Strength and Vibration of Marine Structures

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Lecture - 30
Analysis of Bulkhead – I

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So, they will keep on expanding like that. In our case, it is not like that. If it is beams, beam bending, that is all. Two words will cover everything. It may be simple beam, it can be redundant beam, it will be having this type of beam or that type of beam. So, then what happens is the teacher and the student, they will try to see and judge each other. If the teacher sees that the students can grasp it, they have the capacity to grasp at a faster rate. He will go in an accelerate manner, and he will try to deliver as much as possible. The limit is whatever you can grasp. If we find that students are not in a position to grasp, then they will say it is let me go slow and again the examination. The same way, so there is no set pattern. In fact, over the years now, a pattern is become set, but there is not suppose to be set pattern, no suppose to be distribution, known distribution something of that. So, what happens actually anyway we start with the analysis of bulkhead.

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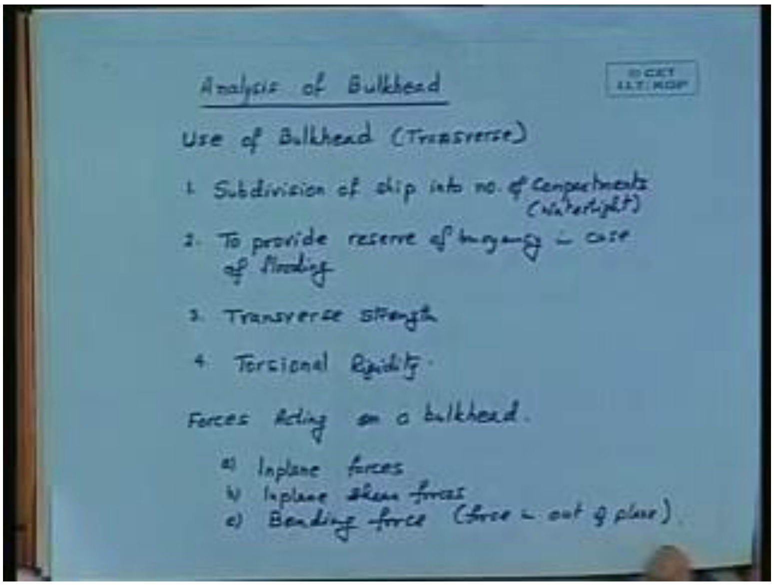

Now, before we go to the topic of bulkhead or the analysis, we should try to understand that why bulkheads are required and once we know why bulkheads are required, then only will try to gauge worth of type of analysis we required. So, let us say use of bulkhead, this can be listed like this number one that when we say bulkhead, it can be transverse bulkhead or it can be longitudinal bulkhead. So, we try to differentiate between the two and we say that transverse bulkhead.

The first and the foremost is that these transverse bulkheads are required to subdivide the ship into number of compartments. So, subdivision into number of compartments and then we try to add an adjective to it, what type of compartment and then we say that we require the safety aspect and first thing because the ship is floating in water. So, the first thing comes into our head that it should be watertight compartments. So, below let us say watertight. That means, when we are having watertight compartments and in case of any damage, a particular hold gets flooded. The ship should still float.

So, that means, the main purpose is to provide reserve of buoyancy in case of flooding depending on the type of ship whether you have one compartment standard or more compartments of standards. More compartments means two adjacent compartments, so that we will decide and accordingly we try to subdivide it. So, this is one part of it. We can further extent that it is not only watertight. You may say it should be gas tight; it should be fire tight and so on and so forth. Many items we say whether tight also some difference between watertight and weather tight. I suppose you all know the differences.

So, the first aspect is from the safety point of view. Next comes, the strength aspect of it. Now, the ship as a whole, if you just consider on the rotate part of the shell, then it is an envelope which keep the sea out and the inner space intact from the sea. All along the shell you will find that the water is exerting pressure in the normal direction, and the vertical component of it is being equated by the weight, but the horizontal direction suppose to get canceled provided the force comes in action equal and opposite.

Now, if there is no member, then how the forces will be transferred from the two sides and therefore, you have these bulkheads, which provide the transverse strength. If you do not have this, then the two sides will collapse. So, the major part is transverse strength. So, the water pressure which is being acted upon on the sides is getting transmitted through this, and the bulkhead comes on the two sides in sustaining the in plane forces. So, that is the type of load which is being transferred to this transverse bulkhead.

