Elements of Ocean Engineering
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Lecture - 26
Mooring Systems

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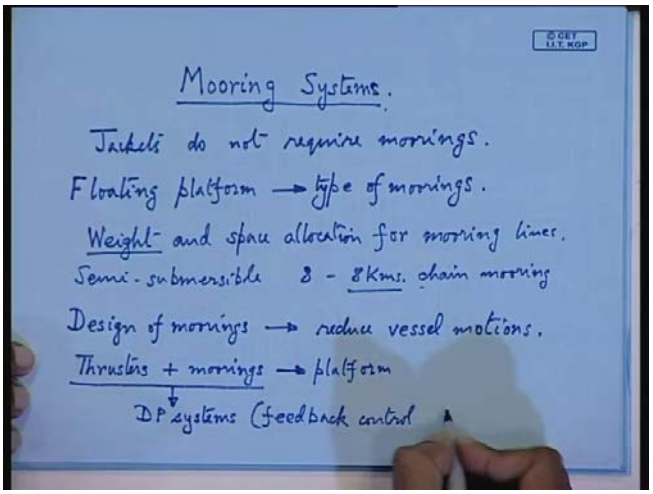

So, the next important discussion is mooring systems. Now, mooring systems take of more than say 50 percent of the cost of your platform especially the, if it is a floating platform. Now, for fixed type, of course you do not see jackets, of course they do not require moorings. So, because these are piled to your sea bed, so of course, obviously, moorings there is no question of having moorings, but moorings you will find they are essential part of the floating platforms.

Now, floating platform design is centered around type of moorings. So, as much as say 60 to 70 percent of the platform cost is taken up by the moorings and not only the, that one the other part that you as a designer. You have to think about is the weight and space requirement weight and space allocation for mooring lines. The example I am giving you say a semi submersible in deep water.

So, all these platforms that is the floating platforms are essentially for deep water. Of course, then the length of the line will be quite large. So, semi submersible example you

have say 8 8 kilometer long chain cables chain mooring lines. Now, the problem is you are the first thing is this will have lot of weights. So, few 1000 tons of weight will go so; that means you have to have suppose sufficient buoyancy in the columns to support this weight from the naval architectural point of view. The other point is where you are going to store this huge this huge amount of chain cable. So; obviously, most of these cables are stored in the columns itself and that will increase the column diameter and the length of the column also.

So, with this the number of engineers they have thought about how to reduce the size of the cables etcetera and the problem of this mooring lines is the basic design is centered around. So, design of moorings so moorings are essentially designed to reduce vessel motions whereas, the primary task of your any mooring lines.

Now, here normally what is done the moorings which are done by means of chains mooring chains? They are adjusted by thrusters in offshore platforms if you come across you will find they are thrusters at the bow and strung. So, thruster support to mooring lines are also given thrusters together plus your moorings. So, these are normally given at platforms. So, the total systems these thrusters plus mooring is called ADP system that is directional positioning system.

Now, the whole thing is actually controlled from the bridge by means of controls or this is called vessel CDF feedback control, Now, feedback control I think I do not know whether you have studied this in your electrical engineering. So, this is actually the job of the electronics or electrical engineer so; that means, the motions of the ship they are given to this controller and automatically it excites your DP system that is your thruster system. Now, the moorings are also connected to the winches. So, those are called moorings. So, these are some of the items that you come across in a ship platform mooring systems. So, mooring systems components you will have.

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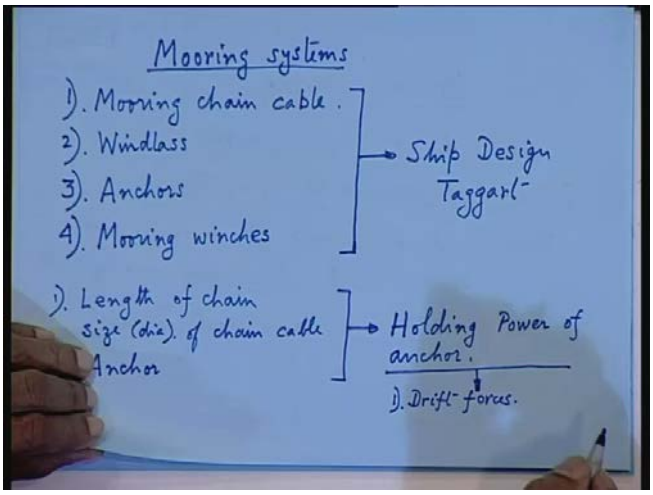

