Hydrostatics and Stability

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Lecture No. # 40
Conclusion

So, welcome to the, to the last lecture of the series. We have come to the fortieth lecture, which is the final one. We have already talked about most of the, I mean, we have covered all the sections leading to the, related to the stability concepts in ships. We, we have started from the Archimedes principle, which is the basic concept of weight equals buoyancy. So, we started from there, we went on to the, what we call as the ship stability concepts. We like the meta-centric height radius and all that, and the relations for all those formulas and we derived expressions for the conditions of stability, which is, that the meta-centric height should be equal to greater than 0, which is the basic absolute requirement for the stability.

So, once we covered the main preliminary background on that, we then went on to study the hydrostatic curves, which we, which are the hydrostatic curves, like the bonjean curves and the other type of hydrostatic curves. We have dealt with all of them, we discussed different concepts related to the, related to the ship stability analysis, like the center of flotation, water plane area, etcetera. And then, the different moments related to the water plane area, these are the hydrostatic calculations, these are the hydrostatic curves. Of course, we draw the hydrostatic for the, these hydrostatic calculation results only. So, we had those curves.

Finally, then we went on to what we call as the stability, statical stability curve and the statical stability concepts, where you drew the GZ curve. I mean, we first define what are, what is meant by the righting arm, the heeling arm and what is the GZ curve for that. And once you have the GZ curve, you draw the tangent at the origin; you get g M at, at phi equal to 1 radiance. So, we did all that and then we fallowed with up the, some of the basic heeling moments that follows. Now, the moment we finish statically stability curves concepts and we, how we, we, we, how we define, how we calculate the dynamical stability as an area under the GZ curve. And once we have this area, you specify, that it has minimum and maximum, it, it has it should have minimum value, so that the stability criteria, it is met.

So, once we finish that, then we, we then went on to some common forms of heeling that are found in the ships. We started with the wind heeling arm and we saw, that the wind heeling arm is followed by the, then the turning arm, then the turning moment, that is, when the ship undergoes turning. It is also, you can also have passengers crowding to one side and we derived, and we had some special cases like grains, where grains can tilt to one side. Then free surface effect, these are different kinds of effects, that lead to the loss of stability and we studied what are the conditions for stability in these particular cases. So, this was almost the 1st section of the course.

And in the 2nd half, 1st half of the course, and then in the 2nd half of the course we went into the different types of, different types of mechanisms, that has an effect of stability. For instance, the 1st one is dry docking, that has a very strong influence on stability. There are some variations; there are some changes in the stability curves as a result of dry docking. Then, grounding, grounding is obviously a, it is a, it is a damage, it is a, it is a damage, that leads to a reduction instability, it affects the, the stability of the ship.

Then, this was followed by bilging. We have already defined bilging and damage stability concepts; we covered that in great detail. Bilging and damage stability can be studied using either of the methods of loss buoyancy or the method or the method of added weight, where you either consider the weight to be, either you consider the buoyancy to be loss from the ship, that is, the value to be loss from the ship, that part of the ship is not really a part of the ship anymore, which is damaged. Then, also the method of added weight, where you add the weight of the added water, the added water, that water that is flooding the compartment, is added to the weight of the ship. So, these two methods where used to calculate the methods of bilging and that was one major section of, one section of the course.

Then we had different concepts related to trimming, how the just like heeling and as we said, most of them, stability concepts are associated with the heeling because heeling and consequently rolling, I mean, as I have already described, rolling is defined as the dynamic form of heeling. So, heeling is the static thing and rolling is the dynamic form, same, both of them occurring along the same axis.

Now, this rotation moment and then, about another axis, about a transpose axis, if the ship heels, if the ship tilts, that is known as the pitching or the trimming; again, the dynamic and the static component. So, we have discussed the, discussed the mathematics dealing with trimming, we have seen many of the formulas associated with trimming; how you find out the general draft, aft and forward; how you find the final draft because of a change in trim; how, what is the method used to change in trim. Find that change in trim, like change in trim is equal to the moment causing trim divided by M T C T, where M T C T is the moment to change the trim by 1 centimeter, and there is also a parallel shrinkage W by T p c.

So, once you have all that, you find final drafts, forward and aft and as we have already seen, most of the ships seem to, seem to follow a rule such that they go in this direction, the aft part is down, forward part is up. So, that kind of trimming is usually seen in crafts and these changes because of different conditions, one of which is loading, loading and the discharging. So, when you put loads on the ship and you take loads from out of the ship, these two will produce trimming. Definitely, that is number one and then it is the transfer of weight. For instance, if the ballast you move from compartment, one aft to some compartment 10 to the forward, that is going to be trimming. So, these are some of the methods, that produce trimming and even changes in density of water, such things can cause trimming.

And we dealt with the mathematic dealing with trimming and then finally, thereafter, we went into the stability regulations, I describe that in detail. The different stability regulations followed by the US navy, UK navy, German navy, etcetera and we also talked about some kind of unconventional crafts and some rules associated with them, some rules associated with the large carriers, etcetera. We discussed all the kinds of stability rules, these are rules, that you need to know in, in any case I mean, as naval architecture it is important, that we remember, we keep in mind most of these rules associated with these, with this stability. So, that is one thing.

Then, once we finish with the stability, the stability rules, the IMO rules, the maritime organization rules, we discussed that in detail with UK, US navy, then went into some concepts of waves. We discussed how waves have an effect on stability, that was, how waves affect on stability. So, that is dealt in, that was dealt in some, some amount of detail.

We talked about how the, we talked about the Mathieu equation, the Stratton's diagrams, all those diagrams, which talk about the stability. It is basically a mathematical concept we are dealing with. Stability, like you say, that phi is the solution to the equation, phi is the heel angle, it is a solution to a Mathieu equation and the, if phi is unstable, it, it grows unbounded exponentially. If it is stable, if the ship is stable, then phi, the heel angle will, will decrease with time or rather it would not increase in an exponential fashion. So, these are to, these were some stability concepts on waves.