Number 2, the ship rolls in the Quarter Sea or Beam Sea. In that case, some sort of a twisting moment is generated and because the whole hull girder is a hollow box, this intermediate wall try to act as diaphragms and provide torsional rigidity. That means, apart from the direct in plane stresses being transmitted to the bulkhead, there is in plane stress also. This in plane stress is basically the shear stress. Because of the torsion, some shear stress will be generated. So, this is also subjected to apart from the in plane direct stress, some sort in plane shear stress, and the very first that subdivision of the ship and providing reserve buoyancy implies that when the compartment is flooded. That means, there is water inside and water will try to exert pressure from inside to all the pipe parts, namely the two sides, the two bulkheads and the bottom.

So, this implies that the bulkhead is also subjected to transverse loading or bulkhead is subjected to load in plane, normal to its plane. That means, exerting some sort of a flexural deformation or bending, right. So, now once we know what the use is of the bulkhead, the forces are automatically coming into the picture. What are the forces, which are coming into picture? So, then we can say the forces acting on a bulkhead, we can name them in plane stresses or in plane forces b in plane shear forces, and this is the bending forces or force in out of plane direction.

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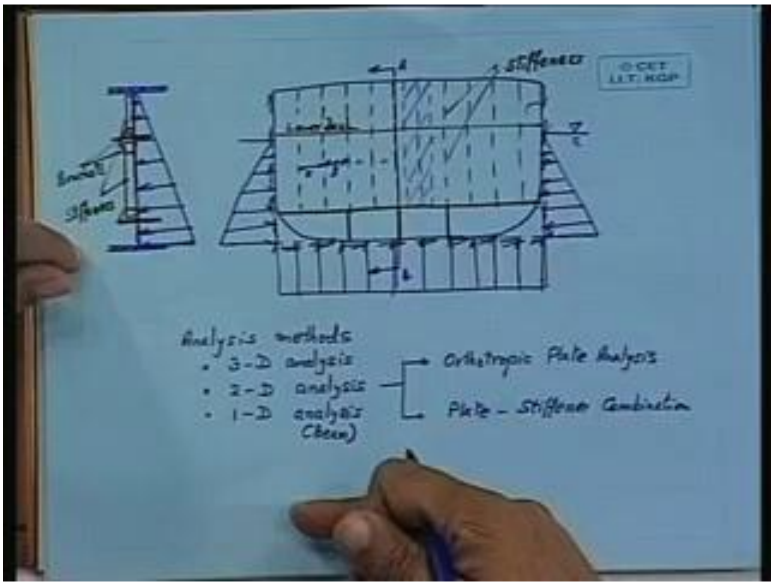

So, after defining this, then let us try to draw the bulkhead. It is let us put the water line here. So, this is the hydrostatic loading coming from here. This is the load coming from the bottom pressure and then you may have some sort of shear loading here, right. Then, let us take a section somewhere here, draw the plate. This is the bulkhead plating and then the hydrostatic loading in flooding condition will go right up to the top. When we say flooding condition, then we are saying that it is still floating, but wherever is there whether it is up to the deck or up to some predefined line or whatever it is, so this is loaded like this, right.

Now, this is the load, which we have seen, but if you see the construction, then usually what we will find that somewhere here, you will have a double bottom, a usual construction technique within the double bottom. You will have certain girders here and the bulkhead. This is the inner bottom may be that you can have some sort of an intermediate deck. We can say some lower deck and then there are stiffness provided to this plate here and I am simply drawing with the dotted lines at some constant intervals. So, this stiffness I can draw it here, and may be they are connected with some sort of a bracket here.

So, you have two sets of forces. One is in plane force; another is out of plane force. So, these are in plane forces and this is the out of plane force. They are all acting simultaneously. Now, if we try to analyze them on any, by any analytical method, then this ship will come into our way, but for the analysis sake we can always consider it to be a perfectly rectangular plate and we can try to analyze the plate. Now, the method of analysis of this can be listed like this. You can have one method. It is a two-dimensional structure, you have two-dimensional plate in one plane and then on that plane you are having some stiffeners.