So, in mooring systems if you think about the total system as such mooring system, the essential components first you have mooring chains or sometimes this is called a chain cable. Number 2 is you have windlass where you wind this chain on the deck windlass actually keeps on winding this chain cable and lifts what is called anchors. Anchors are the objects which are connected to your chain cable at one end and it gives the sea bed it clamps your sea bed.

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So, those are called anchors and there are number of types of anchors. So, whether you have a bow anchor say this thing what is called heavy mass the displacement type of anchor. Now, large number of categories of anchors according to the ships or the vessels they are connected with. So, mooring chains windlass anchors next you have mooring winches.

So, these are some of the equip equipments for a ships or for a platforms mooring systems. Now, all this in detail actually I will not be able to discuss in this class. The proper class will be your ship design; you will find this in you read this book ship design in ship design by taggart describes all these system. Now, so far so good now how design these all these items say mooring chain first of all you have to design say the first one length of chain cable. So, I will just work out a problem where you can find out this length of chain. The other thing that is you have to design is size that is the diameter of

the chain cable. Now, how you are going to design this. So, this size of chain the basic design for any chain cable or the number 2 is called the anchor size or anchor mass.

So, these are designed based on the holding power, holding power of the anchor you have to calculate this holding power of the anchor. So, this is given by formulas which are given in your Lloyd resistor, or if you turn the pages of LRS or ES you will find your formulas for calculating the holding power of the anchor. The holding power of the anchor if you want to calculate then you have to calculate what are the loads which are coming on to the ship. So, what type of ships that are come into the ship? So, you will find basically you will find drift forces. I do not know whether you have been taught, how to calculate drift forces which are coming on to the ship then. You have what are the other forces one is drift and the other you will find is forces from current.

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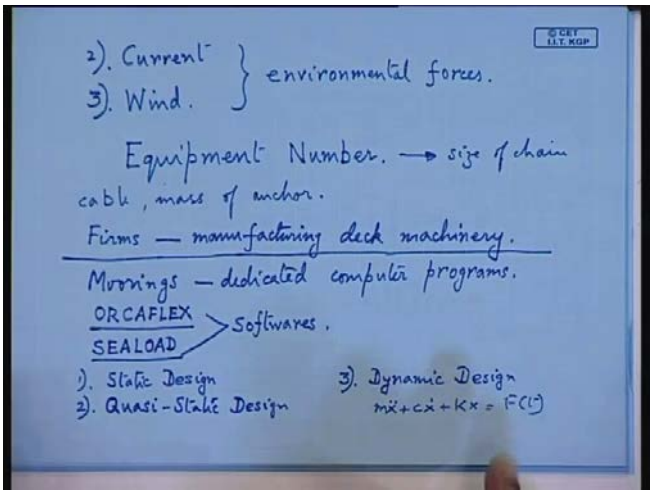

So, your calculation actually is not that easy current then you have wind. So, all these forces are coming on to the ship this is the environmental forces which are causing tension in the chain cable and ultimately your force is going to be anchor. So, you have to be very specific of the calculation of these, what we will call the environmental forces on ships. Now, this actually I think you are taught in your that sea motions or sea keeping class environmental forces. So, you have to calculate this forces unless you calculate these forces, you cannot find out the holding power of the anchor this is your first job. Now, if you turn the pages of Lloyds register or ABS you will find.

So, they give you a formula for calculating the holding power of anchor and with that you end up with a certain number which is called a equipment number equipment number. So, this you have to calculate by looking into the pages of Lloyds. And after you have calculated the equipment with other is you automatically you will get the chain cable size. So, you from this you can calculate size of chain cable size of chain cable then you can calculate the mass of the anchor. So, all these things will come automatically. Now, these anchors and chain cables they are not manufactured in the ship yard. So, there are specialized companies or firms which companies or forms which specialize in manufacturing what is called deck machinery.

