Elements of Ocean Engineering
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Lecture - 31
Mooring Systems (Contd.)

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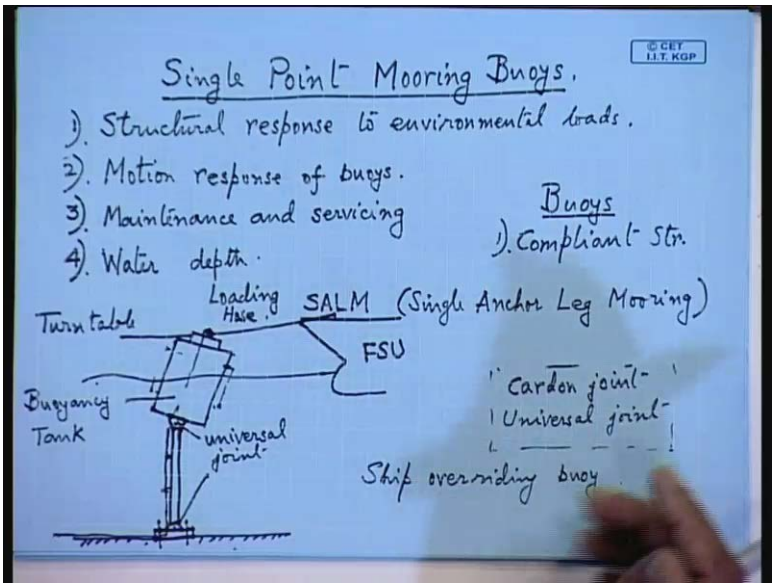

So, we will continue with single point mooring system, which have been most widely used, now there are various forms. So, these are called single point mooring or single point mooring buoys with more precise. So, here it the prime consideration is you I told you last class number one is environmental loads now environmental loads you calculate the structure response. So, this you have to calculate from the structure. So, structural response to environmental loads and the most important after that structure is the motion response. So, all these buoys consideration has basically evolve how to reduce the buoy motion. So, buoy is motion response of buoys, here two primary consideration. Number three you can write is maintenance and servicing.

Now, servicing is actually very crucial because, you are dealing with oil. So, there are last class I have given you one diagram of an ALC where you see number of joints. Now, these joints have to be properly maintained, otherwise your buoys is going to snap because, buoys come under this category that, I have told you buoys are basically compliant structure that is it moves with the waves. So, there are three types of offshore structure that at the beginning I told you or the fixed category other is the fully floating

and between these two you have complaint structure. Now, complaint structure the essence is that they do not yield completely with the waves, but they go they yield very to a large extent than your fixed structure. So anyways, so, that is why the complaint structure has come.

So, maintenance and servicing is another important area for consideration for buoy design. So, motion buoy design or what else, four is the water depth criteria you will see how the evolution of these buoys have come with water depth. Now, the water depth is not very large you can go for a this is called a single anchor leg mooring or salm system this is called single anchor leg mooring. So, in offshore actually buoys are of different categories, the once that you have seen in the rivers those are very simple buoys.

So, here basically you have a large tank at the water surface and almost in all buoys you will find the buoyancy is subtract by these tank the buoyancy tank is located at the water surface. So, this is single anchor leg mooring buoys and then you have one joint just below the tank, I think this is a universal joint probably is not mention and then this is steel arm or a steel leg which is going to the sea bed and then you have another joint out here. So, this is the salm system, this is sea bed. So, this joint, this you write universal joint, there is one universal joint another universal joint at the sea bed.

And this is the base is actually now, piled you have to do is better to pile the base to the sea bed because these structure are light and normally heavy short of base is not very congenial. Now, here at what you have this is called a turn table. Now, on the turn table you locate your loading hose. So, your tanker maybe out here. So, this is your F S U of floating storage unit as sometimes it is called so, this is F S U and your tanker actually takes the loading hose from these points. So, this is your loading hose. So, this is one design. So, this is a pretty small buoy and this is your buoyancy tank.

So, the barrier of this buoy is a inverted pendulum it can swing in any direction about this joint. Now, as per as design is concerned there are some aspect which you should remember first is the, this two joints designs adding machine design you have done there is a buoy and quarter joint and all these joint designs. So, this is universal joint another joint I just called to cardon joint. Cardon joint actually not give the rotation in all the direction and the other is universal joint. So, in mechanical engineering those of you have done machine design this book of any book on machine design they will tell you

about this two joints. Now, the problem out here is the maintaining of this two joints and you have a riser which is coming from the sea bed and it is taken up on the side of your this leg. So, it is clipped out here.

