Elements of Ocean Engineering
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Lecture - 30
Mooring systems

Start from this, so we revert to this diagram. So, the assumption that we have making is the gravity anchors which can obey gives a horizontal force. Now, we have to calculate this tensioning the chain minimum length of chain cable. So, what was the expression for S?

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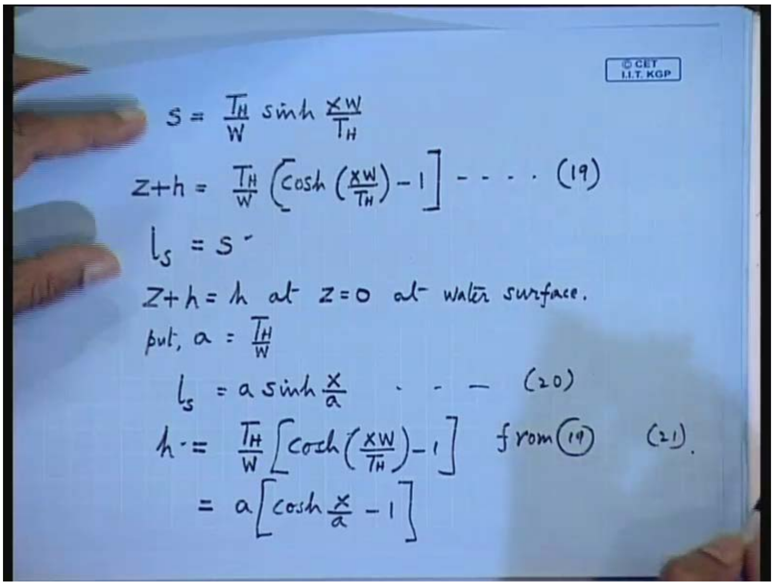

The expression for S at sea bed. So, this was our expression. So, this we have already derived. So, then what was expression for Z plus h. So, T H over W so this multiplied by cos hyperbolic these are how much X W over T H. So, this minus 1 so this you put bracket. So, these 2 expressions we will use now you put l S equal to S. Now, Z plus h is equal to H where; obviously, at Z equal to 0. So, this is at water surface now, you just bit you put this small a as T H by W. So, our expression for l S becomes l S equals to S. So, length of chain cable let us write as l s. So, this is a sin hyperbolic what is this H W over T H this X by a. So, this is sin hyperbolic of X by a. So, that is simple now, what is the value of H? Can you simplify this expression?

So, H we can get this Z plus h write down the expression for h. So, this is your I want to get rid of this Z value. So, this is Z plus h equal to H at Z equal to 0. So, this is H equal to T H over W from this expression. So, this is cos hyperbolic of this, but you substitute this a. So, this becomes cos hyperbolic. So, this you know this is 18 or 19. So, this you write 19. Now, you put a T H over W. So, this will be H is equals to a multiplied by this how much X by a minus 1 now, using this 2 equations. So, we have found out l S equal to S and H value we have already found out now l S sorry l S. We have found out this is from this you used these equations; this is from 19 this is 20, 20 and 21.

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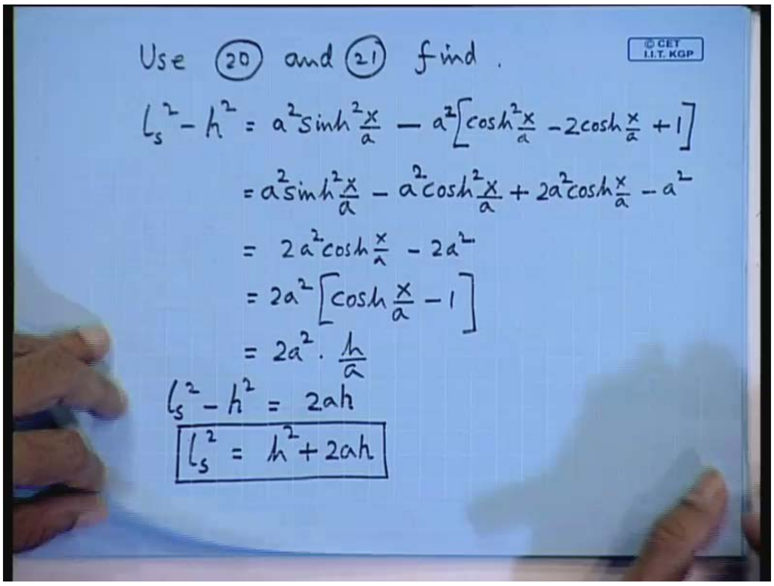