So, these are actually bought out items these are a bought out items by the ship yard itself.

Now, as in your case you have to give the required size of this say deck machineries size now, normally if you order a windlass or say mooring winch. So, these are given by the, if you want to order this. So, these are based on the requisite torque. You have to find out how much torque your mooring winch will give or your windlass will give the along with size of the chain cable.

So, those that is that is a job of the naval architect, he is gives quotation and requisitions all this from the deck machinery equipment supplier. So, you get in standard sizes you will not these are not tailor made items. So, these they have to be ordered quite in advance so the, if you go to the ship design office. So, you have to order after you order the main engine you calculate your resistors and power from that you order the main engine. So, this is your next job is to order the deck machinery item or mooring items.

And prior to that you should have ordered steel that is your plates and sections otherwise your hall shop will go without order there is will be laid off. So, these normally the naval architects job starts from that. So, this is one of the job that you are going to do, but how to proceed I am telling you is first your calculate the all these force that are coming to your ship that is your drift forces current wind etcetera drift. And also your waves that is the horizontal forces which are coming.

And with that you calculate the holding power of the anchor from this you revert to your equipment numeral that is it is to be found in Lloyds or ABS and from this you calculate all this sizes. So, after that this is how you proceed now in case of offshore if you go say

offshore. Actually the offshore mechanics is much more difficult if you want to as far as the calculation of these environmental have come. And there are elaborate computer programs which calculate the mooring machinery or the mooring system.

So, moorings are actually done by dedicated computer programs. So, these actually I am not going to detail those of you in our actually in our department we have a program which is called orca flex. So, you will try to have some exporate to this last process are sent. So, this is a dedicated mooring line calculation for ships moorings. So, nowadays you have software which are specific to your ships requirement like you have for ships motions for motion calculations you have a software which is called sea load. So, this is actually a motion calculation software. So, these are normally done by your, they are done by specialized firms which they have engineers who are dealing with all these software may be.

So, normally if you have experience in all these software you can nowadays your design office will use all these software. Now, what I want to tell you is this manufacturing deck machinery. So, they will have all this soft they will give you indent for all these machinery. Now, moorings are actually based on the static design. So, mooring system design is not that simple there are 3 design stages. First in marine we have this static design that is you calculated the forces and moments which are coming from the simple static analysis. Now, after that you have something in between a static design and a dynamic design which is called a quasi or semi static design this is called a quasi static design. And this last one is called where you complete dynamic design.

So, you can see if you actually go into the calculations of your moving lines you have to do this three types of analysis Now, how this is done I think in subsequent class I will just give you an in about the formula the... Now, quasi static and the dynamic is based on whatever in your vibration class that is you are doing that is you have to formulate equation of motions like this M x double dot plus C x dot plus K x that is equals to your external force which is again dependant on time.

So, this we have basic dynamic equation static design is you I will I will just work out a problem on static design. Now, here the before we go into this complicated thing you should have some idea of. I will give you the various moorings which are done in the

offshore in offshore in you go there are large number of platforms which cat catered which is your called mooring buoys.

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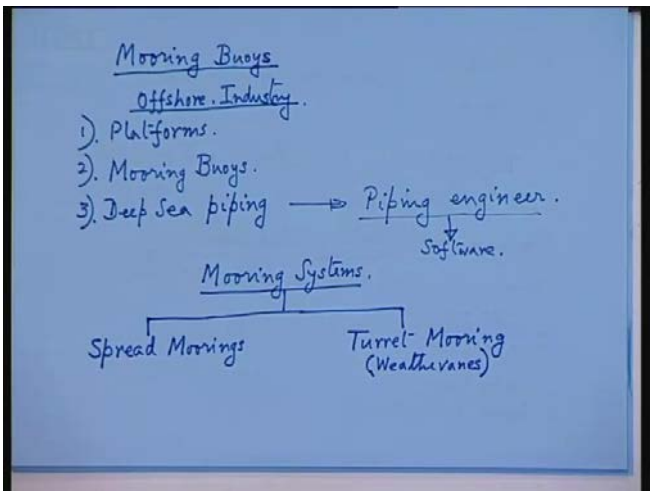

Now, buoys you will find they are similar to your platforms, but small in size now there are large number of moving buoys actually you will find in offshore. So, offshore is actually centered around platforms offshore is centered around design of this platforms if you go into this offshore business then you have mooring buoys. Now, what else you are going to have platforms mooring buoys connected by deep sea piping. Here three major items of offshore industry offshore industry is basically centered around design of platforms buoys and under water piping this is the offshore scenario.