So, so we discussed stability concept on waves and also, we discussed some types of degrees of freedom, some of the degrees of freedom associated with, with the ship. So, we discussed the different equations of motion, where you have the total equation of motion; right hand side, you have the total exciting force or the force, that is acting on the system, which is basically the wave force, and in the left side you have the acceleration, that is added mass plus the mass of the ship plus added mass plus into acceleration term plus damping term plus a stiffness term. So, three terms, which the total of this is equal to the total exciting force.

So, that role equation, you can have coupled equations, you can have uncoupled equations, so we discussed about that in some detail. Then, finally, some basic concepts of waves, we discussed what are wave spectrums, some kind of Pierson-Moskovitz spectrum, like that some concepts, basic concept of waves.

Now, this is the final lecture in which there is probably one more concept, that we could, we should touch up on before we end this series that is related to stability. We mean, it is, it is not stability analysis as such, but it is, it is part of it in the sense that it is, we are dealing with the force that is acting on the ship. We, we are trying to analyze the different force, the total force and the moment, that acts on a ship. We are of course, in this, in this section, we are only mostly concerned about the longitudinal force and bending longitudinal force and bending moment in the longitudinal direction because that is most important in a ship and the transfers component is not such a big threat to the ship.

So, we will be dealing with the, we will just give an introduction, not much, may be just half an hour. We will be talking about what is shear force and what is bending moment in a ship. We have already talked about what is the weight distribution on a ship, we have seen, that the ships have a weight distribution over it, there are two forces, that is, the weight of the ship acting and the other is the buoyancy acting on the ship. So, these 2 forces are acting on the ship, as a result of which it produces shear force and bending moment. So, we will just give an introduction to shear force and bending moment and then, we will just rap up and we will conclude the, conclude this series of lecture.

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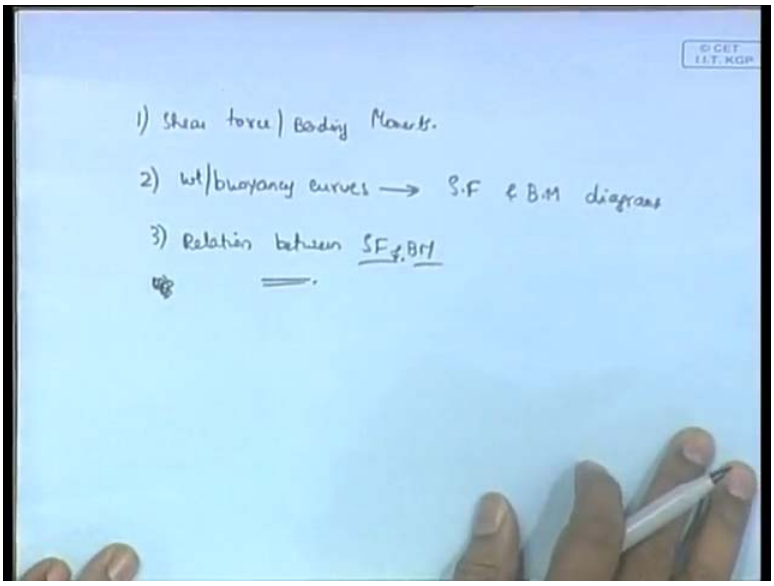

So, so in this lecture we are going to give an introduction to…

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So, we will discuss how we start from the weight buoyancy curves, from this you go into the sheer force and bending moment diagrams. These are, these are diagrams, which explain how these forces and moments change with distance from the ship's aft, aft perpendicular, then we will see relations between these two; there is the relation between the shear force and bending moment. So, this we have to see.

Now, we will just, we will just see, what is the one that basic relation? And then, I think that should be enough. So, with this we should be able to get some idea about what is the shear force diagram.

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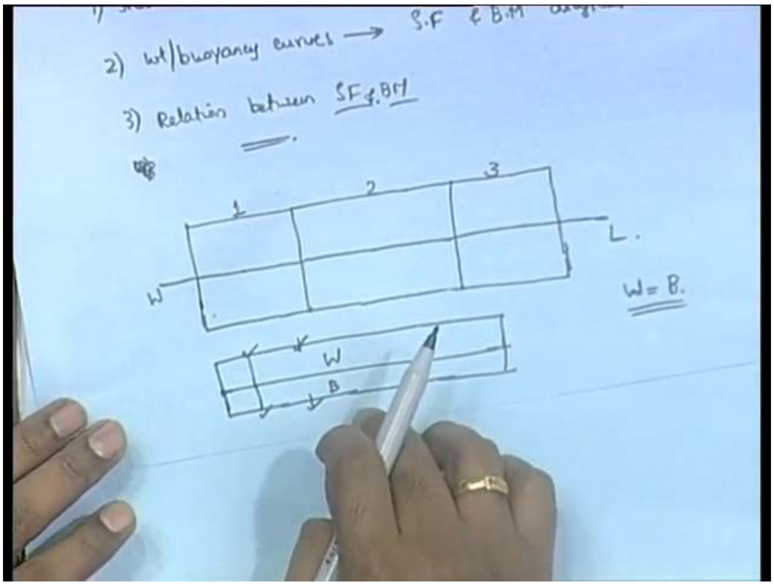

So, now, first of all let us consider a ship like this, that is, we consider a box shaped vessel. Now, suppose, that the ship can be divided into 3 compartments, you have a compartment in the aft, this is the compartment 1, compartment 2 and compartment 3; so, we have 3 compartments. And let us suppose this is the water line, so WL is the water line.

Now, we, it goes without any more explanation, that the weight of the ship should be equal to the net buoyancy acting. So, the total weight of the ship is equal to the net buoyancy acting, where buoyancy is the underwater volume into the density of sea water. So, this gives you the weight of the, gives you the Archimedes principle.

