conventional and this is marginal field, so these are one of the primary considerations for jacket design. So, you centered your platform design according to the quantity of oil in the reserve and what, so this is one of the quantity of oil in reserve or right in reservoir to be more appropriate.

And daily production rate, this is also a deciding factor on the size of the jacket, that this is your daily production rate in terms of barrels per day or BPD why, because the higher the rate that means, your marine riser or the conductor price is going to be of a larger diameter. So, the supporting facility will also has to be more robust to take account of these marine risers.

So, marine risers, jacket also provides support to marine risers, now this is one of the biggest advantages or provides efficient support or rather you write, efficient fixed support to marine riser. So, later when I talk about the drilling, I will show what is the marine riser. Now, you can go on increasing the size of these pipes along with you increase the weight of the pipe, what is you will find is that, the marine risers also encountering larger wave loads.

As soon as you increase the diameter of this pipe, so the wave load is also going to increase, so these pipes you can see, they are literally suspended from the deck and in between, you can give support from the bracings at this point. So, these things, these are actually the structure engineering problem, so here, this is your wave is something coming here and the depth of the structure will be, say of the order of 90 meters. So,

Bombay high is 90 meters, I think not 90, may be 70 meters water depth anyway, so this you have to give support.

So, provides efficient fixed support to marine, this is very important, so you have more number of supports, actually you can have what that means, it will resist the bending moment on the pile. The bending, because of their wave load, you find there is a large bending moment coming on these pipes. Now, you give supports, number of support points are more that means, the failure of the pipeline due to bending will be less, so that is one method.

So, you can do your final element calculations with the beam supported at this point, this point and your support points. Wave load is coming in the horizontal direction, so this I told you is an important study, these are called riser mechanics. So, you have to decide on the thickness of the riser pipeline from your daily production rate. And the number of supports that you can give to the pipeline, if you give more supports then you can go for reduced wall thickness of the pipeline.

Because, the displacement of the pipeline or the mode shaping the vibration is going to be less, otherwise you have to go for the thicker pipelines. So, this is one of the aspects that is to be considered, the other aspect is, when you go for this jacket platform, it is based on the I told you that BPD is coming from the production rate.

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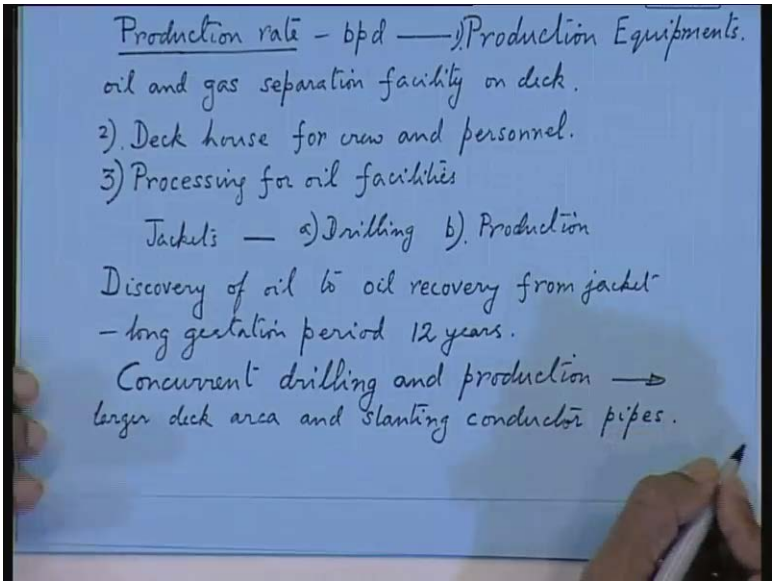

Now, this production rate that is, barrels per day, that is what I told you, is deciding factor on your production equipment. What is your production equipment, now you find that is, from your the marine riser from the conductor pipes, where you take out oil. So, when you lift oil form the reservoir, oil normally comes with the associated gas, but there must be a flare stack, you can see, this g is your gas flare stack.

So, the length of this tank you have to decide on the radiation of the heat from the flame to the platform, that it should not cause unmanageable heat on the deck of the platform. So gas, normally the oil comes with the associated gas and also you have some foreign materials that is, stones and all that will also come out, so those have to be segregated. So, you have oil and gas separation facilities on the deck, so this is one of the major equipments of a offshore platform.

So, that is your oil production that is, oil and gas separation facility on deck and then you have, this is number 1 then you can have number 2, from the diagram that you can see (Refer Slide Time: 28:57), we have a very large deck house for crew and personnel. So, they have to be housed on the deck, on the other you have the production equipment then you have the processing facilities for oil. Now, if you go to Bombay high, you find there are two jackets actually, the platform is of two types.