Now, platforms are just talked about different types of platforms. Now, coming to this mooring buoys and deep sea piping actually after I finish buoys I will come to piping. Now, piping design is very complicated first thing you have to design the structural arrangement and then there is flow and all this things are there. So, this the specialized job of a, the piping engineer see most of your shipyards if you go to your shipyard then you will come across this person the piping engineer. So, he is a specialized person who is dealing with all the piping and nowadays also you have software support software is there for your piping design. So, this is a complete another branch of study, but it is well developed and it is a specialized job now coming to this mooring thing.

Now, the basic system that you have to design the mooring systems, you will find there are in offshore there are 2. They are large categories or distinct categories you will find one is called a spread mooring system it is called a spread. Now, this is similar to your ship mooring system or spread mooring the other find other one is called turret mooring these are the 2 broad categories. Turret; actually you will find that there are you will come across number of diagrams. You will find that the ship actually revolves about this turret, it is structure that is which is housed just below your direct you know moving pool.

And the ship actually rotates about this turret or sometimes this is called weather vanning it weather vanes about the turret. So, the offshore you want to design your platform or a FPSO you first decide what type of moorings you are going to give to the platform. Remember moorings are constitute about sixty to seventy five seventy percent cost now spread. Now, the problem that is coming up with this mooring systems I told you an example that I have given you that a semi submersible may have as much as 8 kilometers of mooring chains. So, here is an example of a spread mooring system if you look from the top.

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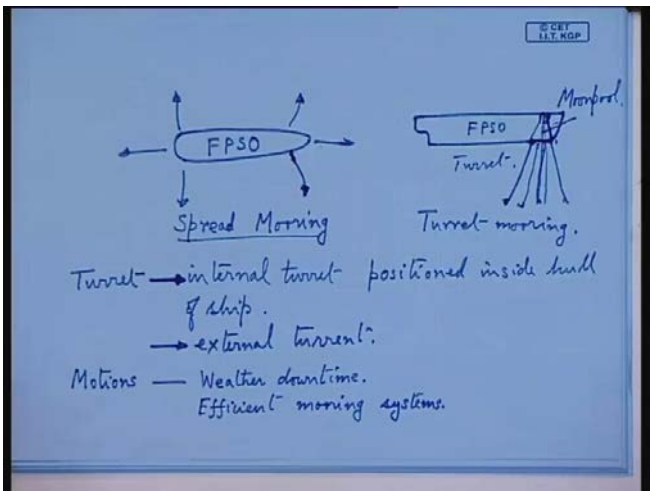

You can have so normally this is an a FPSO or a ship now, at the front you have number of mooring chains which are connected by wires or chains. And here at the start of the ship also you will come across this 3 types now these are anchors. So, this is your FPSO,

FPSO stands for floating production storage and offloading so right. So, this is an example of what is called a spread mooring system; that means, you mooring wires are just spread around the ship. Now, in direct mooring actually you will find that instead of the mooring chains that is your coming from the bow and stern you have a specific location in the ship.

Now, you can house the turret turrets are normally housed either at the forward end of the ship or at the mid ship region. So, some turrets turret mooring are just next class I will show you some pictures of turret mooring. So, you then house the turret outside the just away from the stem of the ship or bow of the ship. So, that is that will be called an external turret or you can house the turret inside the ship. So, there are 2 types of turrets you will come across turret is this is called internal turret. So, internal turret positioned inside hall inside hall of ship the internal turret actually is more preferable because you can have ready access to the turret from the ship. Now, if you are unable to do this internal turret then you go for an external turret

Now, the, you can see that turret is a source of fire; that means, it is a fuel source is not it is it a fuel source. Because the associated piping that is coming from the well head through your conductor pipe or marine riser. There is fire is coming to the manifold in the turret so; that means, it is a fuel source and turret. You know one thing I forgot when you are designing the spaces; you can write down that spaces that is space protection when you are doing this firewall barrier wall blast wall in closed spaces.