So, basically it occupies some volume and the volume means three-dimensions are active. Cartesian system and truly speaking one should try to do 3D analysis, but then the basic plate is in two-dimensional and the beams can be considered that it is embedded to the plate. We can reduce the three-dimensions to two, and we can consider it to be a 2D problem. Usually the detailed analysis is done on the basis of 2D method and there are plates and stiffeners and therefore, two methods can be adopted here. One is known as the orthotropic plate analysis and the second one is plate stiffener combination.

Obviously, we have started with 3D, we have come to 2D and if we take advantage of uniforms spacing of the stiffeners all over, and if we also assume that all stiffener sections are identical, then we need to take one strip out of here and try to analyze it as a beam. Only one part of it we take this much of plate with one stiffener and try to analyze as a beam. Then, we come back to a one-dimensional analysis. That means, you simply consider it to be a beam. Obviously if you go in the reverse order, this is the simplest of the lot. Then, this becomes slightly tougher and this is the toughest of the lot.

Of course, when we say that the bulkhead lies in a plane and if you take the plate and stiffener combination for the analysis should give me a reasonably good result. If I try to take it as an orthotropic plate, then it should give me slightly inferior result and on the basis of one-dimensional analysis, I should get a cruder result. It is quite obvious that if one can perform, 3D analysis should give the best result and if the problem can be done by any analytical method in a complete manner, then that should give you the exact result, but the ship, the loading and the practical nature of the bulkhead will come in the way for a perfect analytical method solution. Therefore, some sort of an approximate method has to be applied for the analysis and then it depends on the analyst that at what stage he is performing the analysis, depending on which what is the expectation of accuracy from the analysis.

So, based on the accuracy level, we try to cut the thing. So, let us see that we are broadly interested in how to design the thing. The greater analysis can take place later on and then we go for the beam analysis.

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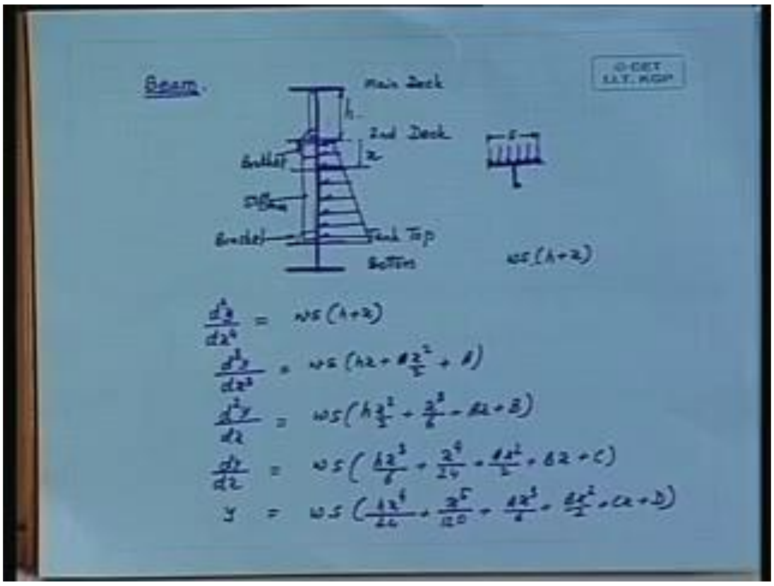

So, we consider plate beam or the plate stiffener combination to be a beam. When we consider this to be a beam, then let me draw the bulkhead once again. Say main deck, second deck or lower deck, tank top and bottom, the stiffener here put brackets here. Let us assume that this height is h, it is flooded up to this. So, I am interested only in this part. So, the loading is in this fashion. You may ask me that I have not shown any in plane loading. Here two things. When we are considering the flooded condition of the bulkhead, then the stress generated due to the transverse load is much larger than whatever is imposed in due to the in plane stresses.

So, if we try to isolate in plane with the out plane, we find that it will be better to just make an analysis on the basis of out of plane method. And then we can also super impose the stresses calculated on the basis of in plane forces, but yes when we try to do a detailed analysis, at that time attempt is made to take all the forces simultaneously to get the true nature of the stress in that particular structural element, right.

