Strength and Vibration of Marine Structures
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Lecture - 13
Longitudinal Bending of Hull Grider – I

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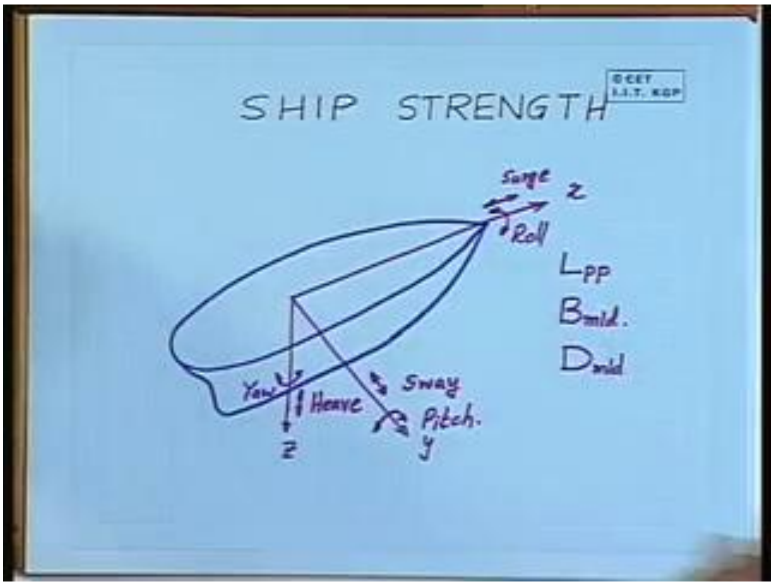

So, we try to visualize the ship as a 3D object, and we put the coordination system according to the Cartesian coordinate system x, y and z. X we normally put it in the length direction, y along the width direction, and z along the draft direction or the depth direction. Now most of you are well converged with the ship shape and you will find that the length of a ship is much larger than either the width of the vessel or the depth of the vessel.

If for a ocean going vessel if we try to see the length by width ratio, this will be of the order of 7 or some such thing, and length to depth ratio will be more than 11 or so. So, the length direction is always more than the width and the depth. So, that one has to keep in mind. Now what are the dimensions when we say that length as in ships we have various definition for the length. Now which length we are talking about as far as the ships are concerned for the strength analysis.

We consider the length between perpendiculars; this notation is LPP, and width we consider as breadth moulded and depth we consider D moulded. Now this ship is to be analyzed for the strength. What we try to do here is first we try to conceive that the ship, what is the purpose of this? The purpose of the ship is to keep the sea out and rest of the materials in and transport these from one destination to another in the safest mode following a particular schedule.

Now this is the primary job of the ship; what are the materials? Materials can be cargo, it can be passenger, and if it is a naval vessel, then it has got a particular machine to be completed. When we say that from one place to another we are defining the route of the vessel, and the ship has got certain designated speed. And therefore, we say that this route is to be covered in a specified time period. Obviously, we know that the way the sea is not always kind to you; there may be certain disturbances here and there.

And because of that some sort of disruptment may be there in your schedule, but we would not like it to happen, and we say that we sail through with minor adjustments here and there but in the safest mode. So, it has to withstand those unkind situations also while moving from one point to another; that means there will be forces which will be applied on to the vessel due to the environment. And these forces will result into some responses, and those responses are nothing but in the form of motions.

And these motions along the three coordinate systems we say that one is a linear motion which we say is surge, another linear motion along y axis which we say sway and along the z axis we say it is here. There are three rotational motions; one about the x axis which we say is the roll motion; one along the y axis which we say is the pitch motion, and one along the z axis which we say is the yaw motion.

Now when we talk about the motions, all these motions are defined by displacement which is a time varying. And therefore, they are associated along with the accelerations, and once accelerations are there under ship which has got certain mass, they will be corresponding forces which will be generated. These are the dynamic forces. Now when the ship is floating in the water in calm condition, then obviously, these motions are absent, and the total weight of the vessel is being supported by the vertical component of the hydrostatic pressure, which we say is the buoyancy. So, the weight of the vessel is balanced by the buoyancy.