So, riser also has lot of motion; that means, you have to design riser in such that this sway motion or probably the angular motion are taken care of and then it comes through this tank goes up and you can load your hose. now what happens in unfavorable weather this tanker will come and bang against the buoy this is. So, you can see this part is very vulnerable although fendering is there, but there is a likely chance of this is called ship overriding buoy. All the way ship is anchored your tanker is anchored, but this you cannot in storm condition this may happen the ship is going to come and crashes as the buoy. Now, in that event this joint is going to be damaged first of all you can see this is joint, this joint is located below the water surface.

So, a person has to go down below the water surface in order to maintain this joint. Joints have to be inspected specially under water part the divers or r o v they go down and inspect the joints, but problem out here is the one problem. You face is the tanker coming in crashing against the buoy and damaging this joint. The other problem is the maintenance part, but if you can take care of this you have this kind of confident. Now, one thing you can see that there is no moving buoys attach to the buoyancy tank of the buoy itself. So, there you will have lot of motions about this joint, there is no restrain actually so, but these are actually small buoys. So, we are not much bother about it the only thing that you can bother is the ship overriding the buoy.

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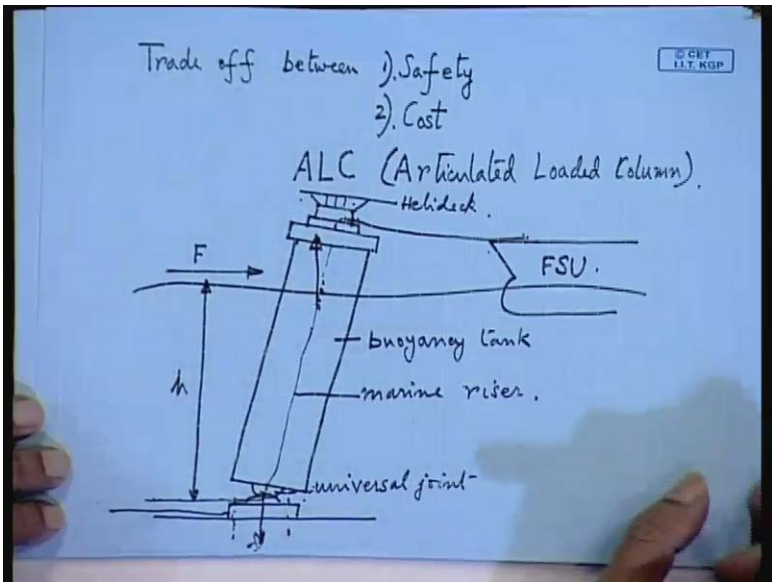

So, in offshore actually the other prime consideration is cost. So, there is always a trade of between cost then always trades of these two aspects between you have to strike a balance between safety. Safety is a very prime consideration in the oil exploration and lifting from safety and cost now, you have to balance between this two. So, which one you will prefer that is once your marine riser. So, this is your marine riser, marine riser being snapped or damaged it is a very serious issue as you can see in the disaster in gulf of Mexico.

So, if you can take care of that, you go ahead with this because this cost is less your other option is you can enlarge the size of the buoy. So, this is a single anchor leg motion. So, this is called a ALC. A L C is another name for articulated loading column this I think I have given you the diagram last class. Now, in this configuration you can see, that the marine riser you can take inside, but this is slightly larger buoy and you can have a heli deck cranson all that on top of that deck

So, this is your buoy and ALC has a tank which is more or less going down to the sea bed is called articulated loaded column or loading column you can say, but again there is a universal joint at the bottom. So, this is another configuration, but this is bigger than the slam concept. Now, here you have your loading hose turn table and you may have the helicopter deck out here. So, this is a slightly larger buoy. So, your loading hose will. So,

this is your water line and your F S U will be located somewhere here. So, this thing again turn table will be here this is your loading hose.

So, this is your universal joint. Now, buoyancy tank, now one advantage you will get from this configuration is that you have giving some at least some protection to your pipeline or riser. So, riser you can take it inside riser is support is through the buoyancy tank and you can take it on the deck. So, this is your heli deck. So, this is your bigger buoy. So, you can see the configurations of buoys. So, the buoyancy tank actually gives you the upward buoyancy that is the writing moment. So, here is the way it is acting down and the writing moment the center of buoyancy you find out, from your hydro static.

So, in any position of the buoy you will always be getting your writing moment, but still there will be lot of sway motion listen it. Be able to getting inverted the pendulum. So, the chance of anchor crashing against the buoy is still there, but with more protection to the marine riser. So, your marine riser is going inside this, now this type of buoy actually the slam on the ALC you cannot install in very deep water.

All you say these are more or less these are all these are compliant structure with connection to the sea bed as you can see these also compliant structure category inverted pendulum. So, the hydro static is simple this is there a writing moment that is all and taking care of the weight and these healing moment will come from the waves. So, this multiplied by this on that is your overturning moment listen it. So, this is your h.