You do proper venting of the spaces proper venting what is venting? That is have suitable ventilation arrangement inside the spaces otherwise there will be collection of there is combustible gases. Combustible gases should not accumulated in a closed space for a certain period of time, because in normally in platforms you will find the flared the excess gas. So, there will be lot of heat is generated and these entered gases will ignite.

So, they will cause a blast so; that means, whenever you have enclosed spaces ventilation is a very important parameter for the space. So, that is why in ships you will find normally in naval architecture. These are the three most important systems that a naval architect should know or as the talked about is the mooring system. Other is the havac system heating ventilation and air condition mooring systems havac systems. The other is the piping system, the 3 systems which are very, very important if you want to do a

good GA drawing. So, this is similar to your both offshore platforms actually the problems in your GA definitions is much more. Because if you have you have limited area; you have to segregate out the process, protect the spaces have access the other thing is that this space allocation and other is the vent venting of the spaces.

So, 3 systems; the naval architect should be very aware of actually there is I will try to give you some idea of all these you know these offshore class. But let us come to the we are now we are gone into the mooring systems. Moorings are also important, because you have to control motions if you are unable to control motions. Then the platform has to be shutdown motions motion restriction I told you that is very, very important in case of platform design ships are to some extent.

It is affected by motions, because they will cause discomfort to the crew is not it crew discomfort will be high in case of very large heave pitch and roll motions or in case of platforms motions are still more important. Because the platform will suffer what is called weather down time. Weather down time; that means, the platform is out of service excess motions excess motions leading to risk of life and risk of riser failure. That is your marine riser if you have excess motions; that means, it is going to break or it is going to snap mooring line snap.

So, we have to shut down all these your because the simple reason is that your platforms are doing you drilling operation or producing oil from a specific location in the sea bed. Or if you have a hurricane or cyclone coming, you immediately you cannot run away from that or if you have a particular unfavorable sea states. So, the sea states I have told you. So, unfavorable sea state you have to shut down the platform it you may not run the risk of losing the platform as such, but immediately you will have to shut down operation. So, that is called a weather down time. So, motion restrictions you have to do very rigorously by with the help of efficient mooring systems.

So, which mooring systems you are going to design. So, mooring analysis is very critical in your offshore engineering study. So, I told you that the 3 types there is your quasi static static quasi static and dynamic behavior. So, I will start this static analysis, but before I go on to this the spread mooring system and just told about the turret mooring systems Now, this is a example of spread mooring system now turret if you have a the that means, you have a moon pool sort of thing out here say this is a forward turret. And

your ship actually revolves around a disk which is secured at on the keel of the ship or the base of the ship. And the ship actually revolves about this about a disc and these are your mooring lines they are corrected by anchors. So, this is called a turret. So, this is an FPSO, FPSO turret design. So, the as an offshore engineer or naval architects, you decide which one you are going to have as spread mooring system or a turret mooring system.

Now, turret mooring actually if you go into this turret mooring actually the in your spread mooring systems; that means, the ship is actually I mean you do not do any design change. But in case of turret you have to design this specific bow of the ship or sometimes turrets. You will find it is located at mid ship mid ship local location of the turret there is an advantage. Because you will not be having the pit pitching motion pitching normally is coming at the forward part or the aft part maximum pitching is going to occur here. Now, if you locate the target at say end ship position or at mid ship you have less pitching motion.

And there is an advantage you will get more larger area of the ship, the cross sectional area of the ship will be largest at mid ship. So; that means, you can easily accommodate your turret now if you accommodate these turret and this is actually moon pool from which all your conductor pipes. So, here your marine risers and conductor pipes will come down from the moon pool you see.