You calculate this l S square minus H square and then you simplify. So, this will be a square sin hyperbolic square X by a; this is simple substitution that is all and this will be T H this is H square hole squared. So, this will be cos hyperbolic square X by a minus twice very simplification. You can bring you can simplify these 2 terms. So, from here how much we are getting? So, X by a and this is only minus a square.

So, can this be simplified? So, this is a square [fl] this is how much? Cos twice cos hyperbolic; this will be 2 a square cos hyperbolic X by this is sin square minus cos square by minus sin square. So, this is equals to no there what a square will be there is not it. So, this will be minus 2 S square while 2 S will cancel out. So, this is 1 I think from here this will minus 2 S square will come. So, this is minus 1 I think. So, this is minus a square minus S square minus 2 S square and this 2 S square cos hyperbolic X by a is come. So, this is 2 a square cos hyperbolic X by a minus 1.

So, these are expressions so from here, but what about cos hyperbolic X by a? So, what was our expression for H? So, from this equation that is you calculate cos hyperbolic S by a. So, H plus a so this is H plus a minus a, H by a plus 1 this is a this 1 is H by a. So, this is equal to 2 a square multiplied by H by a. So, from this expression H by a cos hyperbolic X by a minus 1 so we are getting a ultimately we have got a simple expression. So, that is l S square minus H square is equals to twice a H so; that means, square of this is H square plus twice a h. So, this expression we have got. Now, you write down the expression for line tension. So, line tension what was or equation that T.

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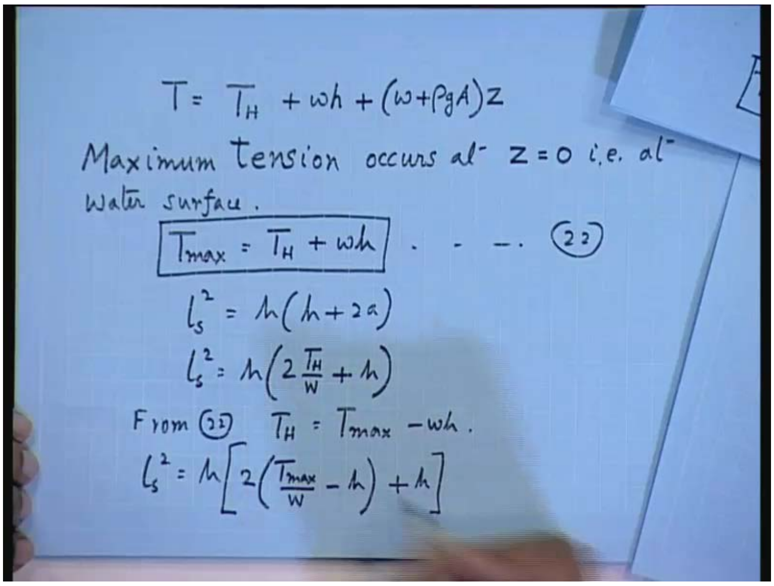

Capital T, T H plus W multiplied by H plus W plus rho g A and you keep outside bracket that Z value. So, this expression we have already derived previously. So, this is where we have I think your note is goes jumble down this expression now, you put Z equal to 0. So, maximum tension where does it occur? Now, where does maximum tension occur? Z equal to 0 or Z equal to minus H you now Z will have negative sign. So, it is minus h; obviously, it is going to reduce this value. So, maximum tension occurs at Z equal to 0 so that is at water surface. So, T max we will get this has T H plus W h. So, this is special to be remember other expressions that we have got that is the length of the chain cable from here that is l square. This is equals to H multiplied by you keep H outside bracket. So, this is H plus twice a now, you a you tell what is the expression for a we have given this is T H by W?