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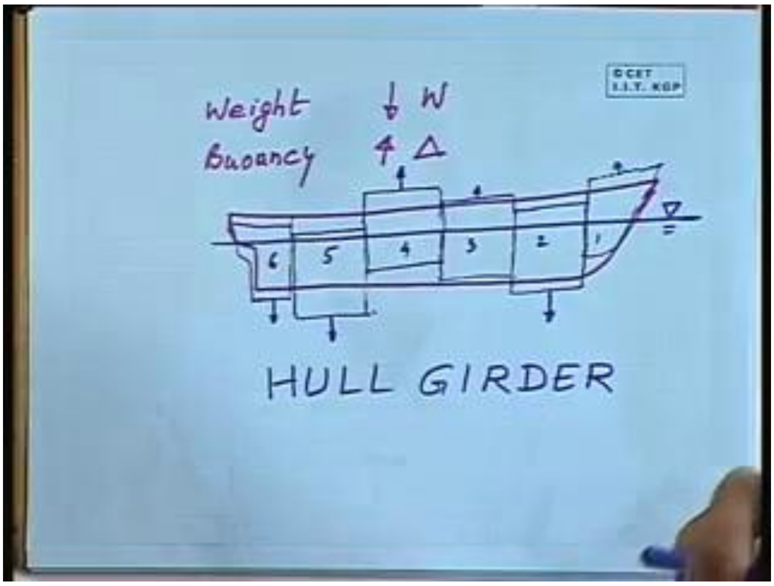

This we designate by W and this we designate by delta. W must be equal to delta for equilibrium, but the distribution of W along the x axis, the distribution of buoyancy along the length may not be identical, and therefore, there is a difference. Now how this difference can be found out? Suppose we take the ship and virtually try to divide into some components or let me give some sort of a division here and say that in calm water this is floating up to a particular water line.

And if I say that the difference between, say, if you want I can just give some number one two three four for these compartments just for understanding purposes. And let us assume that in number one, the weight is more, and the buoyancy is less because the shape is very fine there; the buoyancy contribution is less. If we take compartment two in isolation, we say that the weight of compartment two is also more than the buoyancy contribution of that part of the hull.

Three may be that the hold is half empty; the self weight is not there much, but the vessel is slightly fuller in that is side. And therefore, the buoyancy contribution is greater than the displacement. Similarly, for four the buoyancy contribution is much larger. Five is basically machinery room, and therefore, the weight is much more than the buoyancy here. And six, once again the weight is more than the buoyancy. So, what happens in this case? If we just try to give imaginary cross sections here, we will find that if we just try to remove it, then the vessel would like to move like this.

In this case I am assuming that the weight is more, and therefore, it may come down. It is just an assumption; here let me assume that it is more or less in the static condition and not much of change. Here again the buoyancy is more, here the weight is more, here also the weight is more but due to the stun gear, steering gear and so on, so forth. So, there is a tendency that this part is coming down; this part is coming down; this part is going up; this part is also little going up; this is coming down, and I have assumed that this is going up.

So, what happens at the imaginary cross section? There is a tendency that, say, five and six, they will try to move against each other; similarly, four and five. So, every cross section there is a tendency that the relative part would like to move apart provided you give them a cut there but in effect this is not shown, because the hull is continuous from one end to another end. What it says that some sort of a force is being generated which is trying to slide up and down.

And if this happens, that means there is some sort of a force even in the balanced condition when there is no waves nothing of that sort and even kill balanced condition; under the normal loading there is some sort of a force which is being generated within this hull girder, okay. Now this effect is known as the shear, and because of this nature we say that hull is a girder, or we simply use the word hull girder. Now when we go to the civil engineering definition of a girder, we understand that it is a long structure which is subjected to some load and undergoes a flexural deformation.

In fact, here if you consider the ship also a in the longitudinal direction, then we find a similar effect here that it undergoes a flexural deflection. And therefore, it will behave like a girder as any other girder in the civil engineering sense though this part of the girder is a floating girder; that is all. So, there will be a loading on to this; there will be some shear force generated along the length; there will be some sort of a bending moment generated. If you have any questions here you can ask.

Now once we say that hull is a girder, it makes our life a little easier, because instead of the three axis system x, y and z, now I can reduce it to one single dimension, okay. So, once a structure is brought down to a single dimension, then the life becomes easier, and we can use the standard analysis method for that type of a girder. We will come to the components of the loads and the buoyancy distribution.