Now, here my primary member is between the second deck in the tank top because the span is more and the load is of this nature. So, we set up, we are considering as a beam. So, from here I set up some coordinate system and I say that my x is measured this way to some level here, all right. Now, if you take a cross-section here for this particular strip, you will find that this is the plate width to which some stiffener is attached. Usually a bulk plate and at this level a constant pressure is acting here, which is of this intensity. I have just taken a cross-section here and drawn here, right.

Now, this spacing as we have seen is S and if we say that the water density here or whatever you call it per unit area, then the pressure which is acting here or the loading on to this being the intensity is W into S, and the pressure is basically the distance between from here to here. This is your rho. Rho is embedded here. Mass per unit volume into acceleration due to gravity is this. So, actually what we are trying to do here, this is the pressure. Pressure multiplied by rho and acceleration due to gravity is giving me the intensity of force at this, and this is the strip on which that intensity is acting. So, basically multiplying by that frame spacing gives me the intensity of loading at that particular position of the bulkhead plate and stiffener combination.

So, now for this bending analysis, I can say the basic equation which in two-dimensional d 4 y by dx 4 is written as ws h plus x. That means, the fourth derivative of the displacement with respect to the linear coordinate gives you the intensity of load and from here, this first integration will give you Ax square or sorry, x square by 2 and plus constant of integration. So, let me put A here. I am trying to follow these notations; so that the second integration will lead to I think I will bring it here. So, anyway it does not make that much difference.

Next integration will give you the slope and then finally the last integration will give you (()). Now, ABCD are the constants of integrations and they have to be obtained or evaluated by applying the boundary conditions at these two ends here, right. So, before applying the boundary conditions, let us discuss something about this. Now, we have a stiffener here, we have a bulkhead plate here. This bulkhead is welded to the tank top, and this bulkhead is again welded to the second deck here which is a line contact. Then, we have tried to connect the lower foot of this particular stiffener with the help of a bracket. This bracket can be a simple bracket; it can be a flange bracket to the bottom plate here, or the tank top and here again to the top of the second deck or in the underneath of the second deck by bracket.

Now, they will try to provide some sort of a rigid connection, but one thing we should not forget that this tank top is again made of thin plates, thin structure. The second deck is also a stiffened plate structure. Basically the plate to plate contact is thin. Plate made of more or less the same material normally in the same material, mild steel posses the same elasticity. So, when this pressure is acting on it, this will try to bend the structure here and when it tries to bend it, because of this bracket, we are trying to make the connection rigid, but this being of an elastic material, the entire top structure will try to rotate like this.

No, no buckling. Buckling is not there. See what is happening is this. This is one plate, this is another plate and we say that we have put some bracket here. So, that bracket is a small thing here. So, what we are trying to do? We are trying to apply some load here, so that this will have a bending. Now, at this particular point, the connection is rigid, but this being made the top is also made of elastic material. It is quite likely that this 90 degree will be maintained, but the whole thing will rotate like this. Under this action of force, the whole thing may rotate and therefore, this part is coming into play to resist this rotation. This 90 degree remains 90 degree, so putting it back on a piece of paper.

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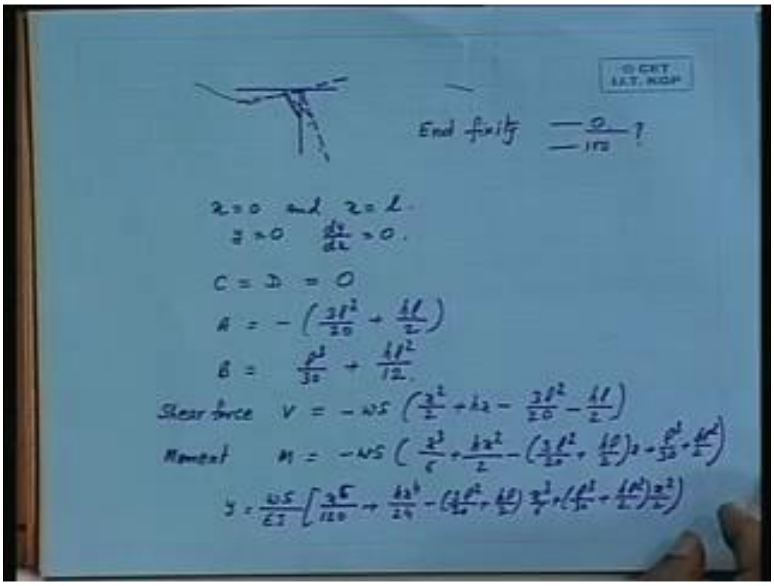