So, moon pool so these are the things which are peculiar to your offshore engineering, moon pool turret you will come across moon pool is a gap in the hall. It looks like an inverted funnel you just make the space hollow and from that you suspend all your the mooring risers followed. So, here actually this is called turret mooring in a FPSO normally this turret moorings you will find normally in FPSO. But in case of semi submersibles and t l ps, because there is no enclosed hall where enclosed hall is not there enclosed hall is not there.

So, you need not have a moon pool. So, moon pool will come only for ships having enclosed hall now moon pool design. So, moon pool design you just do not design. It just to take you know your connector pipes there are other aspects of moon pool design which you will come across that is called water entry moon pool is quite a large structure. It will consume as much space as the hold of a ship a huge structure. So, inside the moon pool you have large amount of water which will come in. And it will slush

against the sides of the moon pool and also against your marine riser it will start vibrating. So, moon pool you have water entry and impact.

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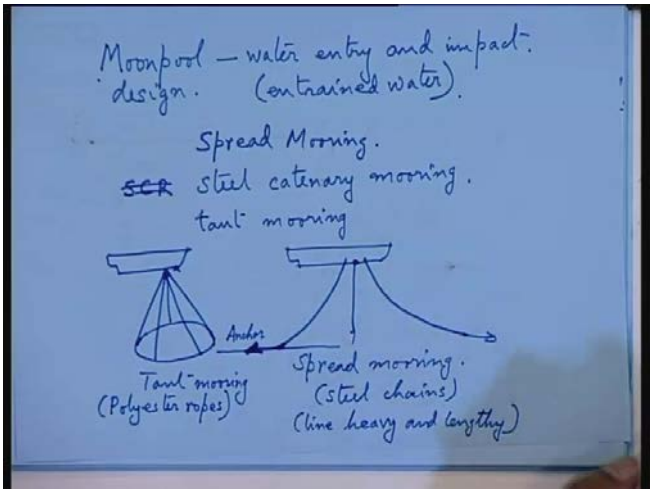

You know those that is another area of study in ship dynamics moon pool; water entry you have moon pool design water entry and impact. So, these have to be specifically configured for moon pool design what is going to be the final shape and the volume of moon pool. So, this is called water entry this is called entrained water; entrained water will cause lot of vibratory forces inside the moon pool. So, the either you will have to damp this entrained water or you or you decrease the size of the moon pool.

Now, the, these are some of the naval architecture considerations you will come across. The other point that is going to another mooring system which I want to tell you is this spread mooring system and turret mooring system now in the spread category also you have spread mooring you have steel this is called spread mooring. Spread moorings you SCRs or steel catenary r of course, stands for risers or this is called steel catenary mooring systems steel catenary moorings and the other one is called a taut mooring system.

Now, here actually in the diagram I you can see this taut mooring systems. Now, taut mooring system will look like this; that means, the mooring chains are. So, this is the circle over which you spread your mooring lines. So, you can have the mooring lines like this. So, your vessel is somewhere like this and the spread mooring system you will find

your mooring lines that is like this of course, in this is a turret mooring. So, it is so this is taut and this is your spread mooring line. So, the this spread mooring lines actually made of steel chains and taut mooring lines if you want to just these are polyester ropes. Now, again you have to decide whether you want to select spread mooring system or a taut mooring system.

Now, why the reason is I told you spread mooring system each of this lines actually you go as far as say 6 or 8 kilometers down to the sea bed. Because a part of the line a large part of the line will be lying horizontally on the sea floor a spread mooring system. You will find that the mooring cable actually lies the large portion of the line in a horizontal fashion of the sea floor at the other end you have the anchor. So, that actually increases the length of the line. So, in steel actually the line is heavy and lengthy line heavy and lengthy, but actually there are one big advantage of this spread mooring system. If you use steel chains is that the stiffness is more. So, mooring system all our calculations is actually centered around, calculation of mooring stiffness.