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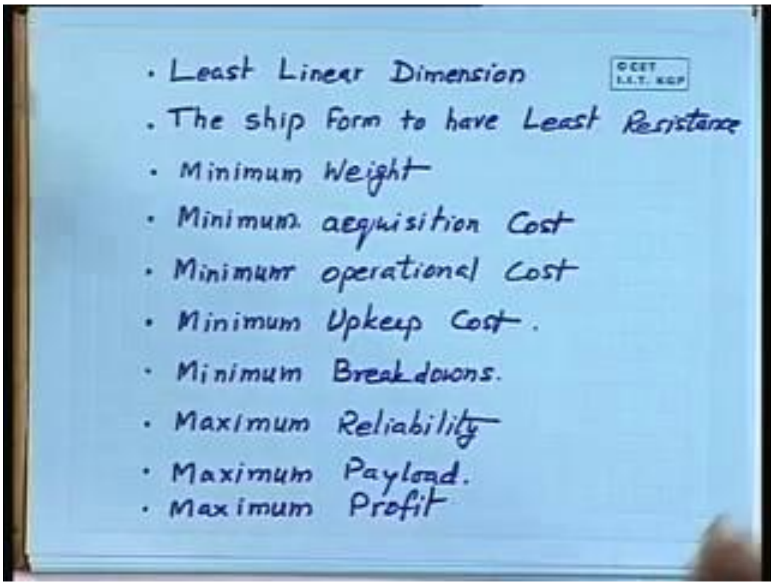

But what basically is to be done here are some of the points which we have to consider is least linear dimension. The basic idea is that the structure which we try to design must be economical not only as constructed but from maintenance point of view and try to give you the largest amount of revenue; that means a structure has to be optimally designed to fulfill the desired requirement. And to achieve that, certain set norms are there that what we should do. These least linear dimensions it is not only from the structural point of view but also from your expenditure point of view if the length is less, your port charges will be less, your penalties will be less and all such dues will be less.

The ship form must have least resistance. This is the second point one should consider, third one minimum weight of the structure, fourth minimum acquisition, minimum operational cost, we should also try to minimize the upkeep cost. Then we should design the structure in such a fashion that there are minimum breakdowns; we should maximum the reliability. So, maximum reliability; we should try to maximize the payload and ultimately maximize profit.

If this can be done then one can say that we have designed a very good ship structurally, but you see that certain of these requirements are contradicting each other. If you say that you are minimizing the acquisition cost, we have a general feeling that if you use cheap material, then your upkeep cost will increase; your breakdowns will increase. So, there are conflicting requirements. But there are certain things which are complimentary to each other; if you minimize the breakdown that implies that you are maximizing the reliability.

If you maximize the payload, obviously, your profit also should increase. If you minimize the weight that does not mean that you are going to have less breakdowns, maybe that it will increase the breakdowns. Minimizing the weight within a structure, it may maximize your breakdown. So, you have to strike a balance between the two such contradictory requirements. Now this is regarding how we try to say that optimize the vessel; obviously, keeping this in the background one has to see that what are the forces coming on to the structure. So, let us try to see what are the loads coming.

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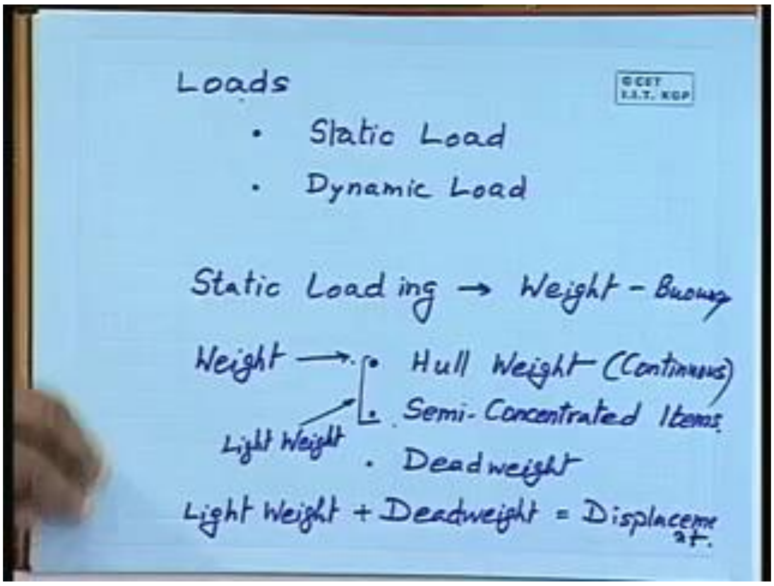

Now loads can be grouped under two categories. One we can say is the static load, and another is the dynamic load. While explaining the coordinate system, I have already talked about the 6 degrees of freedom that particular point on a vessel will undergo and the corresponding motions. And they are related to the accelerations, and they will be responsible to generate dynamic loads while the vessel is in a sea way. Fortunately, for us the motions are so slow or the frequency is so slow that they do not affect us much, and we can neglect for our primary calculation.