Now, you will see, that even though we, we said that, now one thing about buoyancy curve, let us assume in this case we have a box shape vessel. Now, we know, that in case of a box shape vessel, the buoyancy curve will be a constant, means, what I mean is, that if the draft is constant in a box shape vessel, the buoyancy, if you draw buoyancy, let us say, buoyancy per unit length over this distance, starting from the aft perpendicular to the forward perpendicular, it will be a, it will be a straight line, it will just be a straight line; it will be constant throughout the whole length. Buoyancy is not a function of distance, it is not, it is never a function of distance, but on the other hand, the weight distribution for instance, but in, on the other hand, the weight distribution, which is the distribution of weights on the box, may or may not be uniform, it may or may not be a straight line.

What I mean is, if you consider the weight per unit length, it would not be a, it need not be a straight line, but it can be a function of the distance.

Now, let us go, go into a case of a ship, instead of a box we consider a ship. Of course, in the case of a ship, buoyancy curve is not really constant, every, at every length of the ship because there is a difference in the, because of the shape of the vessel changing, the buoyancy curve is changing. But if you, other than that, but if you look at that weight curve of course, so buoyancy curve is also changing and weight curve is definitely changing because you are never going to have a constant weight distribution on a ship. For instance, at those regions where you have the cargo, for in a cargo ship, for instance, at those instance where you are going to put the cargo, once the cargo is loaded, those areas will be much heavier than the areas, let say the four peaks, where you might not be having the cargo. Those peaks, those areas will be more, more light weight, lighter in weight compared what you have in the cargo regions. So, so you can see a lack of symmetry or a lack of uniformity, homogeneity in the distribution of weights.

Now, what does it mean? It means, that what I am trying to point out here is, that when you consider any one point on the ship as compared to any other point along the length, if you take the distance weight and buoyancy need not balance at every length of the ship uniformly. Of course, in this case of a barge, if you have in this case of a box shaped barge, if you have weight uniform, this uniform, then at the buoyancy uniform, then of course, it is a very uniform case and there is as such no asymmetry in weight or buoyancy.

And the net, I have not explained load curve, but the net load curve or the difference between the weight and buoyancy curve, it will just be 0, it will always be equal, means, if I draw the weight curve, let us say, that the weight curve is like this, weight is uniform, it is constant, this, this is what I meant by a straight line, this is, weight curve is like this. And the buoyancy curve, which is in the opposite direction, so let us put it as negative. So, buoyancy curve is also like this. So, these two are exactly cancelling out each other at every length of the ship, everywhere it is cancelling out, here, here, it is this, this cancels out, here this and this cancels out, it cancels out entire, along the length of the ship and there is no problem here.

But this can need not be how it is in the case of a ship or in any, any even for a box shape barge, it does not have to be exactly a uniform distribution because weights, at least the weight, even if the buoyancy is uniform, the weight will never be uniform, there will be a difference in the weight distribution. So, as a result of which what you get is the difference between the weight and buoyancy curve, which we call as the load curve, might not be a straight horizontal line in that graph, but in the, let us, the load diagram it may not be a horizontal line, but it will be varying with distance, that difference, the load curve will be varying with distance. So, it will be some variation, some, some variation is there in that load curve. So, as a result of which, as a result of which arises what we call as a shear force and bending moment; we will see it again.

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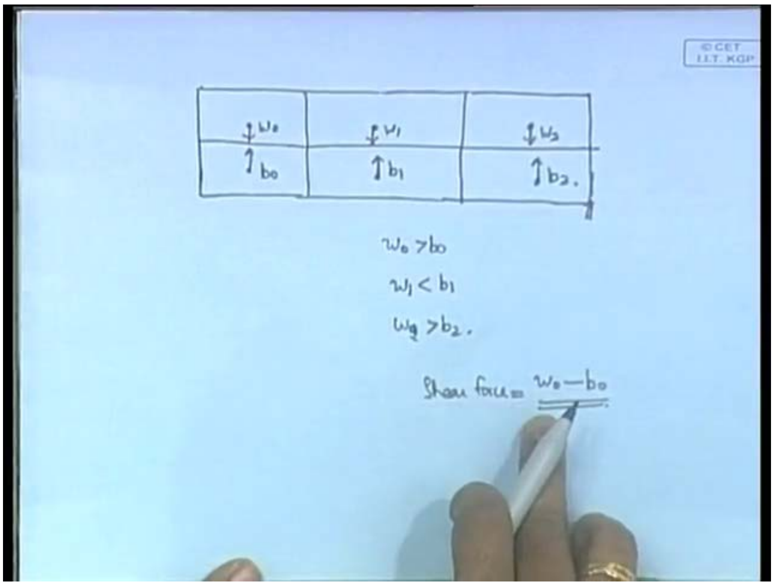

So, we have this, we have this box vessel again. Now, in this case, this is the weight here, let us consider the 3 compartments and let us consider their weights and buoyancy differently. So, this, this is the buoyancy of this compartment, this is a weight of this compartment, then this is the weight of this compartment and this is the buoyancy of this compartment, this is the weight of this compartment and this is the buoyancy of this compartment.

So, in this case in general, what we see is, that if you have higher weight here, now usually in we will see then, so in general, when you look at a ship, this is for a ship, I mean, we are comparing in ships, what you see is, that in general, if you have a higher weight on the aft side or if you have a higher weight, so according to this distribution, what I have drawn here, what you see is, that in the middle part, means, in this midst, mid-portion of the ship, you are actually having higher buoyancy, means, because the volume is in general higher there, the ship is full as we say, means, it is very thick there and therefore, the volume is more and the buoyancy as such. So, what you have is, in this condition is this is one possibility, which is usually seen in ships.

So, what you see is that the central portion is having higher buoyancy compared to the weight. The backside, the aft side is having a higher weight compared to the buoyancy and the fore side, well, in this case it has a higher weight compare to the buoyancy. Now, these, because remember, buoyancy is very small in the forward section because of the shape of the ship. Buoyancy, in general, tends to be small because the volume is, I mean, you know, that the ship is very thin in the forward, it goes like this, it always goes like this and tapers in the front because of its streamlined shape that you require for a ship.