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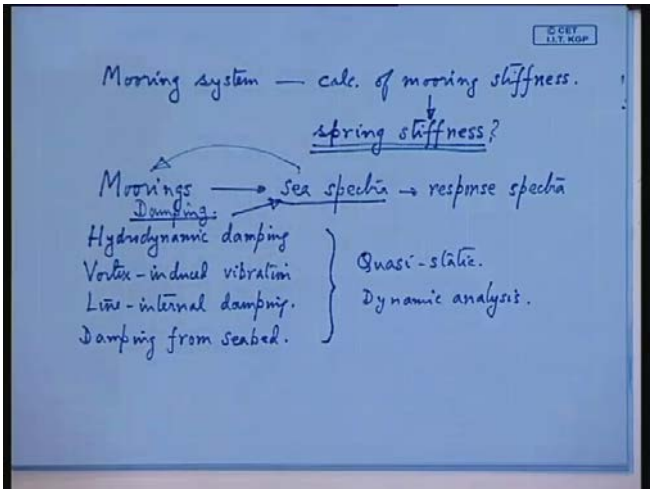

Mooring system is designed around calculation of mooring stiffness now your mooring stiffness it is similar to your similar to spring stiffness in vibration you have common I taught you this spring stiffness. So, this is something like this, but of course,, this is not a spring so but it has a springing effect on the ship. So; that means, if there is a surge

motion on the ship it goes like this then the whole mooring system will try to bring the ship back to its original position. So, that is called ~~a spring~~spring stiffness.

So, that means, in our mooring analysis you calculate this. So, calculation of mooring system spread mooring system has advantages from that point of view the other point that you go is this. This is of course, much more lasting than your the polyester ropes the polyester ropes you will find in that is in the sea water it will trend to corrode faster. But the advantage of the polyester rope is light it is light and we can see in this diagram; obviously, the length of this polyester ropes are going to be less than your steel catenary. So, this is called a catenary in your first year mechanics I think you have across this word catenary chains, how you find out the mechanics of a catenary chain.

So, same thing will come here also you want to design this mooring chain. So, from this diagram you can easily make out that this ship or it appears. So, will have less storing problem for the anchor chains than this kind of a catenary mooring systems, but you have to trade off is it is going to have less stiffness. So, this spring stiffness will be little bit less than your catenary stiffness. But if you can do away with that now, all this things you will have to calculate based on I told you mooring are essentially calculated on environmental loads moorings that is why before mid semester I talked about sea spectra from that you calculate response spectra.

So, all mooring systems are designed around a certain sea spectra which occurs say for the life of the ship or say for 100 year return period or say 20, normally you take 100 year return period to be on the safe side. So, what is going to be your the extreme sea spectra for that based on that you calculate your mooring the reason is because of motions you have to restrict motions. I told you how to calculate this from sea spectra you calculate the response spectra by a transfer function.

Anyways so those are the things which you have to take care of in designing the moorings Now, coming to the analysis part the before you go into the analysis then the lot of things which you have to know that is mooring designs you have what is the damping? First is the calculation of stiffness then you have what is called hydro dynamic damping. So, the mooring stiffness hydro dynamic damp damping then you have vortex induced vibration vortex, induced vibration normally will occur in moorings as well as in marine risers. Then there will be line damping what is called line internal damping,

because of the chains and damping from sea bed. So; that means, when I was discussing about all this.

So, these are the features which you will encounter in either in dynamic analysis or quasi dynamic or sometimes this is called a quasi static analysis, quasi static dynamic not in the static case. So, these damping also these are after this spring stiffness you calculate this damping forces. So, here you vibration knowledge will come into play based on what spectra motions you know the coming to the static analysis. So, this is we will talk about this is the stiffness part next class time is short.

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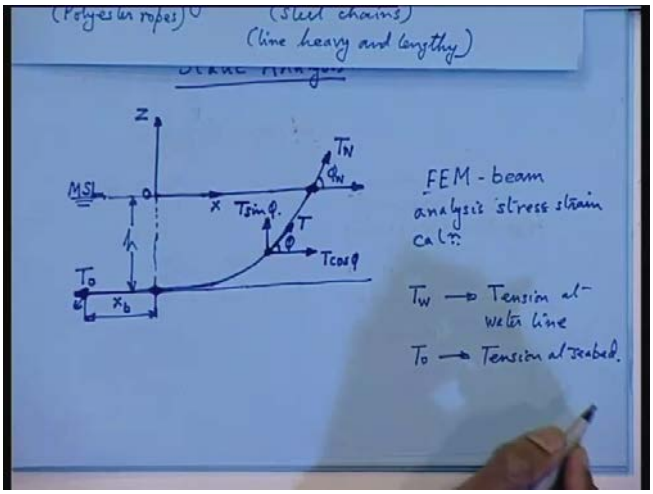