A is T H by W. So, l S square ultimately becomes a H multiplied by twice T H by W plus h. So, now, you tell me the length of minimum line. So, you substitute this expression that is all. So, T H is how much this is say this equation number 22 is not it. So, from 22, you just substitute tell me to what is T H by W or from 22; you write T H is equals to T max minus W h. So, l S square, what is the expression? So, keep H outside bracket. So, this will be twice of. So, this equation will be T H you will put this T max over W T max over W and this is minus H, you do not forget this minus H and outside the bracket you write plus h. So, this is minus 2 H plus h. So, this becomes minus h.

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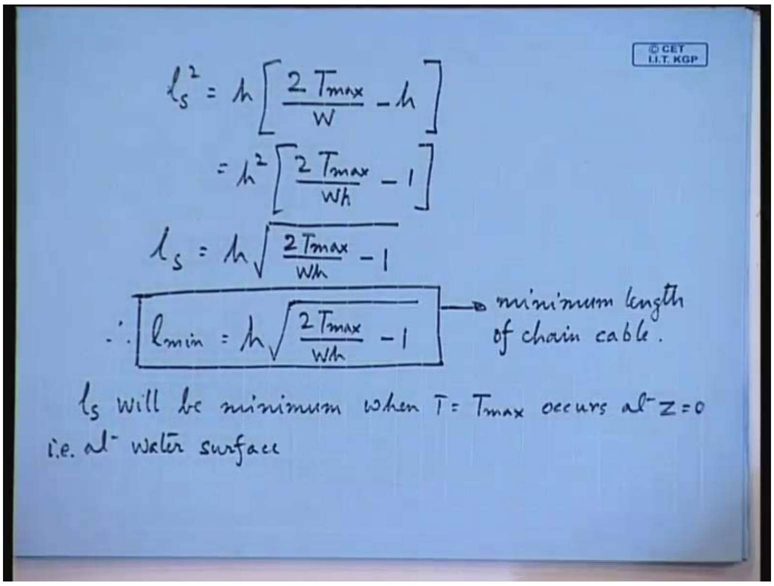

So, ultimately. we are getting l S square as H multiplied by 2 T max over W minus H you can bring H outside. So, this is l square into 2 T max you have a W minus 1 anymore cerebration. So, from this you can calculate. So, l S is equal to H into root over W H will come W H will come the W H will come. So, this is 2 T max or W H minus 1. So, this is what right. So, l S you write therefore, this will be l minimum, because you are putting T max. So, l S we will be minimum when T equals to T max and this occurs where occurs at Z equal to 0 that is at water surface.

So, this is the equation for minimum length of chain cable. So, the 2 vital equations that we have derived are 1 is this same minimum. The other you remember is this expression tension T. Now, the other portion which will go into the descriptive part, before we talk about recoupling terms just to make you familiar with the physical concept of this moorings. The moorings are quite vast in your offshore now, the different types of mooring is first you breakdown into the different types. So, here you will find or this is become a very hedgy. So, offshore mooring systems

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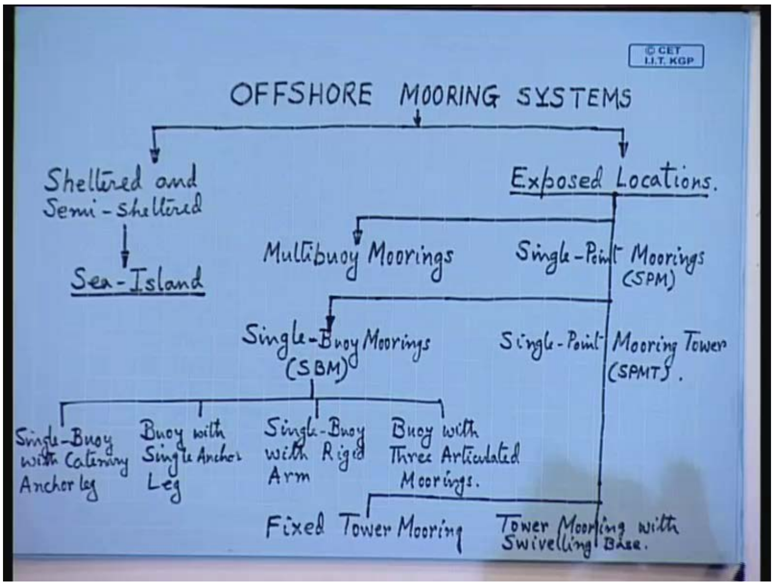