So, this is you wave load say F h is your healing moment and how will you get the writing moment. Writing moment will come from the buoyancy support, buoyancy z you calculate the center of buoyancy you will get from here. So, this will get the writing. So, this is your buoyancy lever and this is overturning moment so, this is your ALC. Now, So, similar thing that now going beyond is now all these things you have design keeping into mind the production rate. So, if you have it has not it is not mention whether this has storage capacity or not can you come back to the later one this is the other one is called fixed tower.

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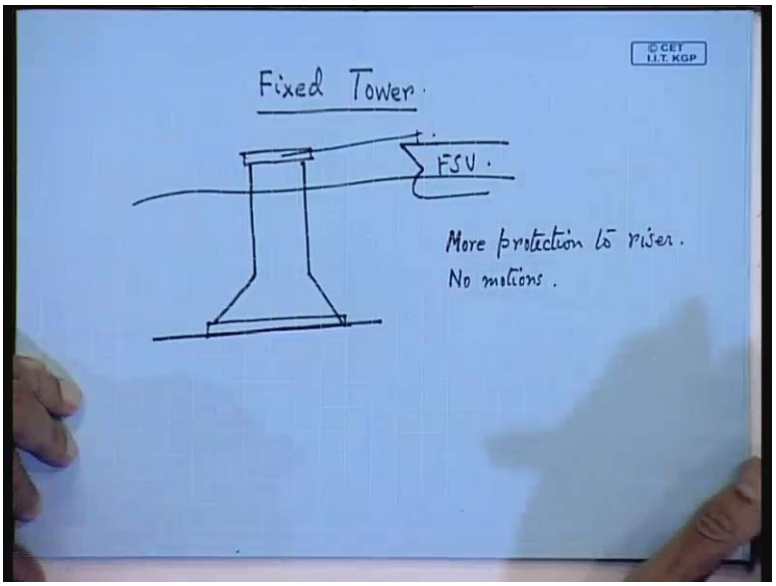

So, in the fixed tower concept; that means, there is no motions you can get rid of all the motions, but you make the base very heavy. So, your loading goes will come here. So, fixed tower is more protection, no motions. More protection to riser no motions, virtually no motions.

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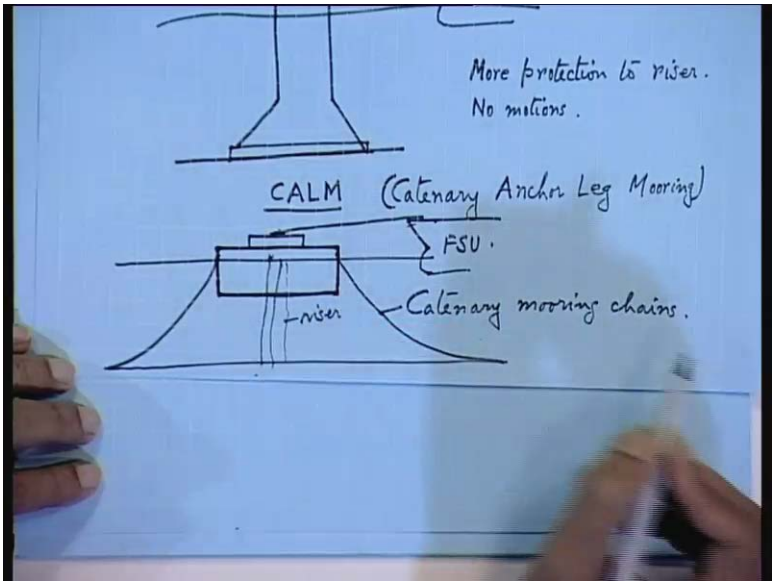

Now, the other varieties the catenary of this told you knows. Now, the most common is you are this calm, CALM these are buoys that you normally see in the harbors. Now, you go to Calcutta port or Bombay port you will see the ships are moored, but those are

mooring buoys those are not offshore terminals. So, these are calm concept, calm concept is catenary anchor leg, this is called catenary anchor leg mooring. So, these are very common. So, this is your sea surface, but the problem is they do not have any attachment with the sea bed or fixation with the sea bed by means of a fixed this thing column or whatever joint whatever it is. It is a absolutely floating type of buoy.

So, calm is floating buoy. So, here you have anchor chain now, these buoy you can see in any port. Now, this also you can use for floating your oil, but your marine riser will come somewhere here. Risers will come out here and then you can take out this oil from the turn table at the top from here you can take out. So, this is a calm concept and this is your buoyancy chamber same thing the only thing white is called catenary because, of the catenary mooring chains. So, as naval architect you see, there you can have to do large number of buoy designs riser you can have one riser. So, many risers need not be shown. So, here also you will find that the ship can damage a buoy in case of very rough weather you cannot stop the ship from overriding on the buoy listen it.