So, because of this, this, so these, so what we have? You have a, remember, in this case also the total weight is equal to the total buoyancy, that is fixed, that is Archimedes principle. It says, that the ship is floating, the weight of the ship is balanced by the upward force, that because it is floating. So, that is fixed, but it is not necessary, that last, the aft part, forward part and middle part in, in isolation have to satisfy the Archimedes principle, there is no such thing, no such concept, no such rule. So, so, there in individual region, there is a difference in the weight and buoyancy.

Now, this weight and buoyancy, so, as you can see, this is the reason for what we call as the sheer force and this difference. In fact, this is in general what we call as the shear force. Now, in detail I will explain in the next couple of minutes, we will explain, we will see what is the sheer force coming?

Now, this is, this is in general what we mean by the shear force, the difference between the weight curve and the buoyancy curve, which we, what we call as the load curve. Load curve is defined as the difference between the weight curve and the buoyancy curve in this case and remember, this is for a ship and so this is the sheer force curve.

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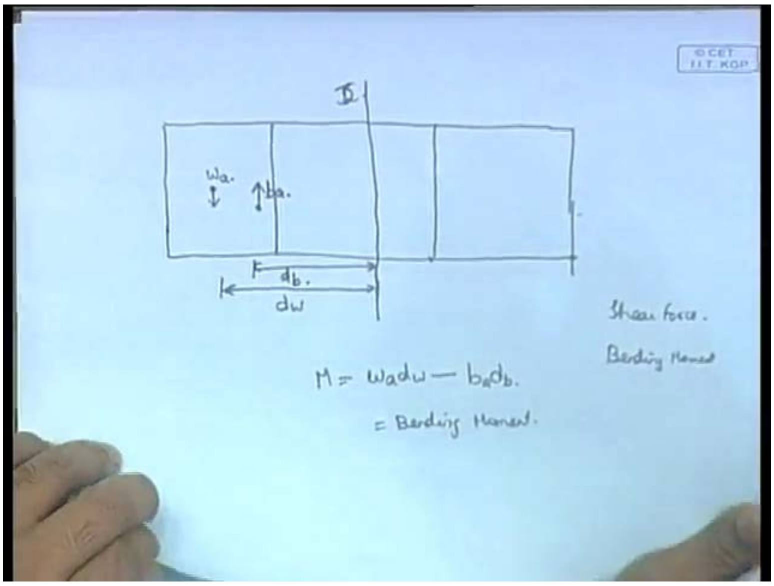

Then, similarly, consider this, same ship I consider, suppose that

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Now, let us assume this is the mid ship section and let us assume, that the weight is acting here, I mean, from the mid ship we take the aft section. So, let us, for the whole of the aft section, means, the whole of the latter half of the ship, the behind half ship, if you take the distance, let us suppose that the L C g of the latter half alone, back half alone is here. Let us say this is W, we will call this the weight W a, and let us suppose, that the buoyancy, center of buoyancy is here somewhere, so b a is acting upward.

Now, let us assume this distance to be d W and this distance to be d a, d b. Now, W a into d W minus b a into d b is a moment, which we call as the bending moment. This is a moment tending to bend the ship. As you can see in the figure, W a, the moment arising as a result of W a, and the moment arising as a result of b a, the two moments, it is kind of tending to bend the ship. Now, this is called as bending moment and it is given by W a, this formula. So, this, as you can see here, now what is, mean, the bending moment, this is the basic.

Now, so, the basic, that difference between the weight and the buoyancy to the left and right of a station, the net force, the net force, that is coming to the left or right of the station as a function of the distance. If you plot, so if you plot the distance and if you plot the difference between the weight and buoyancy, sigma weight and buoyancy as a function of distance, so that, that curve, you will get load curve is just the weight and buoyancy difference at each point.

Now, if you sum them up and if you plot that, so it is the total force, it is a sigma f, which is acting over as a function of distance from the aft perpendicular, that you let us say, aft perpendicular or any other station, it does not matter. So, if you do that, that is what you call as a shear force curve, so you will get a shear force curve and the moment of the, moment of the weight and the buoyancy about the aft perpendicular or about, may be about the center point, about the mid ship. If you do that, that moment is, that moment curve if you plot, the moment as a function of distance from the aft perpendicular to the forward perpendicular that is what you call as a binding moment curve. So, you will have two curves: shear force and bending moment.

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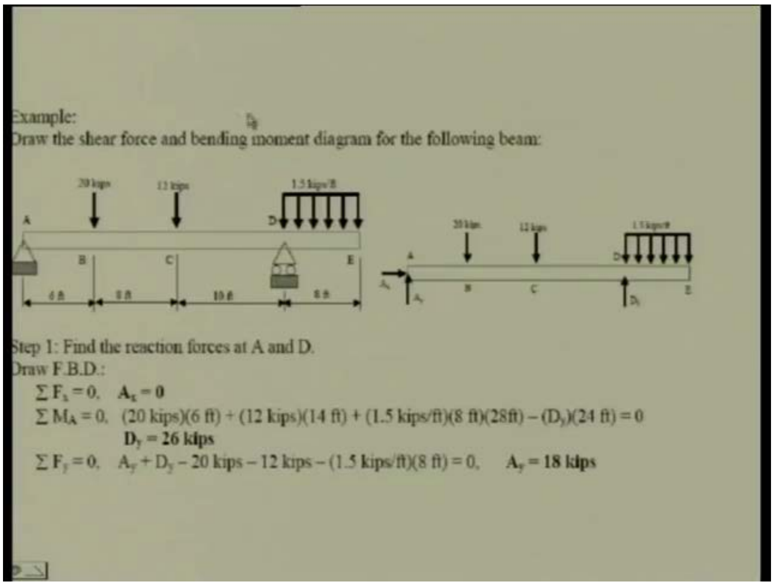

Now, I will see, in case this is not clear we will see what it is, that is, we can take an example, we can look at this, before this I will show. Now, this should explain what, what we are, this should tell you what we are talking about. This is not a ship, I mean, this problem, even if you consider it for a ship it does not matter, but its problem as such is not defined for a ship, ship we are considering as a beam like this. So, it is a, we are assuming, the ship is fixed at both the ends, so something like this. This is a roller, but suppose, it is fixed at both the ends. Now, let us first of all see what we mean by the sheer force and the bending moment.