Jacket 1 will be for drilling, they are solely meant for drilling and the other is for production. If you go and visit an oil field, you will find these production platforms, so they are not doing any drilling operations, they are just lifting the oil, processing it on deck and transporting it to the tankers, they are called oil processing platforms. Now, what has happened over the years is that, from the discovery of the oil in a particular reservoir to the commissioning of the jacket, is a long gestation period.

To oil recovery, there is a long gestation period, now how to cut this down, now this almost takes as many as 12 years. So, people are not ready to wait for such a long time for 12 years for the oil to come out of the reservoir and then market it. So, nowadays, the technology has been developed for concurrent drilling and production so that means, you do the drilling and the production at the same time. Now, if you want to go for this that means, this calls for larger deck area and slanting conductor pipes. So nowadays, the drilling technology has also developed with the years and this types of drilling is called deviational drilling.

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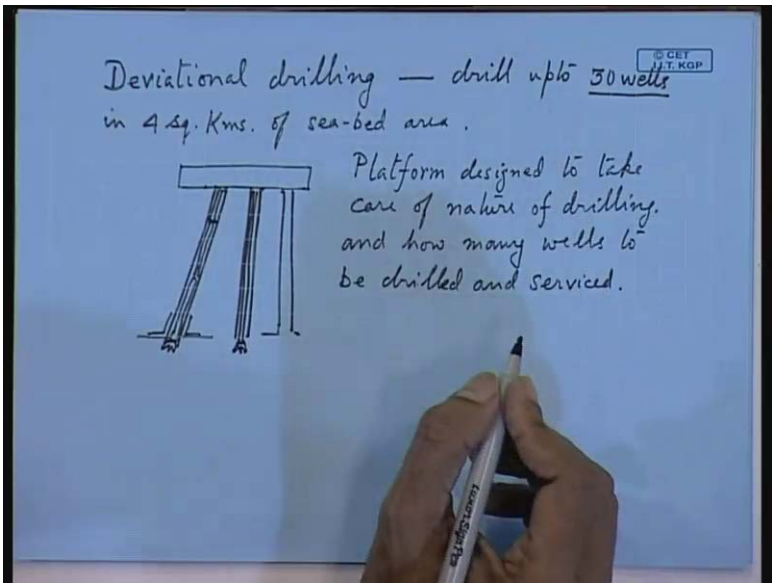

Now, here in this, you can drill as many as the number is I think 12 or 30s, so 30 wells, so deviation drilling, you can drill up to 30 wells. So, drilling can be done upto 30 wells and you can service as much as within 4 square kilometers of sea bed area. So that means, here you have jacket platform and you are drilling so that means, your drill string or drill pipe is not vertical, I am just giving you an exaggerated view. So, this is one drill pipe going in this slanted way, so through this, you have your drill string that is, your resume drilling riser.

Like this it is going and then you have the drill bed, so this is called deviational drilling or slanted drilling. So that means, this deviational drilling, it is done at an angle with the vertical and there are wedges at the sea bed to keep this in place. So, here you have one drill string, you can have another drill string which is vertical. So, like this, you can service 4 square kilometers of sea bed area and you can drill as many as 30 wells. So, this is one aspect of drilling technology, which has developed in order to drill more oil wells from a single platform, so this is done in this fashion.

Now, this requires expertise, whenever you building this kind of platform, platform is always designed to take care of nature of drilling. And more important is, how may wells you can drill and service wells to be drilled and serviced, so this is another deciding factor. So, all these production facilities, the deck actually you build this structure which you can see here that is, there are two major components of jacket platform.

What are the major components, two major structural configuration, one is your this underwater truss, there is this truss you can see, is massive. So, 90 meters say, this will be around say 13 or 14 meters by 10 meters small jacket, the other is the deck module. So, these are the two distinct structural configurations, which are fabricated separately.

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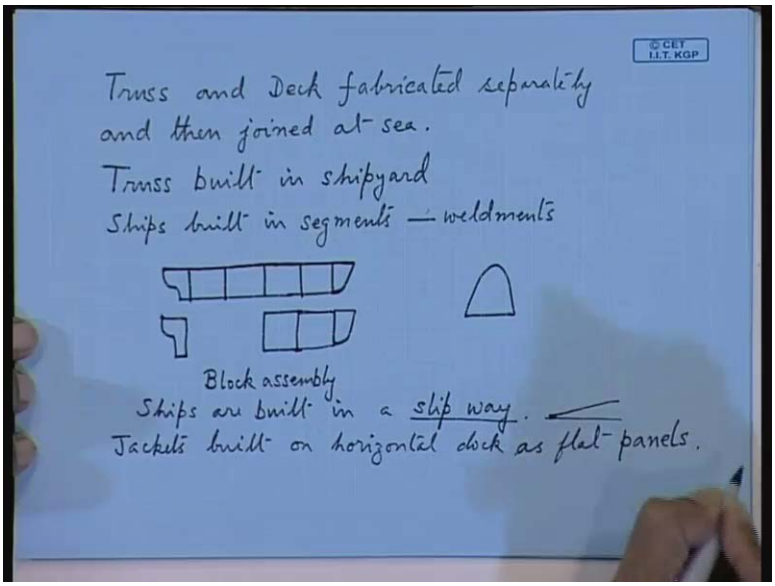