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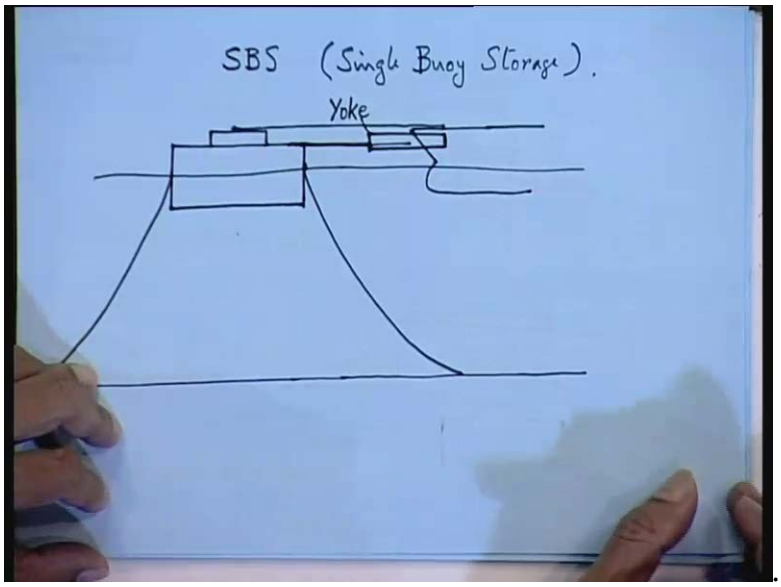

So, a variation of this concept has come this is the calm is very and you have what is called single buoy storage or and S S B S. Now, mind you these pretty small buoys I will talk about the larger variety. So, this is single buoy storage it may have some storage capacity in your buoyancy tank, but the prevention of the ship overriding the buoy is taken care of by means of a yoke, you have to design a yoke.

So, this is your turn table now from this turn table say this is your water line. Now, your ship is floating at this water line. Now, how to prevent the ship overriding the buoy so, your motion calculation are quite complex in this cases because, you have to study the vessel motion along with the buoy. So, you give a arm rigid arm like this fixed to the ship. So, this is called a yoke, y o k e.

So, this normally you prevent the ship from crashing against the buoy and of course, your loading hose will come from this end and go here and the same catenary concept is out here. So, this calm and the S B S you can employ for deep waters because, they are fully they are the fully floating variety. They do not have any structure going to the sea bed. So, these are S B S support. Now, the larger varieties that will come these categories that is called spar. Spar is also very common buoy, but this is very large SPAR do you know, what is the meaning of spar. Spar is a common word in civil engineering which normally means a tall cylindrical structure.

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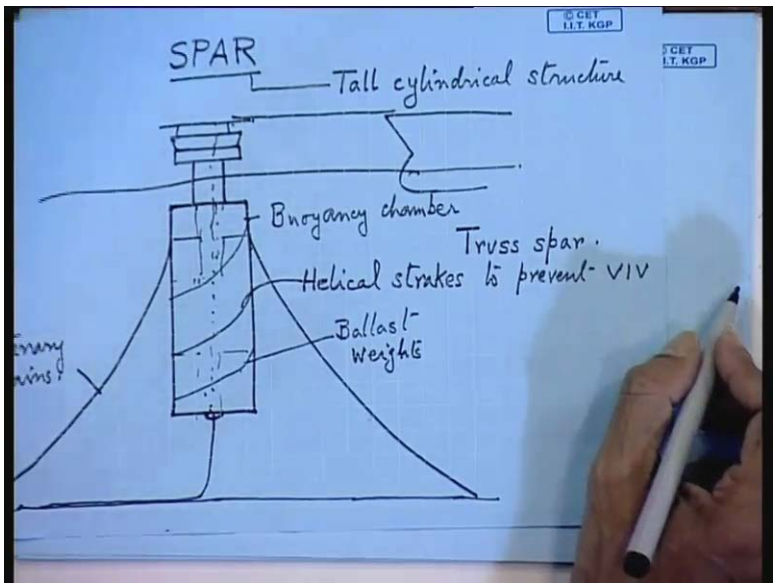

So, this spar concept is a pretty wide spread in offshore engineering. So, here you have a neck type of column and here you have the larger buoyancy tank. Or now, see in this spar actually you can have there are two types of spar which is called a cylindrical spar and spar next class I will give the detail diagram of a spar. So, this is your spar. Now, here this is your water line is somewhere here or now spar concept spar normally does not have any attachment with the sea bed. Sea bed you are free and you can attach your

moving chains in this form. And your marine riser is taken care of comes like this inside the tank. Sorry, this is little of center it goes out like this. So, normally the spar you will find the empty tanks the giving buoyancy or located at the top and down below you can have water ballast tanks or weights.