Because of this bracket connection, I am in a position to maintain this 90 degree, but the whole thing can rotate like this because this is in a position to rotate. As far as this connection is concerned, the connection is rigid at that particular point, but as far as the structure is concerned, structure is having a freedom to rotate in a limited manner. Now, this is what is important here that will say that while providing the bracket, it becomes rigid, but at the same time the structural configuration is such that it does not behave like a rigid connection.

Now, here we differ from the standard boundary conditions that the slope is 0 or the moment is 0. As you can see that there is some slope, it is not 0, but as we can see that the joint remains 90 degree. Both the conditions are being met here. A part of simple support condition that it allows the rotation. At the same time, the 90 degree remains 90 degree which is a part of fixed end condition is a very difficult type of a joint. We have welded it. Yes, and that is because the material property when we talk in concrete beams, then such a heavy wall and this and that we rarely find any visible deflection there, but here these types of deflections can be measured if you use a theodolite or some such thing.

So, this was being realized earlier and one said that it has got a limited rigidity or you can say limited flexibility, and then we say some sort of end fixity. The term used is end fixity. It is neither 0 nor 100. It is in between the two, but what is this quantity is a question mark. If we say end fixity is 0 means simple support condition. If end fixity is 100 percent, fixity is 100 percent, then it is a clamped condition, rigid condition, but as we are seeing neither it is simple support nor it is rigid. It is something in between the two, but how much it is a question mark, but we realize that it is something between 0 and 100.

We come back to this and try to evaluate this on the basis of first that assuming that the end fixity is 100 percent. That means, it is fully rigid that the usual condition and therefore, we should go with that and then we will see that how the result have to be interpreted. So, what are the conditions? So, at x is equal to 0 here, and x is equal to l here. We say y is equal to 0. It has to be 0. It is connected there and also this slope, this relative slope is 0. So, if you apply these conditions, this remains 90 degree. Therefore, this does not deflect with respect to this. So, there is no slope.

No, we are putting the bracket and therefore, we are assuming that the welds are not getting strained. The entire structure is rotating. So, somewhere here the stresses are coming. So, now, at this moment I am ignoring that. So, if I ignore that, then because of this particular pressure, my structure should deflect like this only. So, putting this boundary condition, we get the value C is equal to D is equal to 0 and A is equal to minus. I am straight away writing these values and then we can write shear force, write the expression V moment and displacement y.

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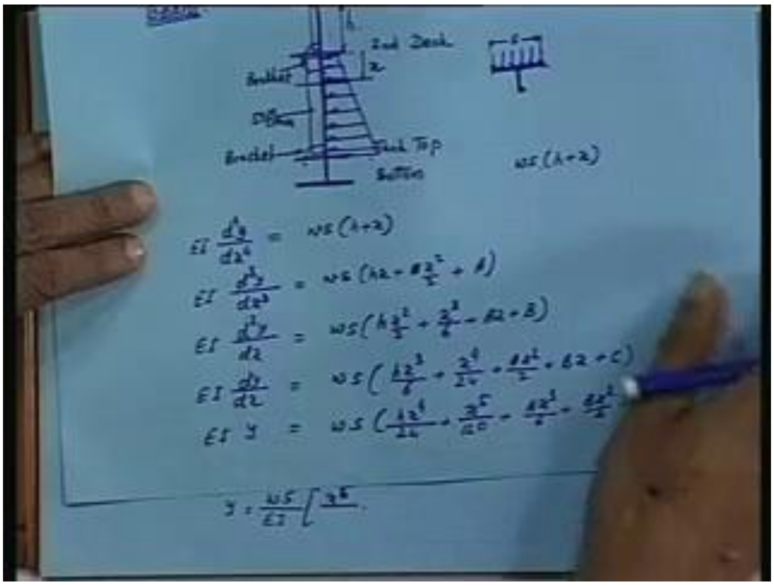

I have forgotten to put EI here. EI will come here. So, after putting the EI term, that EI comes down here. X to the power 5, 120 plus hx to the power 420, 4 minus 3 l square by 20 plus hl by 2. This term x cube by 6, l cube by 30 hl square by 2. So, these are the expressions you get after substituting and evaluation of this A B C D, and if you try to plot the curves, what we will get here.