So, when you have like this, suppose you are giving it different forces, like in this case some 20 kips, here 12 kips and 1.5 kips per feet, this is in the FBA system, let us assume 20 Newton, 20 Newton, 12 Newton and 1.5 Newton per meter. Suppose, we have a distribution of weights like this, so two forces are acting at one point, these are the point forces and there is a line force. So, that is a uniform force that is distributed in line direction.

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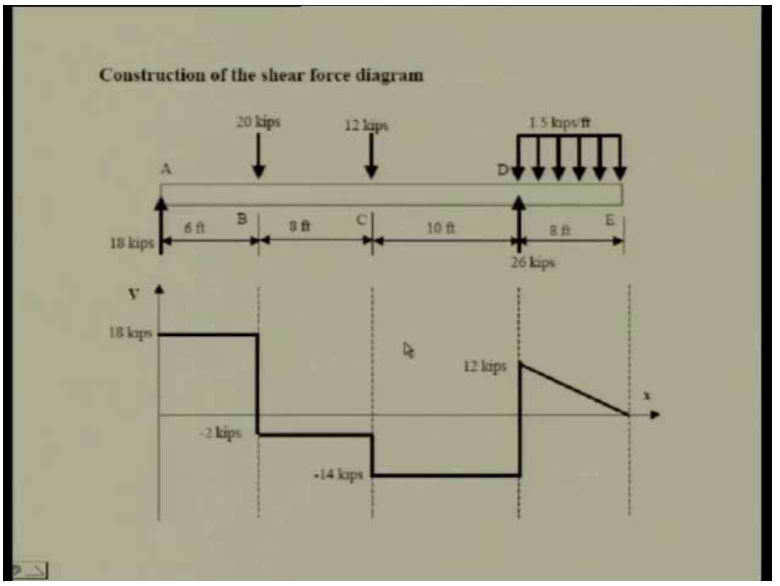

Now, what do we mean by the sheer force diagram as such? Now, so, let us look at this. So, here you have the beam again, so this is the beam. So, these are forces acting. First of all, that is, this one force here, 18 kips; here you have 20 kips at a distance 6 feet; 12 kips here at a distant 8 feet and a 26 kips at a distance of, whatever. The sum, 6 plus 14 plus 24 feet, from this distance, from this point, from the aft, from the total last point. So, you and after that, there is a uniform load distribution per unit length.

Now, what do we mean by the sheer force diagram? So, if you draw the diagram at this point, at this point, oh sorry, at this point, here you have, as you can see, here 18 kips. Now, from here, from this point a to the point b, you do not have any other force acting. So, the sum of the forces from a to b, if you keep doing is, 18 kips is remaining constant, there is no other force acting here. Now, at this point, there is an 18 kips, this force to this force is another, added another force of 20 kips.

So, this kips is acting and another minus 20 kips is acting, as the result of which there is a minus 2 kips here. So, this minus 2 kips acts here. So, this comes down and it is here, now minus 2 kips and after that there is no force acting continuously on the, on this beam. So, all this distance is minus 2 kips, acts constantly over this distance and at this point C and additional minus 12 kips acts, another minus 12 kips is acting here, that is again a point force, it is acting only at this point C. So, what do you have? So, this minus 2 plus minus 14 minus 12 sums up to minus 14. So, there is a minus 14 kips, it comes up to minus 14 kips here, that is the total force here. Then, there is no other force acting over this distance. So, this minus 14 remains constant over it.

We are actually summing up the forces here, make sure remember that. So, here I am summing 14 kips plus 0 kips. So, that is, that minus 14 kips acting here. So, it, that minus 14 kips acting and this is the force here, total force and at this point 126 kips plus twenty 6 acts. So, minus 14 plus 26, that is plus 12 acts here. From here onwards there is a constant force per unit length, so, so it is acting in the opposite direction. So, a minus force is acting, this was upwards. So, this is positive and here this 1.5 kips per feet is acting downwards, it is a load; remember, these are all loads.

So, what we call as shear force is a sigma load. So, this is itself is a load, the load is acting 1.5 kips per feet at this point. So, as you can see, when you keep adding up, when you keep adding the minus values, this 26, which exactly 12 here, this 12 when you keep adding, a negative value, keep adding negative, it will keep going down, it will keep going down till the end where this, where this reduces to 0.

So, there is no force there, so, so as you can see here, the net force, the net load, this sum, this whole sum, that is, 20 plus 12 plus 1.5 into this distance, whatever, should be equal to the net force acting in the upward direction because the net, I am talking about a ship or in this case also, it is true, in case of ship also.

What, what I am saying is, that remember always, that when you look at the load curve, the top area above the midpoint, mid-line, so there is a mid-line. Now, over this mid-line, there is some area below middle line, there is some area. So, the some of the areas in the, above the mid-line will, will be equal to the sum of areas in the below the middle line, opposite in direction. They will sum up, they will, they will be equal, it is what, what we are saying is, that is really, that the weight equals buoyancy; that conditions hold well. So, in this case also, the net forces will balance because the, the whole beam is static, it is not moving at all, so it is in equilibrium. So, the net forces will balance, the net force will sum up to 0.

So, this is what? And so this diagram, which we have drawn here, this is this diagram, is what we call as the shear force curve and these are the values of the shear force as a function of distance. Shear force is usually denoted as v, v as a function of x. So, this v as a function of x is what we call as the shear force diagram and this is the shear force diagram for this particular beam. Then, these sign conventions you can look for shear force. If you are taking the moment about some point in between, you, this is plus v, this is plus v, this is minus v, this is, anyway that is not important right now for this ship problem.