So, you have ballast weights down below. And instead of this cylindrical tank you can replace part of the cylinder by means of a truss, these are called the truss spar. The other one is, I think the name of this one is probably, I think is cylindrical spar or something I give you the truss spar I have not shown out here, but basically this spar will have a buoyancy tank at the top or rather you write buoyancy chamber. We have ballast weight down below or ballast tank down below to main keep it up right and your now, the motions actually to prevent there will be lot of search around these motions.

So, there is at restricted by means of these catenary chains so, your tanker is out here. Now, a variation of this spar instead of having long short of tank out here, there is having the same diameter. Another problem with this kind of spar concept you will find, you have lot of ballast induced vibration. So, what they do, they incorporate some helical strakes around this shell of this spar these are called helical strakes. So, this prevents VIV, volt indexing vibration these some of these concepts will come across.

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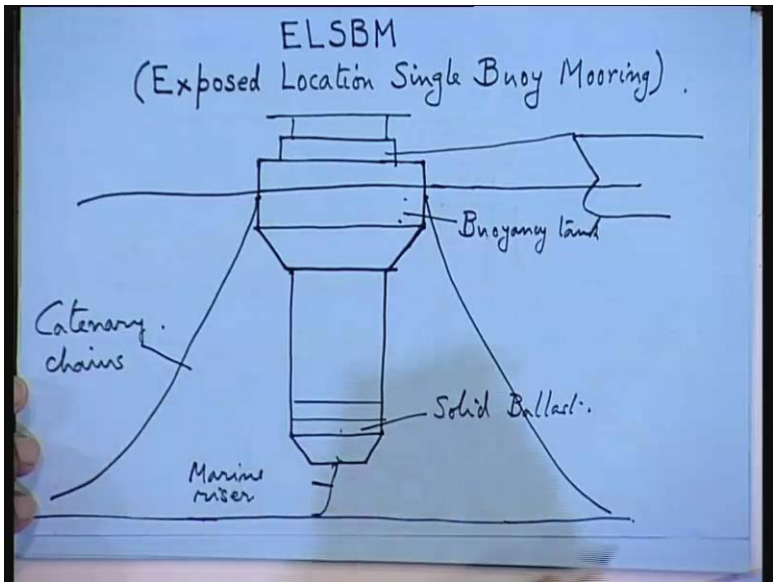

Now, the other one that is quite common, but not so common as your spar as your E L S B M, E L S B M is a larger buoy. So, the full form is exposed location single buoy

mooring as E L S B M. Now, E L S B M you have larger buoyancy tank at the water surface. Now, can you tell me what your this difference between spar and E L S B M which should have more motions. E L S B M or spar now, remember in the naval architecture field were decides your hydro statics r n p the motions in offshore actually there motions are very very important. So, which is going to have more and less motions?

So, this is the diagram of a E L S B M. So, motion calculations you have to do tank. So, your marine riser same thing this is your sea bed and your marine riser you can take it up from down below inside the tank, but here actually the larger tank is at the water surface. Now, giving what giving your larger deck area so, here you can have your heavy deck turn table etcetera all this have out here. Your FSU will be somewhere here. So, you compare this with the spar. So, spar design where so, spar gone at the back.

So, this is your spar. Now, spar you can see at the water line you are having a smaller water plain area, but most of the tank is submerged large volume is submerged below the water line where as in this case a considerable volume is at the water plain. Now, motions especially the hive motions are governed by water plain area. So, you have more water plain area at the mean sea level you are in for larger hive motions. So, your hive motions are going to be more out here. So, the same configuration you have your buoyancy tank out here and the weights ballast weight down below. Ballast or here you can give solid ballast. Now, to prevent the large amount of motions you have catenary anchor leg chains. So, your marine riser goes inside, more motions than your spar, but larger deck area support.