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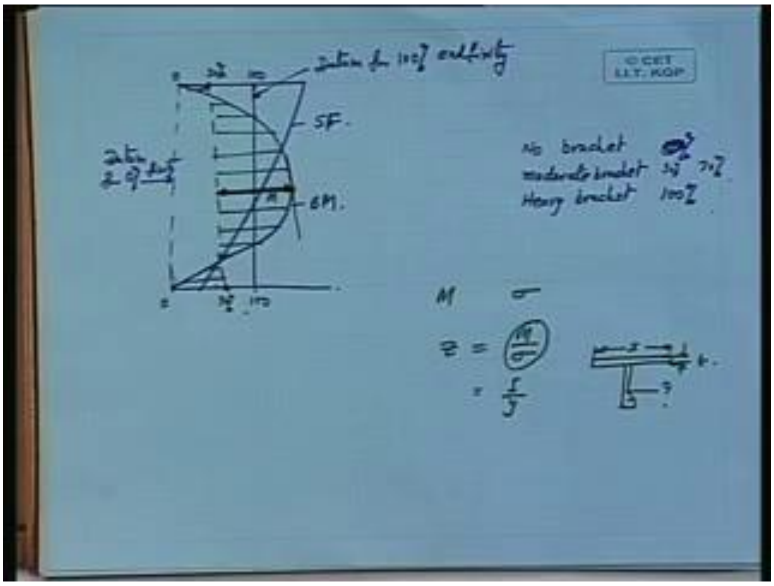

This is a bending moment curve and this is your shear force SF curve, and this is the datum line with which I have got the thing. So, now because I considered here the datum as 100 percent fixity, so we say that datum for 100 percent end fixity. Now, let us try to see what happens if the two ends were suppose to be simple support. If the two ends are simple support, then the bending moment should be 0 there. So, if the bending moment is 0, then if you join these two lines and start measuring the bending moment from this datum, then they are 0.

So, we can say that this is the proposed datum for 0 percent fixity. This is an assumption because we are trying to make the bending moment 0 there. See according to this expression I have tried to plot shear force and bending moment, which goes like this with respect to this particular datum which is 100 percent fixity I have considered. Now, if I assume that the end fixities are 0 percent, then that implies that two ends are not capable of sustaining the bending moment. So, just making the two bending moment 0, if I join this straight line and consider this to be the datum, then with respect to this line I can say that this is for the 0 fixity bending moment curve. So, you have 100 here, you have 0 here, you have 0 percent, you have 100 percent.

Now, as I told you that the brackets can be of different types, you can have the condition. No bracket. This will, sorry this will mean 0 percent fixity. If you have moderate bracket and you can have heavy bracket, when we say heavy bracket we consider big dimensions thick plate with a flange and so on so forth, then in that case, we can say it is 100 percent fixity. If there is no bracket, then we will say that it is 0 percent. It just that the two plates are welded like this bulkhead comes. No, you have the deck here and the bulkhead is coming and they are simply welded on the two sides. It will be still watertight. So, that connection I consider it to be no bracket. There is no bracket between the stiffener and the underneath of the deck. So, that is 0 percent. If there is a heavy bracket, then 100 percent and if it is a moderate, then I have to make a decision.

Now, what is the size, what is the thickness and so on so forth? Of course some analysis has been done, and if analysis is not there, people use their own judgment and try to put some 30 percent figure or 70 percent figure anyway. Whatever may be the percentage, only the experience will try to tell you. Now, with this condition if I have to draw a bending moment diagram and shear force diagram, what I do first? I use this expression, substitute the value, draw these curves and may be that my bracket connection are such that I get in the top 30 percent and at the bottom, I get 70 percent end fixity.

So, this is my 0, this is my 100. If I say 30 percent in the top, so I try to measure 30 percent here. This is 0, this is 100 and 70 percent at the bottom. This is 70 percent and when I join these two line points, this gives me the datum for the condition which I have chosen and now, if I measure the bending moments like this, so this becomes the bending moment curve for this particular condition. Based on that now you have to draw a parallel line with respect to this, and find out where the maximum is coming. This is the value of the maximum bending moment and this is the location where it is acting.