And the static calculation load what we have just seen here when we consider it to be a girder, then whatever loading is coming; this is due to the static loading. Now for the static loading, what we do? We try to find out the weight of the vessels first; for static loading let me write down here. Loading will be given by weight minus the buoyancy. So, we have to first find out what is the weight distribution and then find out what is the buoyancy distribution.

Now this weight of the vessel, we divide into three parts, hull weight and then we say other item which we normally say is the semi concentrated items; hull weight is considered as the continuous material. Then we have what we say is semi concentrated item and then we have the dead weight. The first two together comprises the light weight, and therefore, we said that the total weight or in other words light weight plus dead weight are equal to the displacement. I suppose it is big enough for you to see this.

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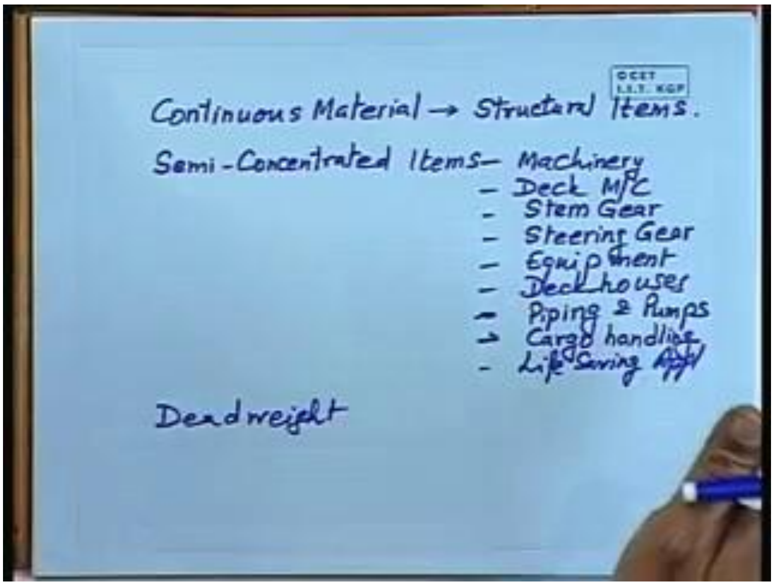

When we say continuous material, we have all structural items here. And in semi concentrated item, we can list down that the major part of it is the machinery. If you are very particular you can say that it consists of main machinery, auxiliary machinery, deck machinery and so on, so forth. So, I will just say the machinery means whatever comes in the machinery room, engine room, then we have deck machinery, then you have stern gear, steering gear, then you have anchor windlass, etcetera, which is general or chain and anchor and windlass and so on, so forth. So, we say equipment; they are known as the ships equipment.

Then you have deck houses and then we have other piping, etcetera; piping and pumps let me put together. You also have some sort of a cargo handling equipment or gear whatever you call it and life saving appliances. You can list whatever is there for fighting, life saving, etcetera; they may be heavy weight; they may be less weight. I have not taken here those communication systems; that also comes under this. So, these are all a must for the ship; if you do not have them, then the ship is incomplete.

So, whatever is the bare minimum with which whatever is the regulating authority gives you a certificate as, yes, the ship is in a position to sail that what I say is being covered under semi concentrated items. Apart from the continuous hull, all these items taken together that forms the ship for which you are ready to sail out provided you have taken the consumables into it. And all the consumables like fuel, oil, fresh water, ballast water if required, crew member, their effect and food and store whatever you call; these are all consumable which is a must for sailing.

So, that consumable along with the cargo is termed as the dead weight item, okay. So, I am writing here for completeness continuous material semi concentrated items and dead weight items. Now in ship building what happens that when you build a ship, this continuous material is basically you are fabricating; you are building the ship, and all the semi concentrated items are basically bought out items which are being fitted in the vessel. A little bit may be that the houses are also fabricated and put there, but machinery deck machinery, stern gear, steering gear, other equipment, piping and pumps, cargo handling gears, life saving appliances; everything is bought out item which are now put in the ship, and they are being fitted there.