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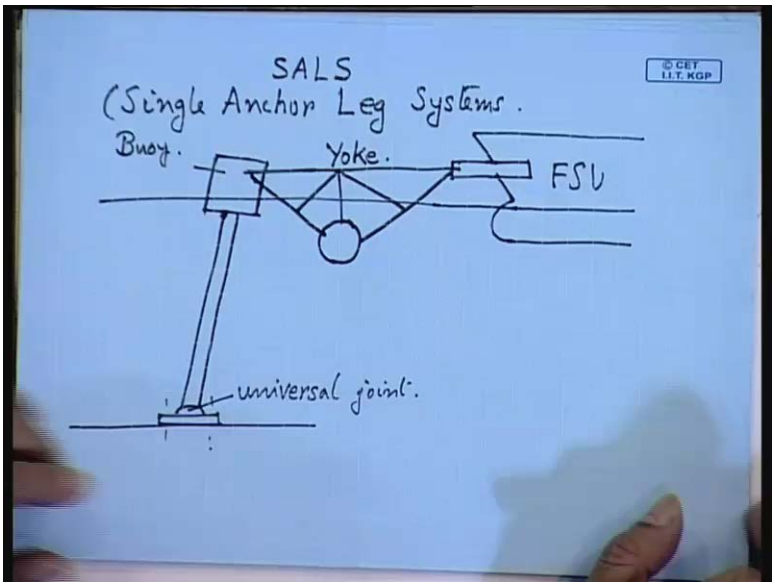

So, this is called a E L S B M. The other one is called sals, S A L S this is a single anchor leg system. Now, here the buoyancy tank is located somewhere here, the arch part is protruding out of the water and here you get a column steel column and universal joint will be down below. So, pile it now, in this system you have a larger yoke. So, this is your yoke, with the buoyancy cylinder and a truss.

So, these structures have to be design taking into account your extreme weather conditions. So, 25 years extreme storm so, this is your FSU. So, this system is called yoke. Now, you can see a very large yoke attach to the buoy. So, this is your buoy, buoyancy is coming from this tank and this is a universal joint. Now, since this structure this one the other category is your ALC that one, I have talked about this one and also the surround system there are to be positioned in shallow waters, the deep water you go for A L S P N and spar. So, shallow water where you can have fixity with the sea bed you go for this thing sals.

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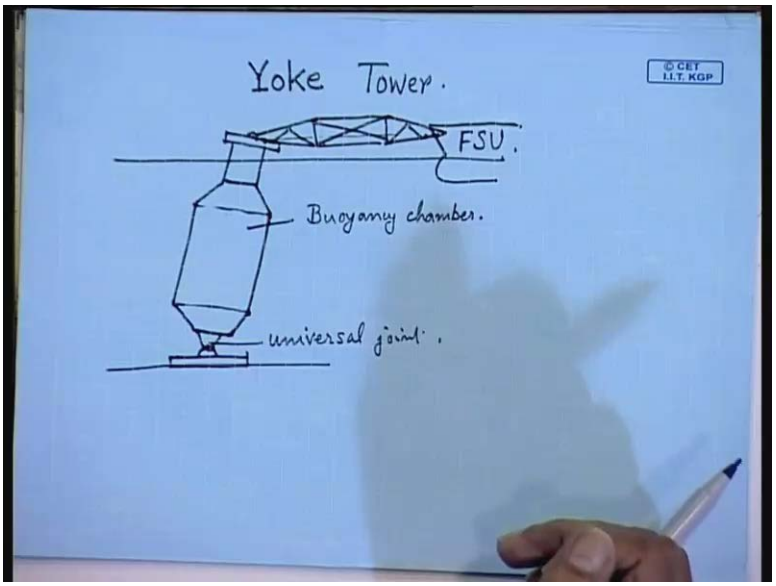

Now, you keep on increasing the size of the sals you have a yoke tower, but always have fix they are fixed with the sea bed. But the buoyancy tank you can see buoyancy tank is located below the water line, those of you have got class you can go. So, this is a yoke is called the yoke tower. So, here also there is a universal joint, this is your buoyancy chamber. Now, you have a bridge type of truss. So, the truss is quite large out here.

So, in these two systems that is your sals and your yoke tower the loading hose you can load it from here you can take it through the yoke. So, you can give some protection to the loading hose. Here also you can the loading hose is not soon axis the loading hose is going over the yoke somewhere it look. So, the chance of ship over riding the buoy and damaging the loading hose is not there. So, this is the larger category. So, this is called the yoke tower. Now, where you have of course, this type of structure, we not to be formed in tropics you will have in Canada etcetera. This is called a monopile.