Now at the beginning of the class I gave you classification of offshore structure, you remember that. So, what are the 2 major classes? So, offshore mooring systems. So, these you should study with the classification of offshore structure. Offshore structure primary class as fixed and floating another fixed category also you will have subdivisions. So, similarly, out here also you will get a large number of subdivisions more than your simple offshore structures. Now, primarily you subdivide into this 2 locations. The first one you sheltered and semi sheltered. Now, what is this sheltered in semi sheltered business now here you go what is called the type of fixed structure. This is a fixed structure that we have out here these are called sea island.

You just imagine you are making an island in the sea artificial island. So, these are called sea island example you can find is that I think they have this kind in Bombay. So, there are offshore terminal the offshore or terminal is a sea island now here at this end these are call exposed locations. So, this variety the sea island; you will find normally in the outer harbor. So, Bombay outer harbor if you go you will find a sea island. So, that is a that Mahinkrikar whatever it is that. So, that gives a sheltered to the waves now; obviously, you will not try to transfer oil from your tanker to the say j T where you have a lot of motions.

So, those motions will come when the tanker is brought in a exposed locations now exposed locations the number of buoys and mooring systems are quite large. So, you will have a tree sort of thing out here now here actually you have to play around with the design. So, here you have multi buoy moorings systems. So, this sea island is more of your civil engineering structure engineering job. This is more you are the naval architecture aspects of primary concern is reduction of motions the other hand you have single point moorings. So, normally these are called SPM there are large verity of SPM you will find.

So, right view come from this you have the 2 primary wants or your single SBM moorings or rather it is called single buoy moorings. Now, in this you are study of offshore moorings system; you come across different configuration of buoys. Your TMP tension like platform semisubmersibles is nothing but a large or massive buoy. So, there are very simple buoys actually. So, these are the categories of these are actually various types of buoys you will find. So, single buoy moorings now in short they are called this single point mooring you will have these are the fixed types of structure.

So, these are the floating structure this is SBM this other one is called single point mooring towers this is call SPMT. Now, under this single buoy moorings you will have a large category of buoys. So, as many as 4 types you will get, but the problem is there are. So, many variations of the buoys, but which one you select this is single buoy with catenary anchor leg a buoy with single anchor leg.

Now, what is the difference between catenary and the single anchor leg? Now, single buoy to with rigid arm the last one of SBM is this is buoy with thee articulated moorings. So, these are the 4 types which come under SBM. So, single buoy moorings Now, single point mooring towers as you can see that from the name suggest that these are the fixed tower. So, you will have only 2 such types. So, fixed tower I hope you can see this already this coming too much down. So, fixed tower now what are the functions of this buoy and tower mooring with swiveling base. So, these are some of the broad categories of your mooring systems. So, you can see the mooring systems are quite the most specific than you are just description of offshore structures. And if you going to the offshore engineering field you will be asked to design all these things. Now, the point is your buoy design.

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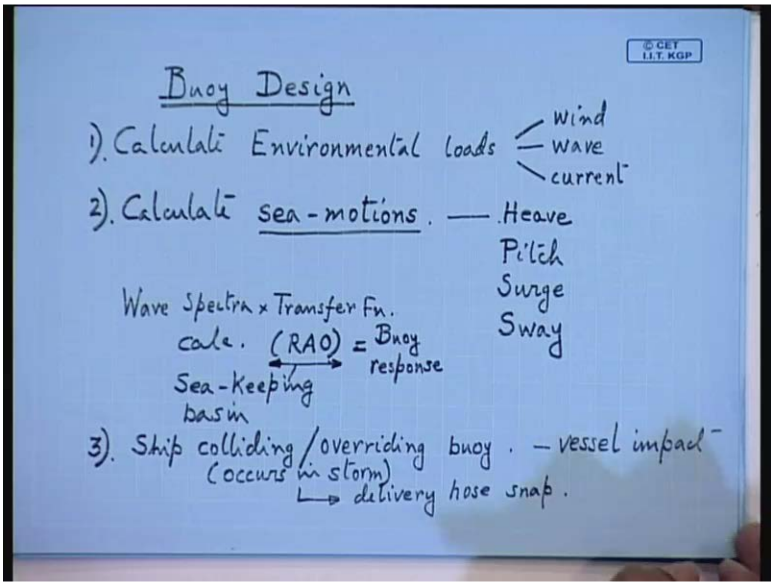

So, basically here actually we are dealing buoy design now buoy design you can see various. I will just draw some figures if you have come time you can see the categories of buoy, but how you going to design? So, first thing as any offshore structure or any structure for that matter calculate environmental loads.