So, obviously, when we try to buy the things we know from the specifications, how the weight is distributed of that item; what is the weight of the item, and where the centroid of this item lies. So, this information the supplier will give you, but for the continuous material this we have to generate. And when the hull is complete, then we have the compartments whether it is a fuel tank or it is the cargo hold, the space is available and we are suppose to find out what type of material you are loading in this, where the centroid will be, and what is the weight of that depending on what is the space available.

So, this we have to calculate, the continuous material we have to calculate. Now if we can have the details of all these three weight components and then add them together, then only we get what is the distribution of the weight along the length of the vessel and the way the vessel is floating at what draft under what condition with what trend, etcetera, draft forward, draft half, what is the shape of the vessel, then how much of buoyancy contribution you are getting along the length of the vessel, which we can find out from the ship property given in hydrostatics. So, then we go for the weight distribution.

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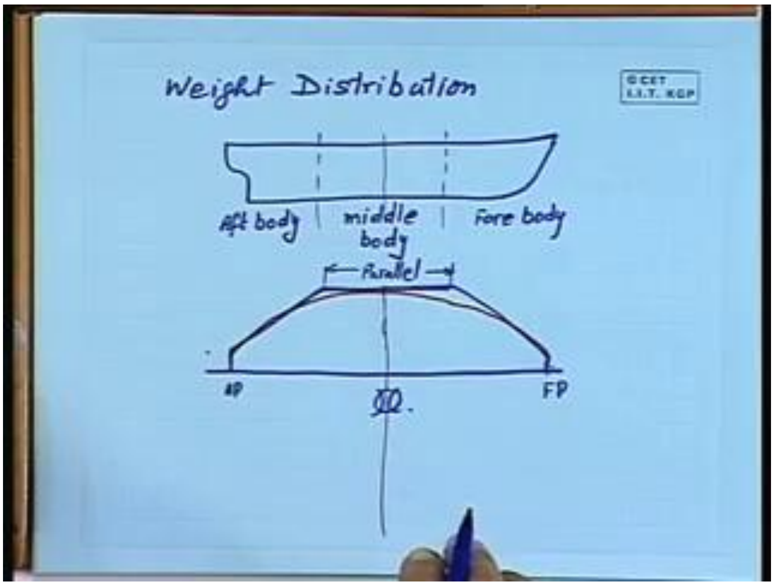

Now how do we get the distribution? We have defined the three types of weights are there which makes the displacement of the vessel or the total weight, and there also we can divide that one is light ship, then add the headed weight; it becomes the total displacement or the total weight of the vessel. Now in the continuous material which we say is the hull, basically the hull up to the main deck including all structural items in it. Now you are very much familiar with the ship structure, and you will find that there are enormous numbers of such items. Getting the individual details of each and every item and locating where it is and putting the centroid there and then trying to compute the overall centroid and the total weight is an enormous job.

May be there are tens of thousands of such items are there and every likelihood that some items are not recorded properly or some items are not properly put in the vessel. If it is recorded in the drawing in a particular fashion, the same item has not been manufactured because a particular thickness plate is not available; you have given some substitute item and put it in the ship to complete the vessel. If it is recorded, fine; if it is not recorded, then what are you going to do? So, doing that lengthy calculation, one can still go wrong and come out with an erroneous result here.

So, what is basically done? When the ship is more or less complete, you try to carryout inclining experiment to find out the weight and it’s CG. So, the weight and the CG of that half finished vessel through the inclining experiment can be found out. I suppose all of you are familiar with inclining experiment; I need not going into the details. Now once you get those and then whatever fittings have been done which are bought out items, their location is known, and we can start deducting the weight and the moment of those weights with respect to the longitudinal access system and get what is the total weight of the continuous hull material and its centroidal position.

But still we do not know how the weight has been distributed over the length. Now there can be two variations; number one, majority of the cargo vessels have some sort of a parallel middle length or we call parallel middle body. So, if we try to draw a ship, I am once again drawing it here. We divide it into three parts, and we call the first part as the fore body, the rear end we say half body, and the middle part we say parallel middle body or the middle body; let me just say middle body. It can be parallel; it may not be parallel.

Fore part and the after part we know that from a fuller section, it is converging to a final part and then vanishing it. So, definitely the weight here in the fore part and in the after part will be some sort of a tapering towards the end. Middle body, it will be full, but what will be the nature? That we do not know, but another thing we know that some vessels are very full in ship like tankers, where this block coefficient defined will be, say, 0.8 and above. There are other types of vessels like the naval vessels segregate where the block coefficient may be of the order of 0.55, and it is very fine in ship.