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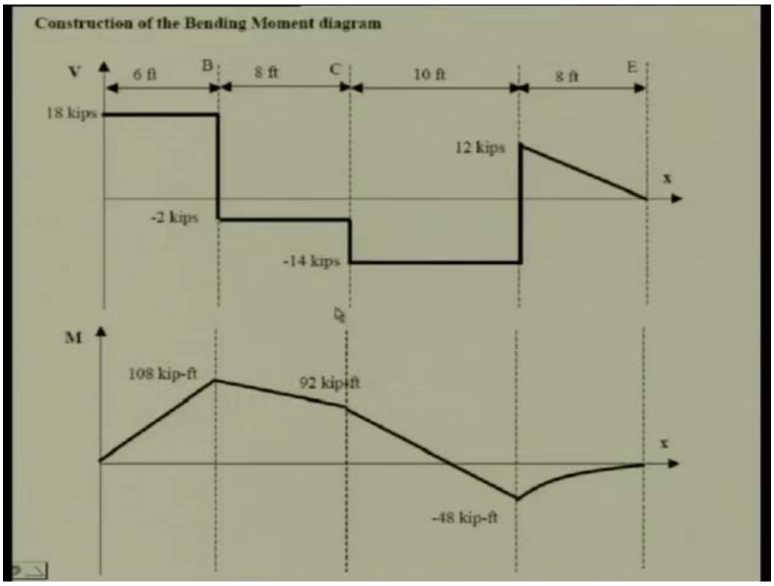

Then, then we come to the bending moment diagram, this is the next, next, next concept we are dealing with. So, what we have here? Now, see we have the different, this is the shear force curve we have drawn, the shear force curve what we got here, same curve, this we are going to put it here. First, now we take the moments of the forces about that distance, now what do we mean? Now, 18, this is 18 kips acting constantly; now 18, 18 kips into x at any point here, it is probably 1 feet, 2 feet, 3 feet, 4 feet, so 18 into that into, 18 into 1, 18 into 2, 18 into 3, all those distances it keeps producing this moment as a function of distance, that is what comes here moment as a function of distance. Then, suddenly, it goes down, it is minus 2 kips. So, as you can see here, it is the sum, it is the sum total. So, it will keep going down after that.

So, once it reaches the maximum here, why it, it is like this? 1, then 2, 3, you are sum, you are putting the moments, you are actually summing it up and, but the moment it crosses here, the force has dropped to minus 2 kips. So, beyond that the bending moment will start reducing, it will keep, it will keep here as you can see, it keeps reducing and once it comes here, it is become more negative, therefore bending moment should decrease even further and in fact, bending moment has gone negative here, it is become negative here.

Now, here, there is, at this point there is a sudden increase in force again, positive force, the force becomes positive and as a result of which, the, it is start going up again and this is a straight line, it becomes a curve here. So, this is what we mean by the, and v is written as M, this is what we mean by the bending moment diagram. So, this produces for you the, this is mathematics or the details of a, what we called as a shear force and the bending moment diagrams.

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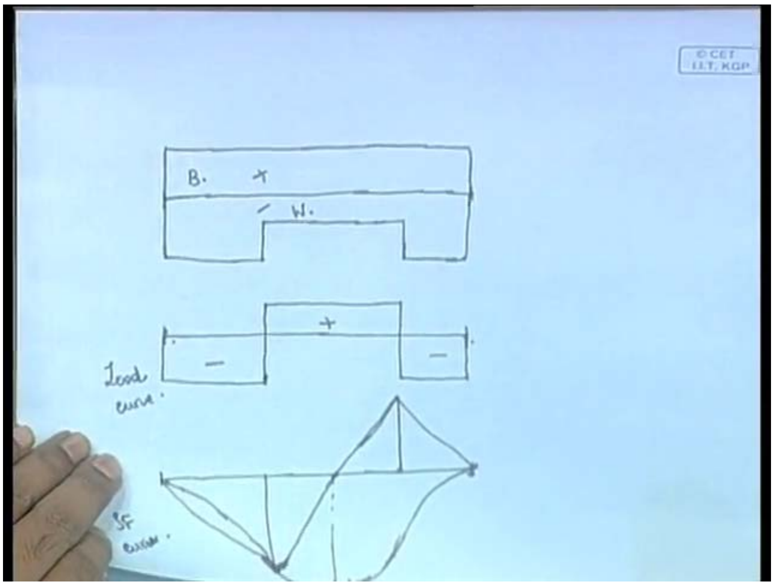

Then, in case of a ship you will see, that so similar to this, we will first of all have or we draw for instance the, the weight curve and the buoyancy curve. In that we have drawn for a box shape barge, it is, in that case when it is floating you will have a buoyancy curve like this, this will give you the buoyancy curve. I mean, you can draw it either ways, some books usually write v, the weight of the curve, weight of the ship on the top and the buoyancy as negative, here it, they have drawn it this way. So, buoyancy is at the top and then the weight curve is drawn below.

So, in this case, what the design says, as it is many times seen is that there is the higher weight, here lesser weight at the center and, and slightly more higher weight at the forward again. This is the design according to the, this for this case. So, this is the weight curve and as a result, now the resultant of these two, remember one is positive, one is negative, the resultant of these two gives you your load curve. So, this is called as a load curve. So, this, if you fix like this, so this is like, these whole lengths you will have the load curve, you will have, remember here this is more, less than this. So, it will come like this and here, it is very less, this is much more. So, it goes up here, it is more again, so it comes down.

I do not think we need more explanation for this shape of the curve. This is how the load curve should look like because here, this side is much more than this side, so it should go up, it is positive here. So, it is negative here, positive here, negative here, or in the usual notation you will see, that this is positive, negative and positive because this weight is usually taken as positive. So, you have your load curve, this is what we mean by the load curve. When you sum up this load curve, what you get is the bending moment, these, the sheer force curve. So, the curve will look like something like this.