Now, this you have to get from there is your wind waves and current. So, whether it be your tension like platform or semisubmersible you need for this smaller buoys your environmental load calculation is a must. Or these you have to find out the forces from wind wave and current this is your first job. Number second job is calculate sea response or other you write sea motions very important, because you are going to transfer oil from the buoy to the tanker and any undesirable motions.

You can calculate all these specially here you will find the most troubling is your heave excessive heave on the buoy will cause your loading hose to snap. So, heave has to be calculated or the other motions pitch. Pitch is another determinant of motion and surge and sway motions surge is on the longitudinal direction that translation and the sway. So, these motions have to be calculated heave pitch surge and sway motions. Now, how do you calculate that you know this you have to first thing? Normally you have to find out from your the forcing spectra that is normally your a wave spectra or current spectra. So, this I talked about in your mid semester that is the wave spectra the, you find the equations. You have to multiply by certain function which is called the transfer function.

So, your transfer function is normally in our naval architecture calculation. We will say this is your RAO that is your response amplitude operator now; from this you get buoy response now you can do all this in your tank. But this is not done in your that a that ship model tank that we out here you can ask process whether you can get do this motion. You can find out these RAOs there is, but it is a good experimental study the normal experimental study. I do not know you have making some experiments doing experiments in the tank you know that model testing that you are doing that is the one part of your job.

Now, other is RAO calculation, can you do now your since you are having a wave maker you can make a model of offshore structure and find out the response of the offshore structure with a certain wave spectra. So, these calculation if you ask process and if can be done and you can do it and see how it is the RAOs are normally calculated from tank experiments.

So, in matricide they do this form as sea keeping normally they do it in a, what is called a sea keeping basin. So, that is a square tank which of course, we are not having here sea keeping, but the problem in the in narrow tank that is in your rested tank. You will have the wall effect that is the wave should come and reflect from that 2 wall, because the, your the bread turbinate tank is hardly how much 4 meter or some 4 and half meter.

So, you get lot of wave reflection, but still you ask process and you distinguish them and we can go about. So, anyway so this is your second job is calculate sea motions. What is the third important aspect for buoys? The third most important aspect is ship colliding or overriding with buoy.

So, whenever you are doing buoy design this factor has to be taken care of that is ship colliding or overriding buoy. So, then; that means, your buoy went to get damaged that is in offshore rather important any of study is vest they called it vessel impact. Vessel impact especially on the structure estimate calculated a ship colliding or overriding buoy especially this occurs normally this occurs in a storm. So, storm conditions, you will find this sort of thing happening; this collide this collision or overriding is taking place there is a chance for delivery hose snap. So, your delivery hose starts breaking at this junction and of course,, if you cause damage to both your ship and buoy colliding with and buoy. So, collusion is another important aspect that you have to keep in mind, and when you are doing these motion calculations.

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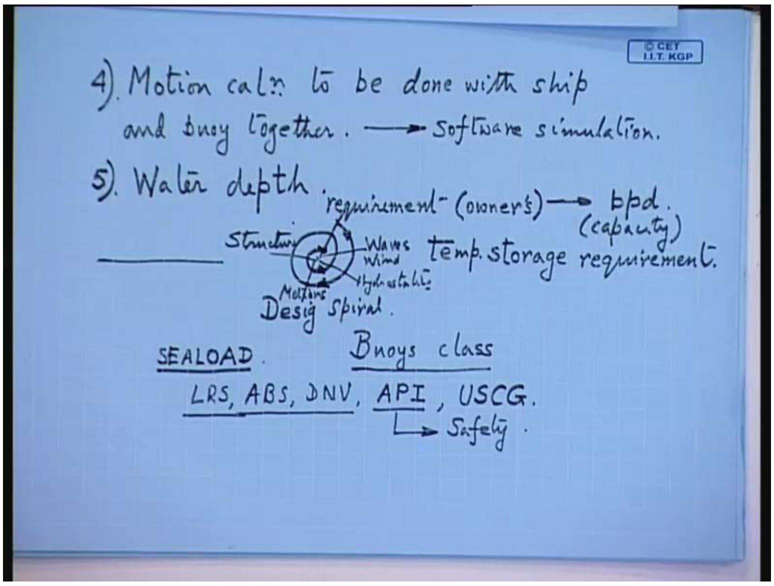