So, these are the two extreme cases; within this extreme case all other cases will fall in. So, in one case we can say that let me draw the mid ship section somewhere here. In one case we say that over some length, the weight of the hull remains constant and then it tappers down, and we say that and after perpendicular let me write after perpendicular here and forward perpendicular here. Some ordinates here and then I take a linear distribution. This is only to make my life easier.

Another type of vessel which I have just discussed I say that there may be some sort of an after and forward perpendicular because I am not going up to the two ends of length over all. Some weight is there, but it can be a distribution like this, because there is no constant section going in the mid region. There is one section which is maximum and then it is tapering down, okay.

Now where the middle body can be considered to be more or less constant in nature? That we say is the parallel middle body, and the other one we do not have any parallel; we have a maximum section somewhere. So, these are the two extreme cases. One is depicted by a blue line here, another one with a red line, and these two types of weight distributions can be made. Now where the parallel middle body is of a fuller section, we will extend for a larger length.

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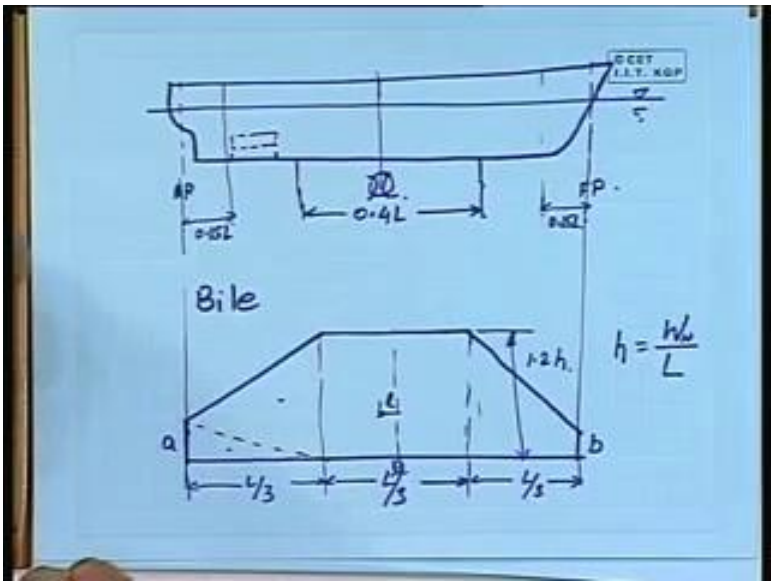

Usually if you see the rule book, then you will find; I am coming to the rules for a little while where the scantling calculations are defined in this fashion. By definition this is your forward perpendicular, and you can have your after perpendicular somewhere here passing through the radar stock, and this becomes the length between perpendicular; you take half of it, sub divide, somewhere here is your mid subsection. Now 0.4 L around mid subsection; yeah, 7 and half percent I think.

Student: Collision bulkhead?

Collision bulkhead comes at 7 and a half percent; this is 15 percent of this.

Student: Collision bulkhead?

Collision bulkhead comes 7 and half percent after forward perpendicular.

So, the ship is basically divided into this. The fore part is 30 percent of the length, off part is 30 percent of the length, and mid part is 40 percent of the length, but from the fore perpendicular to 15 percent behind, one set of structural requirement is there. This is known as the panting region. And in the after end, again the rule requirement is that part of 15 percent from the after end, there is some sort of an additional strengthening to house all those radar equipment, etcetera.

And in the mid sub section because the maximum bending moment will take place there, and therefore, 0.4 L is must have another set of scantlings. So, in these sections we have to have different scantlings and the place where it is not mentioned by the rules, these scantlings has to linearly taper down from maximum to minimum whatever is there section. So, even from this point of view, we can say that the rules says 0.4 L at mid ships, and we can consider that because after that the weight has or the scantlings have to taper down; obviously, the weight per unit length will also taper down.

So, this 40 percent length where the section is same, the weight per unit length will also remain same, but depending on exactly to what extent the maximum section continues is spread over within the mid ship region which will be decided by the block coefficient or the fullness factor of the vessel. So, one mister Bile by who suggested that the weight of this vessel continuous material, you divide it in this fashion that over the mid parallel middle region, you define what is the parallel middle region.