Now, let us, we have a look at this static analysis now you consider a reference axis. Now, you take this axis on the sea bed sorry not on the sea bed on the still water level say axis you take this is your x. And this is your positive direction of the z axis now, actually there is a little bit or law in the analysis, but we will take care of that. So, this is your water plane or sea level now, say your ship is out here so; that means, you give a force on the winch. So, T w so here if you look at this diagram there are the anchor line is supported by. So, here this is supported by a windlass.

So, this is taken up like this and this is ~~would~~will on a moving windlass on the deck of the ship or deck of the platform. So, this is one support point another support point you are getting where sea bed. Now, here the, what I am doing this calculation for static analysis that is I am just making a free body diagram of a section of the steel cable. And

you can calculate all the forces normally if you want to there are complicated analysis that is in your you can make a FEM model for a say chain cable if you want to do this in segments.

So; that means, you nowadays because of your FEM has more rigorous analysis is done say FEM beam analysis, FEM beam analysis is normally done for this. But this is very complicated you know you will unless; you know FEM you cannot do this or calculation of stresses and strain FEM beam analysis for stress strain calculation. So, this actually I am not going into details. So, those of you who want to take this as a project and all that they can do, but the why this is done I am telling you. Now, in most cases actually there is a tradeoff between these 2 systems that is the tout and the spread moving system.

Now, instead the engineers instead of making the catenary change in with steel you. It is divided into segments some of the segments they make of nylon ropes and some segments you can make of the steel cables followed. Now; obviously, you are having say 2 different materials altogether in various segments of the chain cable. Now, you want to do the analysis proper analysis then your simple static analysis which I will we will do in the next class will not help. So; that means, you have to take care of this FEM beam analysis.

So, FEM beam analysis you have to do for a curved beam element made up of different materials. So, that will; obviously, give rise to different stresses and strains that are coming on to the chain. So, once you know the stresses and strains specially the stress at the various segments then you can decide on your chain cable diameter or you're the configuration of your polyester ropes. So, this there is a complicated another area of complicated study. So, you can see first thing if you want to do is you have to formulate you're the motion coming from the sea motions. So, that is one area sea load sea motions and the other is your structural analysis which is coming from the FEM part.

Anyways so this we will discuss later now coming before we close the normally the static analysis is done like this. So, here it is say your chain cable is coming. So, this is the position of the deck of the ship or you can say this is coming from the over here it fall this coming from the sea level. So, phi w is the angle that your chain cable is making with the mean sea level and this is taking a catanery shape. Now, what happens is if you have a anchor line you will find a large portion of the chain cable lying flat on the sea

bed. So, this is your anchor is coming out here and this is the depth of water. So, this is water depth you can take this as h now this distance that is from the origin to this anchor line. So, anchor line normally you can write like draw like this.

So, this distance you write this a S X b now, there are in our analysis there are 2 things that you have to calculate. You calculate the length of chain cable say you take a small portion of the anchor line you find out the tension. So, tension out here on the water line. So, this is given as T w and tension at the horizontal level is given as T 0 at sea bed level. So, T w; you write tension at winch now one thing you note that the direction of the tensions are different so; obviously, sea bed tension. That is actually your tension is supporting your main weight of the chain cable remember that. So, we will find out from that formula and t w is tension at water line.

And T zero is tension at sea bed sea bed tension. So, you have to actually calculate this now remember that this is the starting point of your say your static analysis now. So, you take a segment or a, you have to draw a free body diagram of a part of a chain. So, this is your tension. So, if the tension at a particular point of the line is making an angle of phi then the horizontal will be T cos phi and in particular this will be t sin phi you are having a class no. So, anyway we will I think on next class on Thursday we will talk about this. So, after this you construct your free body diagram for this part of the chain. So, we will continue with this next class and our goal is to obtain the length of the line.