See depending on the bracket, say suppose I take a very small bracket on the top. Obviously, it is not 0 percent end fixity because I consider if there is no bracket, then it is 0 percent. So, if I give small bracket on the top, I have to from my experience I have to say that whether it is going to provide me 30 percent end fixity or not. So, let me assume that I have taken a small bracket and the contribution of that is to have 30 percent end fixity. Similarly, at the bottom I take a slightly larger size, a thicker plate, no flange. If I take a flanged one, then I say 100 percent there is no flange and therefore, I say that it is going to provide slightly more. So, it is 70 percent.

So, this is 0, this is 100. Proportionately I take 70 percent here. This is 0, this is 100. Proportionately I take 30 percent here and then I join these two line points to get this line and this is the datum for the bending moment and shear force. So, with respect to this now I try to find out where the maximum occurs and how would I get it. I have to take a line parallel to this. Wherever it becomes tangential to this curve that is the point where the value is maximum and the position from top or bottom, wherever you try to measure that at this location the maximum stresses come. So, once I locate this, then at this level whatever is the maximum bending moment, that bending moment I note and then whatever is the permissible stress value given to me based on that because sigma is equal to M by z.

So, I try to find out because sigma is known to me. So, I try to find out the section modulus required is, and this is nothing, but this value is I by y and based on this. Now I can design what this combination should have because this is known to me, this is known to me or I can find out what is this and I should get what is this stiffener. So, this is 2D. I am trying to analyze it, sorry as a single dimension now what are the drawbacks here. I think I should stop now considering the flooded condition of the bulkhead. Then, the stress generated due to the transverse load is much larger than whatever is imposed in due to the in plane stresses.

So, if we try to isolate in plane with the out of plane, we find that it will be better to just make an analysis on the basis of out of plane method. And then we can also super impose the stress calculated on the basis of in plane forces, but yes when we try to do a detailed analysis, at that time attempt is made to take all the forces simultaneously to get the true nature of the stresses in that particular structural element, right.

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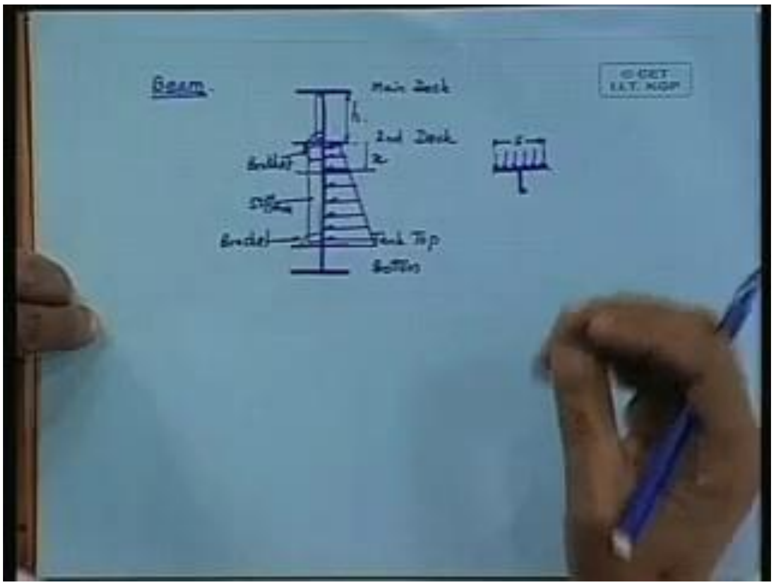

Now, here my primary member is between the second deck and the tank top because the span is more and the load is of this nature. So, we set up, we are considering as a beam. So, from here I set up some coordinate system and I say that my x is measured this way to some level here, all right.

Now, if you take a cross-section here for this particular strip, you will find that this is the plate width to which some stiffener is attached, usually a bulk plate and at this level a constant pressure is acting here which is of this intensity. I have just taken a cross-section here and drawn here, right. Now, this spacing as we have seen is s and if we say that the water density here or whatever you call it per unit area, then the pressure which is acting here or the loading on to this being right, then let us take a section somewhere here, draw the plate. This is the bulkhead plating and then the hydrostatic loading in flooding condition will go right up to the top.