So that means, truss and deck fabricated separately, you do not build the truss along with the deck and then joined in the sea, joined at sea, so two major structural configurations are the truss and the deck. Now, truss also you cannot build at one go, the truss that you see in this figure, it is built in the ship yard, truss built in ship yard. Now, how are you going to build this truss, so you have to have some knowledge of ship building production. Now, ships are normally built in what, I do not know whether you have done ship yard organization or ships building.

Ships are normally build in segments, I come across ((Refer Time: 38:55)) ships built in segments. Now, these segments, they are called weldments that is, say this is the hull of the ship, you do not build hull at one go or for large vessels in the hull shop, they divide the hull into parts like this then you build say the 4 pieces built separately. So, this is one hold, the whole assembly is done like this, so these are the various blocks that are built, so basically this is called a block assembly.

So, these weldments, say this is the forward portion, you can build it upside down like this, because it is easier that way then you put it right by means of cranes and join these

sections or weld these sections. Now, this kind of thing is done in the hull shop, if you go into the ship yard you see, but in this case of jacket type of platforms, jackets, you can see that this is a truss. So, here you do not build the jackets, jackets are normally built not in a, now ships you will find they are built on, ships are built where, ships are built in a slip way.

Now, you should be conversant with all these terms, but jackets built on horizontal dock, the slip way you find that, there is a certain declivity or inclination. Jackets do not build on this kind on declination, you build on a horizontal dock as flat panels. So, jackets you can see, these are composed of large number of pipes, which are welded together on to this. These are the major columns and here these are the bracing members, so you build them on flat, laying flat on the dock, say those these are the columns and these are your bracing members.

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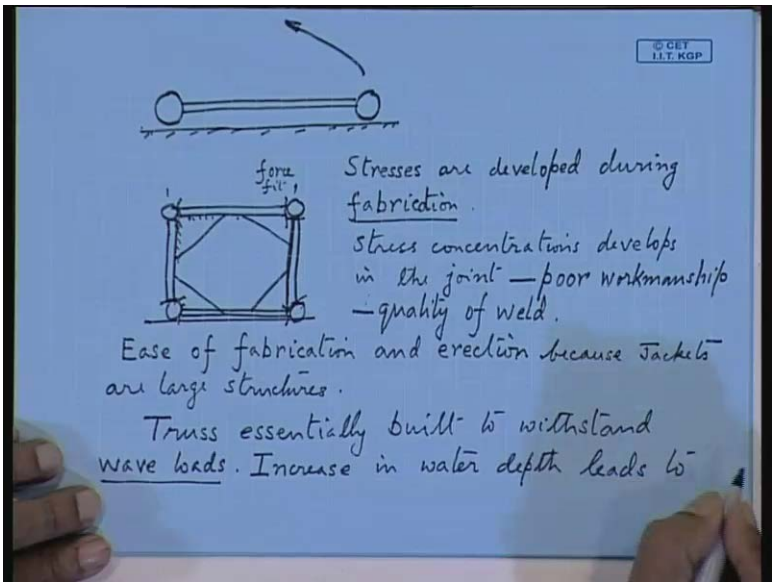

So, these are you build them on flat on the dock, because it is easier, easier this way to fabricate and then you rotate it by means of cranes, you lift this up. So, this gets a vertical mode, you bring another panel by means of cranes and joining the bracing members, weld the bracing members together and that is how, your jackets are built. So, when you go for the training at the end of third year, you happen to visit any of these offshore companies, you can see these fabrication things down.

So, this is one aspect which has to be covered, now here lot of stresses are developed at the erection stage. Stresses are developed during erection or rather you write during fabrication, this is just one example. Now, if you are not careful, you will find that this panel, you have not been able to bring closer together, sufficiently close for this bracing member to be welded or sometimes what is done is, you force fit. So, this is a very precision kind of task, you try to force fit one panel with the other panel, normally if you are not careful then I will do it.

So, what will happen, a lot of stresses will develop at the junction between the columns and the bracing members. And when you release them, when the jacket is released or when it is being transported to the launch bars, you will find cracks are developing, these are the favorable spots for, what is called stress concentrations. So, jacket is normally a huge structure and if you are not very careful during the fabrication stage, this leads to stress concentrations developing at the joint.