Then, so this will be the shape of your, this will be the shape of your shear force curve. So, your shear force curve will look this and beyond that will be… So, and once you, so this actually gives by shear force curve, is got by finding the area under this curve, area under the load curve. If you plot the area under the load curve as a function of x, if this is x, you plot the area under the load curve as a function of x, you will get the shear force curve, that is this curve.

And when you take moments, actually there is another way, which is, actually just to take we will see how it comes, that is, actually if you take the area under the shear force curve, again you will get the bending moment curve. So, this, we give you the bending moment curve and in case of a ship you will see, that the bending moment curve is maximum, usually in the mid-ship, this is somewhere around the mid-ship where the shear force curve becomes 0, you will have bending moment curve maximum. And so, this is the basic concepts of a shear force and bending moment.

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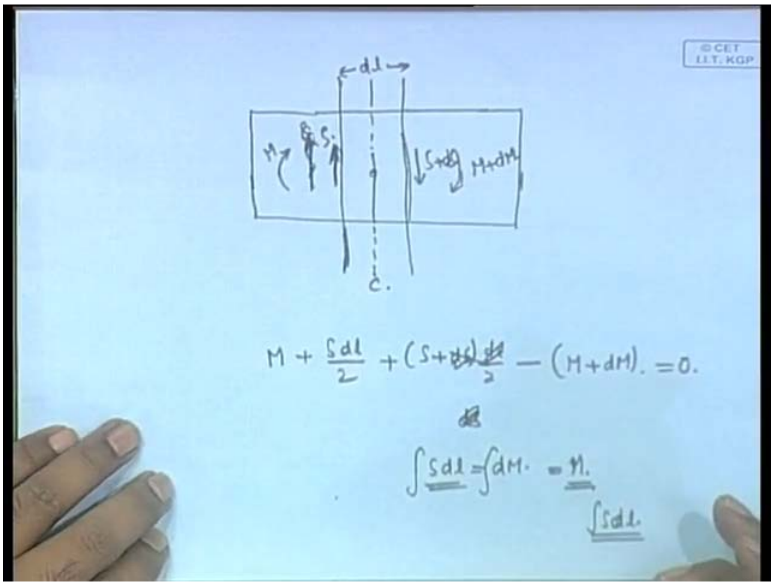

Then, we can see, suppose you have a ship like this and suppose you are taking moment about this station.

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Suppose, this distance is d l and suppose this is M, this is M plus d M. suppose, now we are taking moment about this point and suppose the, at a distance S and here it is not at a distance, here it is S and at a distance here, at a distance d l from this, it is S, is your shear force and here it is S plus d S is your shear force in this direction, the net.

Now, if you just take the moments about this point C, you will see that M plus S into d l by 2, this is d l. So, this is the l by 2 S plus into d l by 2 plus S plus d S into d l by 2 minus M plus d M. For this actually you can go back into the sign convention for Ms. So, if you take, so if this is positive, I mean, one is taken, this direction is taken as positive, this would be positive, but since it is like this, it is negative. So, M plus d M, so this is equal to 0.

Now, if you neglect d S into this thing, d S into d l, suppose we neglect this, it is too small, you will end up with expression S d l equals d M or between these two points, S d l between 1 and 2 is equal to integral d M, which is of course, equal to M, the total moment. And therefore, the bending moment curve is just got by doing S d l; what is S d l? Again, it is just an area under the S curve, there is area under the sheer force curve, will give you the area under the shear force curve, will give you the bending moment curve, that is what they are.

This equation is saying, this equation says, that if you just take integral of S d l, that is, your area under the shear force curve, if you, if you, if you just draw, that means, you will get your bending moment curve. So, this usually, way instead of taking moments about the forces, moment of the forces about that fixed point, the station, whether it be the mid-ship or the any another point, so instead of doing that, you can just take the area under the shear force curve, that is much easier and that is done in practice and that will give you the bending moment curve. So, that will give your bending moment diagram. So, this is the normal mode of practice for getting the shear force and bending moment, bending moment diagrams in ships. It is very important because this is very important in the structural analysis, structural design of the ship. So, when you are doing structural design and these are the primary part of the computations relating to this structural design.

Now, based on, based on what we have already discussed in the latter half of, in the latter part of the series, we have already seen, that the wave, wave has an effect on the stability of the ship. Just like we said, that in this particular problem also, where we are dealing with the, the structural design, which we said, the shear force and bending moments diagrams, they are also in fact affected by waves. How will affect waves, how will we, it will be affected by waves? We can see directly from the derivation, form the shear force curve, for instance look at the shear force curve, we have seen, that what is shear force? It is the area under the load curve.

Now, how do you get the load curve? Load curve is got by subtracting from the weight curve, the buoyancy curve. Now, again, what is the buoyancy? How is the buoyancy? What is, what determines the buoyancy? Buoyancy is determined by the underwater volume.

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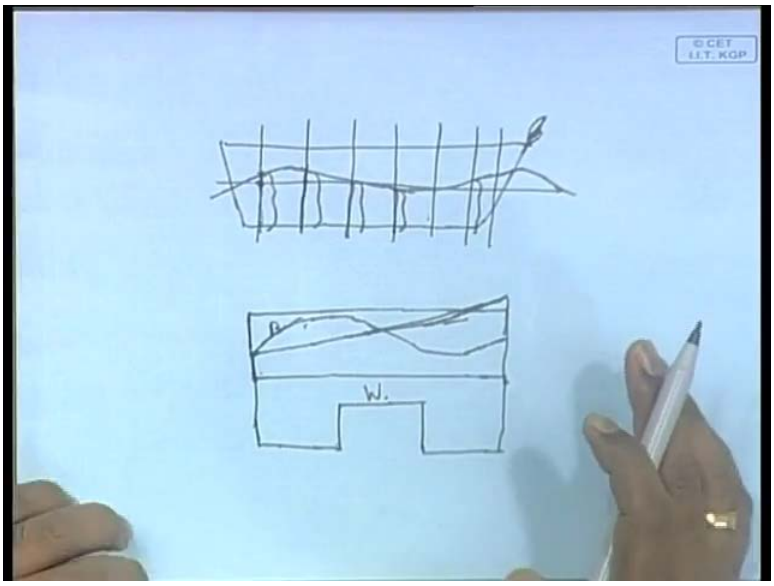