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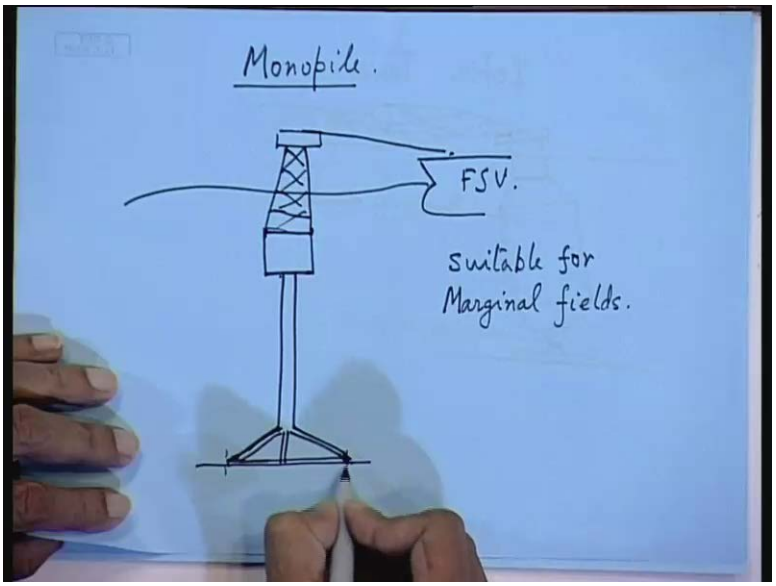

Now, there are specifically design to ward of icebergs that is floating ice. So, here you make this structure out here and truss shape it. These are not floating these are absolutely fixed structures. So, you have a buoyancy tank below and you have just one column, but these are very slanders structures not dual form heavy duty there base is some kind of a tripod type base. So, these are monopile construction.

So, your water surface is somewhere here now. Now, these types of structures are suitable for marginal fields. That is where you do not have too much of oil, they are called a marginal field. So, marginal field you do not waste your money on having a very large structure. Now, here actually you make a steel base done make it out of concrete, this is sea bed loading.

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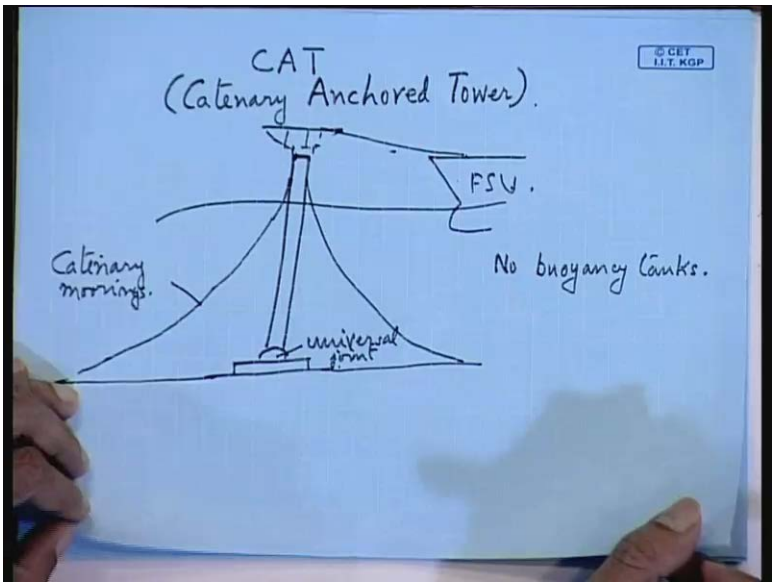

Now, the tower concept you have another called C A T or catenary anchored tower. So, this again is not a large structure this is also a small structure you simply have a column through which you can take your marine riser, but this is going to involve above the base by say universal joint. So, this is called a C A T. So, you have a heavy deck etcetera out here loading hose and always, but there only difference is you moore it by means of a chain.

The column is actually moved by means of catenary chains and the other thing that you can notice is no buoyancy tanks. So, these are very tall and slanders structure no buoyancy tanks, catenary anchored chains catenary moorings universal joint. So, this is the specialty. Now, the last two where I T s are what is spar I have already talked about there is another configuration which is called a semi spar.

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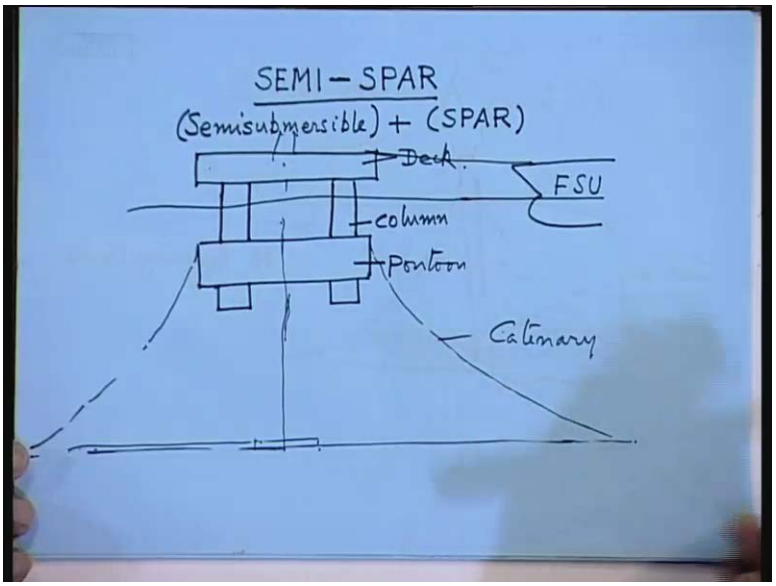