Number 4 is motions calculations and this is quite complex actually. So, motion calculations to be done with ship and buoy ship and buoy together. So, is this a quite complex task motion calculations are normally you can do some simulation in the computer nowadays they have lot of software which can software simulation you can do a engineer archflex they does this. So, this software simulation and math is quite troublesome. So, if you go deeper into the offshore field you have to be very proficient in your writing your computers and maths.

So, these are the 4 aspects which has to remembered and the last what is your last most crucial aspect. Very crucial is I told you in any portion engineering water depth is another very important factor buoy design. So, these are some of the points to be remember in buoy design. Now here your ship design you come across first you do your, you begin your design spiral and these are the spokes. So, there will be number of iterations going on till you come to the final design either you can go like this or you can reserve in the reverse direction.

So, you have to construct the design spiral. So, here it may be you start with your requirement. Now, what is your requirement? So, 2 things we are coming into this; one is the environmental you begin with environmental load calculation. And the other part is your requirement or owners requirement. Now, what can be that now buoy you will find there will be lot of topside equipments say pumps compressors pipings and all that?

So, though the capacity of those equipments or size are detected by what detected by owners requirement, what is the owners requirement BPD of oil balance per day of oil that you are going to drift from the seabed on to the tanker? So, this is your capacity and normally these buoys they do not have any storage. So, this is the capacity and if there is any storage requirement or temporary right temporary storage then ultimately you are offloading your cargo to a tanker is not it. So, storage requirement and this is very important. So, these are the 2 things you start.

So, here you find out your waves wing etcetera load from this you calculate hydro statistics buoy has a hydro statistics has to be calculated. Then out here you have motions like this you go on and keep on iterating that iterating means you change the dimension of the buoy. So, dimensions are basically you are diameter at the depth of the length of the buoy, the other dimension is you see buoys are normally seen in shape.

So, you keep on changing till you get the favorable response here motions then structural structural will be there. So, nowadays you have softwares which calculate all these if you go to the design office or your consulting firm you will be asked to handle of this software the orcaflex sacks. And all these things and do all these calculations there are another software is there they are called sea load. So, actually the bigger multinationals they have their own design and researcher wing. They make their own softwares they do not rely on any external software well external software nowadays the software that you are building is based on certain theory.

So, simply if you tell your client that your engine this software he will not be satisfied. You will say what is what software, what you have done, what is your wilier in the theory, what your analysis, why you have used this sacks and not and sees and not that software is very if your client is knowledgeable and intelligible? He is going to ask all source of uncomfortable questions. So, the normally all these multinational companies they have their own software’s is not it and if you use any tailor made software. Then you can use it, but those are things normally the client either client will loss or ultimately you all these buoys have to be classified by certain your class societies any marine engineering or ships or offshore structure has to be class you know. So, the, you have to convince this servier with your calculations and with their minimum requirements. So, either it has to be ABS class ABS.

DNV class and normally if you are in the American waters you have to follow API code. So; that means, here a chap which or your client if he is very experienced then you have to convince him. You know specially on the on these 5 requirements software you are using algorithm your vised. And of course, you final result that you have got the a structural arrangement thickness and all that have to oked by these people ABS. DNV; you have loads by in offshore actually the more popular class classification societies are ABS DNV. API actually they are more concern with safety American petroleum institute, you may have USCG regulation if it is in the golfo Mexico united state coach god.