Now, suppose that we are the ship now. Now, suppose that the ship is on a wave instead of being on an even, instead of being on an even water line; the ship is now on a wave. So, how does the ship, how does it look like? For instance, this is the ship on a, instead of being on a water line, horizontal water line, now the ship is on a wave let us say. So, the wave is like this, it does not mean, matter how it is, but we have already, we have already designed, we have already told, discussed how two types of ships can exist on two types of wave. One, the ship can exist, the center of the ship, the mid-ship can exist on a, the mid-ship can rest on a wave trough or it can rest on a, wave truck, wave crest. And we have already seen when it is resting on a wave trough, we call it as a sagging wave and when it is resting, on a trough, on a crest, we call it as hogging waves.

So, two wave conditions, these are two extremes. So, when it is existing, when it is resting on a crest, you will see, that the stability is reduced to a maximum, is reduced to a maximum and when it is resting on trough, either stability is reduced, stability is increased. So, other than that, how will it affect, how will this wave affects this shear force and bending moment, this structural calculation how will it affect?

So, what will see first is, that if you have a wave like this, this is the position of the water line, this is the direction, this is the location, the curve showing the water line. Now, that means, the volume of the, under the volume of the ship at different stations, under the water line will be different here as compared to a horizontal water line. So, if you consider this to be the stations in case of a horizontal water line, let us say, the water line is like this, this draft is the same everywhere. So, it becomes a very simple Bonjean curve, Bonjean curves are all taken at the same draft or of course, even in case does it even keel of course.

There can be a slightly modified case, when it is in a trimmed condition, in a trimmed condition, the drafts can vary with distance, but even then it varies in a very linear fashion. So, drafts are all in a linear fashion varies and you get the different, you get the different drafts. But in the case of a wave, as you can see, the draft varies in a, probably a trochoidal or a sinusoidal fashion. So, like this, depending up on the type of wave, see this is the draft underneath here, this is the draft under, like this is the draft, this is the draft, this is the draft, this is the draft at this point like this. As you can see, these are the different drafts. So, draft is in a sinusoidal or trochoidal fashion, it varies throughout the length of the ship and as the draft increases or changes, increases or decreases; consequently the volume under that curve also will increase or decrease.

So, the volume is now a continuously varying function over a whole area and over the whole length of the ship. So, from the aft end of the ship to the forward end of the ship, the volume of the ship keeps changing, volume under water keeps changing and consequently, the buoyancy keeps changing. So, buoyancy is, is now a function of, is, is very much a function of the distance; in fact, it is almost assigned.

So, buoyancy, you, if you put a buoyancy curve, maybe something it looks like the weight curve, let us assume that. So, the weight curve, let us, look the same as before something like this, the weight curve if it looks like before, so this is the weight curve, this is the weight curve. Now, the buoyancy curve is going to be completely different.

Last time we had a, if it is on an even keel where there is no difference in the, this would be an even keel condition. That means, the buoyancy is exactly, of course a ship is not, it is, this is not a ship, this is probably for a box shape barge. For a ship the volumes will be different and the buoyancy is not going to be exactly like. So, for a box shape barge, this will be like this; for a box shape barge there is a trimmed condition, it will be like this. Something it does not have to be there, but here like this, a linearly varying. So, for a trimmed condition its buoyancy will be in a varying function like this. So, buoyancy will be different then.

But in the case of a ship, that is, now with the wave, its buoyancy will be completely according to that wave. So, may be like this, the volume is of course, we are assuming it is the box shape bar. So, it is probably something like this, like this, you will have a, depending upon where the ship is placed on that wave. So, the buoyancy curve will vary upon, means, the water line will vary. As a result, where is the crest, where is the trough, depending upon the water line will vary and as a result of that, you have the buoyancy curve varying with distant, along the length of the ship. Now, so this is the, how the wave has, so when the buoyancy curve varies first.

So, buoyancy curve varies, consequently the weight minus buoyancy curve will also vary, weight is fixed, we have that curve. So, this weight minus buoyancy curve will have a particular fashion of its own. Now, if this is the weight curve, this is the buoyancy curve, this is your buoyancy curve now and this is your weight curve, and the weight minus buoyancy, another curve will come, some particular fashion, some other curve will come as a function of distance, that gives you your load curve and then, that curve, you now need to, that curve you now need to integrate over the whole length of the vessel.

So, you find the area under that load curve, that gives you the sheer force curve and you take one more, once more you take the area under that curve, you end up with the bending moment curve. So, you see, how the wave influences the, you see how the wave influences the, the shear force and the bending moment curve. So, these are some effects of waves on the shear force and bending moment.

So, this is, in a sense we have wrapped up very, very quickly, in a span of 45 minutes I have explain to you what is the, quickly the shear force and many more, this is, I mean deriving the shear force and bending moment diagrams for different types of beams and different types of, like cantilever beams, and other types of beams and plates is, is a big subject in itself, like we deal with it in strength of materials. So, that is just, I have just touched on it and that is also used in ship design.

In the structural analysis we deal with the, this kind of shear force bending moment curves and once you have these curves, they are then fed into, get, you can find the different deflections and possible deflections. And we have, find possibilities of structural damage, of failure, anything can be, that is the final set of calculations.

So, this is the last part of the, last part of the stability lectures and right now, we have more or less wound up everything related to the stability. We have done the, starting from the Archimedes principle, we have now done the ship structural stability analysis on waves and even the details of, little bit of details about waves also we have covered and with that I come to a, we come to an end of this lecture series.

So, alright, thank you very much.