What is this semi spar? Semi spar is a semi submersible; there is a combination of a semi submersible plus spar. Now, you all know what is a semi submersible, T L T semi submersible I have talked about these are combination of a semi submersible and it is spar. So, the semi submersible you have columns and down to you have a pontoon, but I since this is also spar concept you find that the columns are sticking out of the pontoon below the bottom of the hall. So, that is why it is also called a spar, spar actually means the, is a cylindrical structure tall long cylindrical type of structure, which is called a spar.

So, this is the semi spar. Semi spars are not that common, but it is still there and water surface is somewhere here. So, these be as more or less like your semi submersible you have your breathing your riser will go out through this. So, these are your columns, this is your pontoon and this is your deck. So, your prutings total unit is going to be located out here. So, I can from here you going to take it. So, this has storage capacity in the pontoons. Now, you have to move it semi submersible is always move by catenary anchored chains. So, this is your catenary and your riser is coming from here from the wheels. So, there is a semi spar concept, last one to some extend I have talked about that is called a turret or turret mooring.

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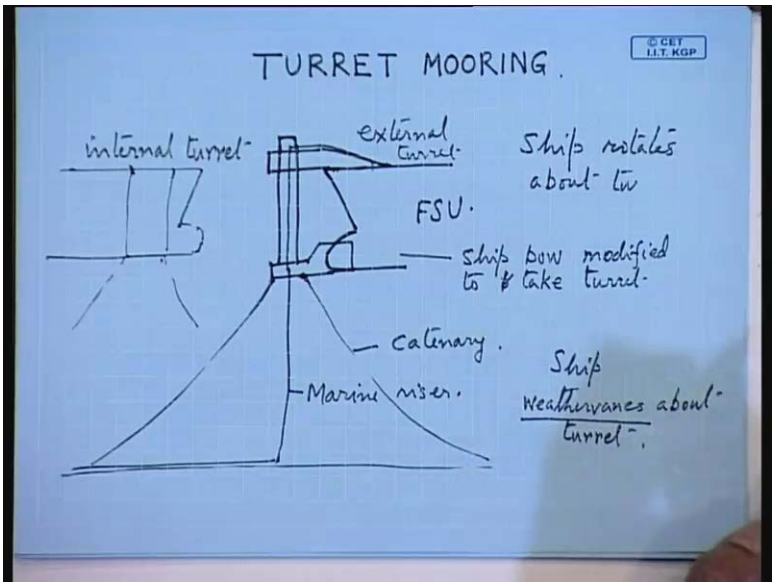

Now, turret mooring actually there are two types, one is called a external turret and other is a internal turret. Now, the one which I showing out here is an external turret. So, external turret is a structure which is fixed to the bow of the ship, it is called a bow turret. So, your taker is somewhere here, you are sorry, your tanker will be somewhere here, now this advantage of this type of turret moving is that the ship is literally claimed to your moorings there is no chance of the hose getting damaged. So, this is your combination of a mooring along with a what? Along with a yoke. You have to make a structure like this which fits smugly to the bow of the ship.

Now, this from here actually there is a, the mooring or the catenary moorings are attached at a rotating table fixed at the bottom of the turret. So, actually the ship is able to revolve about the turret. Now, your marine riser are will come from this it will be taken up here it will go up and then right down to the tanker. So, this is your catenary, this is your marine riser. So, ship bow modified to take turret.

Now, these turret mooring is quite common. Now, turret actually the position is normally you can position it at the bow because, the ship will not be in danger of overriding your catenary chains or you can have a internal turret. And normally turrets are positioned at the bow the ship. Now, internal turret is, it will be positioned; however, insider the ship at this location. So, your mooring will come out here, the ship is able to ship rotates about turret.

Now, in your this thing your interviews and all this, they will ask, they might ask all these questions, you know what is the turret mooring. So, immediately you just draw this diagram and you just tell them there are two types of turrets. One is called the, this is an external turret and this is called an internal turret and they might ask you why you go for turret mooring, why not the normal moorings. So, what is the reason? Reason is you have a single system about which the ship can revolve or rotate. Now, that is called ship weather vanes. It is called weather vanes about turret.

So, the ship is efficiently about to weather vanes about turret. So, that is the main advantage of turret mooring. So, all this question there, I think nothing high large scale maths is there, but these are common practical questions normally they are asked, students are asked. So, you just have so, this is about turret mooring. Now, next class we will try to finish this turret mooring system and then we will go to structures.