So, because you're dealing with a flammable material that is oil so; that means, they are stringent safety and pollution requirement say specially in the US kost. So, those requirements have to be satisfied. So, here the, that I was talking about only 1 aspect. And 2 also we are not fully cover that is your the static analysis of the mooring chain that simply use you just go on see designing your buoy; your simple buoy will ask for. So, many equations and. So, maths and all that your efficiency f d and what not would be there, because of the integration of all these motions and environmental loads.

So, that is the scenario and remember all these loads and motions they are all coupled may have heave along with pitch surge and sway. So, you have coupled motions. So, the maths part is quite complex, but in your engineering actually you have to understand the physics beyond all these motions anyway. So, that is gist of the problem and coming to the buoy description since we have some time the, on the, those consideration that is your environmental load and the 5 points how many 5 points that you have underline? Those are the other point that is important is which going to pay the bill.

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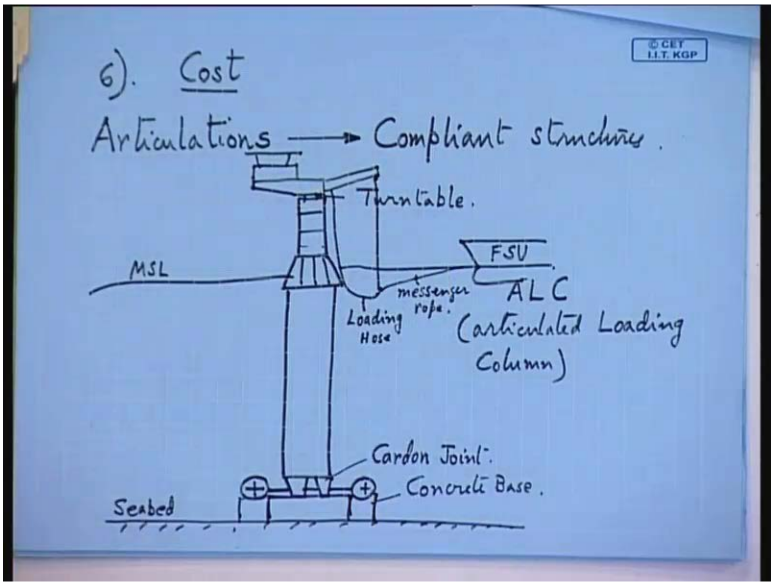

Cost; this is the last point although very important. So, those are some of the decisions and here there are some diagrams they are called articulations. Now, remember in our classification of offshore structures there is one particular category which I told you which is called complaint structures. Now most of these buoys come under that category so articulation at part of compliant structures. Now, here is an example of a articulated mooring.

So, that is called ALC; ALC you will find now these buoys are quite massive in their form. So, here you have a deck you may have a crane now, normally these buoys are deck you will find a turntable. You will have a here it has not been shown the whole thing actually rotates and out here you may have the in waterline. So, this is a cylindrical buoy you know buoy mechanics is if you go for this joint type of thing and see that. So, then it is quite complicated you have to make a structure in the seabed like this.

A concrete base now this is called a cardon joint. So, one joint can be in this region and other joint of course, here not been shown this is your concrete base or the diagram that I have drawn out here. So, these are normal fenders you will get this is your waterline this is called a ALC articulated loading column. The articulation is at the seabed to this is a seabed line now cardon joint I think will give you motion in wonderation. But not in this directions not in universal joint the other structures you can just out here is your loading hose normally this is your special point. Now, this hose is taken up by your tanker by a messenger rope. So, your tanker is somewhere this position is called a FSU floating storage unit now, this is your loading hose your messenger rope.

So, this is one type of buoy. So, there are various forms of this compliant structure of articulated type. So, here you have just 1 cardon joint; you may have other joints normally you find joints coming joints are located at the seabed. So, these are mean serial and this is your seabed. Joints should located at seabed another the waterline at in the all cases of this columns.

You will have a turnstile over which you have your winches helideck; you comes over here and may have deck hose also these buoys are not small buoys. I can see in the Hooghly river that onet a anchor line is just a hook to a mooring buoy that of buoys not there where huge buoy actually. So, this is your the marine riser is actually enclose within the buoy; this is your marine riser is protected. So, this is may be concrete also concrete column; this is your marine raiser. So, marine raiser is somehow protected from collusion from the tanker may other cases you will find that this is expose. So, which one you are going to select, it is a up to you.