Now, there is a particular name given to this aspect of ship building, in ships also you find you have not made this panel perfectly matching with this panel then you have lot of welding stresses coming out from this figure. And then you will find cracks being developed, so this aspect of ship building is called workmanship or sometimes this is a result of, what is called poor workmanship, it is a very important part in shipbuilding. So, this actually the workmanship tells you a lot about quality of weld also, anyway this is what is coming up right here.

So, the problem with the jacket is in the shipbuilding or in these platforms, you always go for ease of fabrication and also erection. How much easily you can do it, without lot of stresses and strain coming on to the platform, because these are essentially very large structures, because jackets are large structures, ships are also large structures. So, they have nearing tendency to become to have all these unfriendly odd sort stresses coming up, so these has to be taken care of.

Now, you build a truss, truss is essentially built to withstand wave loads, the major load is your wave load increase in water depth. Now, if you increase water depth, what will happen to this truss, so if you want to build this truss, so the truss is built to take care of the horizontal wave load, there are other waves on your current and also your wind load.

So, increasing water depth lead to increase or decrease, what will happen if you increase water depth, increase in truss size why, what has depth got to do with truss size.

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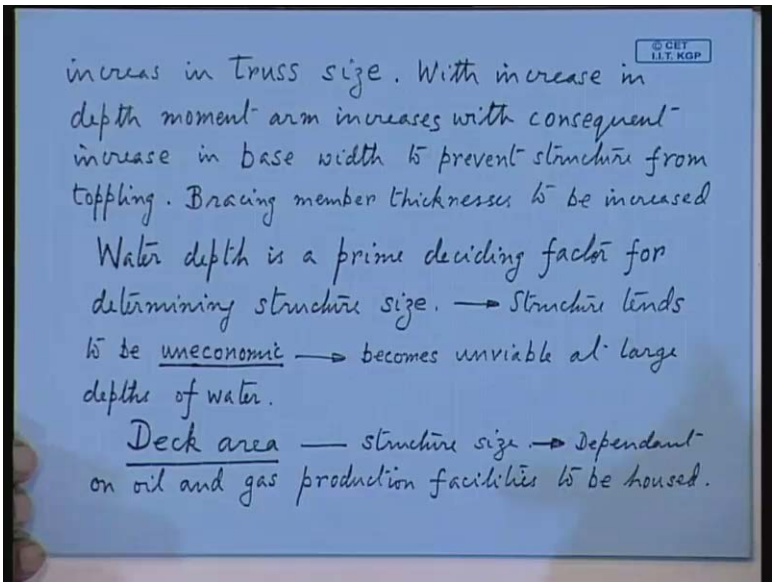

How will you increase the depth of the sea, why the truss size has to increase, because you have to lift the deck above the water. And this is a certain height above the water, they call it air gap, so you have to maintain constant depth. So now, if you increase depth vertically, you are also do increase the base width, the reason is, you have to counter the overturning moment. So, once you increase the depth that means, the momentum is increasing, so with increasing depth, the momentum increases with consequent increase in base width.

So, in your offshore engineering, so this is you have to play around with the environmental load and moment. Moment is also a very important factor, momentum increases with consequent increase in base width so that means, to prevent this structure from toppling. Now, so far so good, but what will happen to the size of bracing members, so that means, first is with increase in depth, you are also increase in width, so that means, all these length of the bracing members are increased, followed.

Now, the structure has also increased in size, both length, that is depth wise and breadth wise. So, now you cannot have the same thickness of bracing members, because a greater amount of load is going to come. So, bracing members size, so write bracing members thickness is also will be increased. So now, you are encountered with another twin

problem, so the structure you have increased in size and you have increased all the thicknesses and column diameters.

And you have also increased by that manner, the wave load that is coming on the structure. So, as a consequent of that, you have to increase also the pile diameter and the length, so with the increase in the size of the structure, all your parameters which define the geometry of the truss has increased by simply increasing the water depth. So, whenever for the fixed structures, water depth is a very important category in determining structure size.

So, you find that, water depth is a prime deciding factor, it is deciding factor or a governing factor for determining the structure size. So, here, you will find structure tends to be uneconomic, so the owner of the platform is not going to pay you, if you indiscreetly increase the structure size. So that means, your jacket platform is going to become unviable after certain depth. So, this is an example that I have given, where the water depth is a overriding consideration.

So, it becomes unviable at large depths or at large depths of water, so this is one reason, so this is the main drawback of the jacket platform. The other parameter which defines the size of the jacket is this deck area, deck area is another important parameter for structure size. Because, what essentially you are doing, is this truss that you have built, it is giving a support to the deck.

So, if you increase the deck area, obviously you cannot have a very narrow jacket, your deck will start bending like this. So that means, you have to increase the structure breadth wise or width wise. So, that will come, because now this is primarily dependent on oil and gas production facilities, that you are going to house. Now, this brings us to the end of this lecture now, next lecture I will continue with this and go to the gravity platforms.