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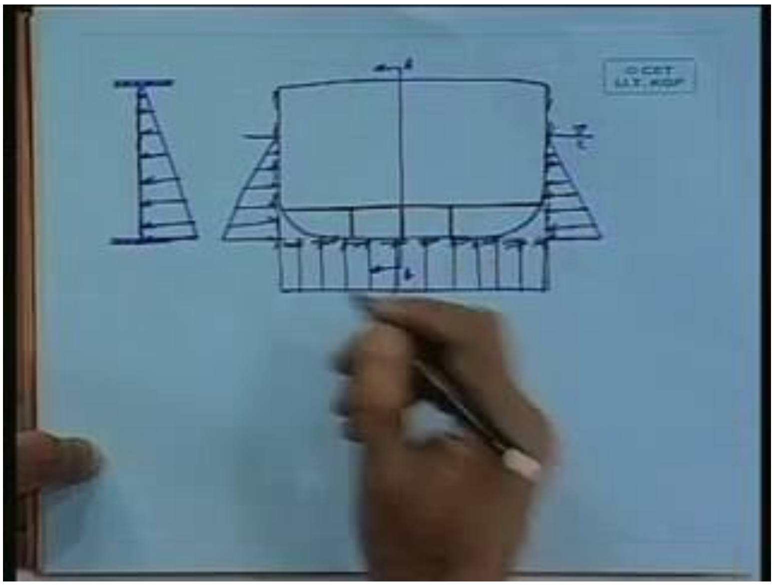

When we say flooding condition, then we are saying that it is still floating, but wherever is there whether it is up to the deck or up to some predefined line or whatever it is, so this is loaded like this, right. Now, this is the load which we have seen, but if you see the construction, then usually what we will find is that somewhere here you will have a double bottom. Here a usual construction technique within the double bottom, you will have certain girders here and the bulkhead. Then, getting the stress value is not a big problem because section modulus is known to you, bending moment we are calculating M by Z will give you the stress value.

Then, many times if suppose you are having a three point supports, you have this, you have this, you have this or as I told you that stringer is there. Here the back paper I kept, say you have used a stringer here. So, now, you have one support, you have second support and you have third support. You have done this type of a beam problem with Prof. Sheikh. I suppose, yes or no? You have done it multi-span problem or multiple support problems. In determinate beam problem we have done it. So, you can even start that way because in all those methods which we have used, you can start applying it to any type of problems. You can say the bulkhead bending, you can even say that the top deck bending, you have the hatch and beams, you have one bulkhead here, another bulkhead here.

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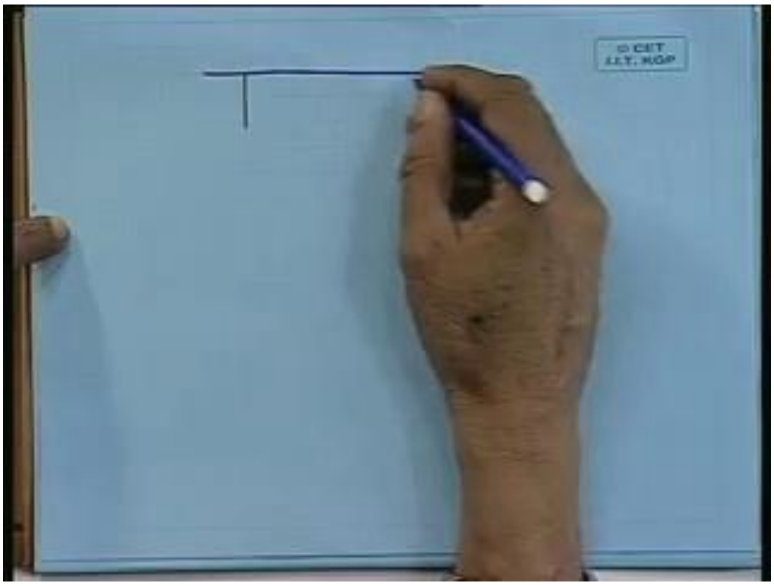

So, if I try to say this is the bulkhead, yeah sorry this is the deck. You have the bulkhead here.