And you consider the weight to be like this; you say that the ordinate here is A, the ordinate here is B, and this maximum ordinate is 1.2 H, where H is defined as W by L. And for usual shapes he says that you take this as L by 3; this also you take L by 3, and this also you take L by 3. Through the inclining experiment, I get the hull weight; I think it will be better if I put a suffix h here weight of the hull. And if this is the mid ship, the centroid of the part this small l will be the l c g of this weight part with respect to either AP or mid ship whichever is convenient for the calculation part.

Now we get w h, we get L from our calculation which is based on the inclining experiment. There is no problem as far as these two quantities are concerned, but to draw this simple diagram, we have two unknowns here. One is the left ordinate a and the right ordinate b; how do we try to get this? It is a very simple figure. You have two trapeziums here and one rectangle; obviously, we are taking the rectangle to be symmetrical about this mid ship. And therefore, area under the rectangle can be calculated, but the moment of this will be equal to 0.

Then about the mid ship you can find out the area; if this area can be calculated a plus 1.2 h divided by 2 into L is the area multiplied by this can be divided into two triangles very easily like this. And you can say that the l c g here is one-third from this end, and l c g of this triangle is one-third from this end. So, these distances are known. So, what one can do is one can find out the moments of all the individual areas about a particular reference axis which can be taken as the mid ship section.

So, that will give me one equation the moment expression. The other one is sum of all the areas, which is nothing but representing the weight of the hull. So, I get two equations here, and there are two unknowns, and this can be easily calculated, okay. So, once this is calculated the distribution which I have assumed is okay, and this is an assumption. And majority of the ship hull weight will follow more or less this diagram, and on that basis only he has given this particular distribution.

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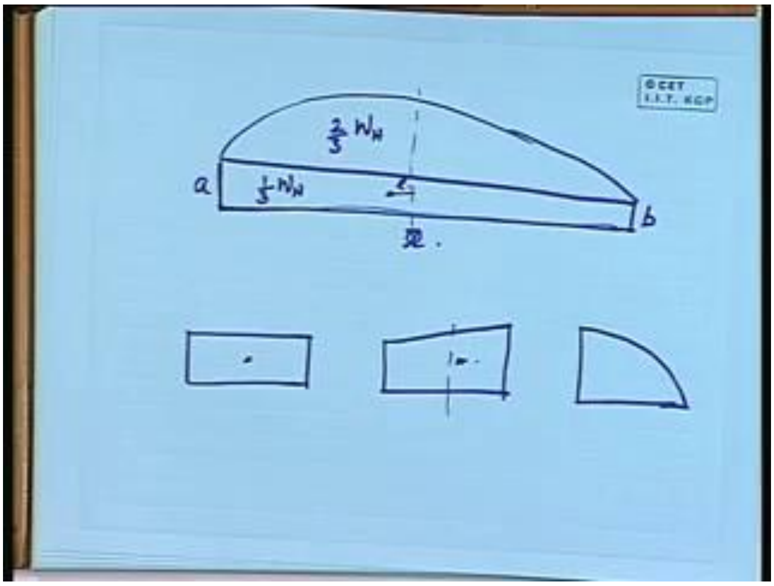

Where it is not possible to represent in this fashion, then I call it to be the hugest method. The weight is divided into two parts; one part is a linear trapezium like this, and another part is a semi circle or a parabolic distribution like this superimposed on this. Now this parabola is symmetrical about the central line. And therefore, it is not going to contribute anything towards the longitudinal central of the gravity position, but the linear distribution here which is a trapezium is going to decide about the l c g position.

So, l c g of this will be the l c g of this item, and a and b can be calculated from here. Now this part in some book says that it is 1 by 3 w h, and this is 2 by 3 w h. And therefore, this also can be done in a very neat manner; only thing instead of getting linear lines here, you are getting a curve and that is all. So, these two types of variations give us the hull weight distribution. Now regarding the semi concentrated items, we normally use one of these a rectangular distribution. If it is rectangular, its center of gravity is at the center; it is a trapezoidal distribution either this way or that way where the centroid will be somewhere here.

And third one may be a parabolic distribution which can be considered something like this or a combination of two of these figures or whatever it is. So, we breakup the whole thing in some sort of a very simplified diagram which are engineering acceptable to us from the engineering point of view, and they are easy to calculate. So, if suppose we say that the weight of the main machinery or the main diesel engine I say some 560 tons and it spreads over because we know the location. It is positioned; I will just try to take a diagram out from here.

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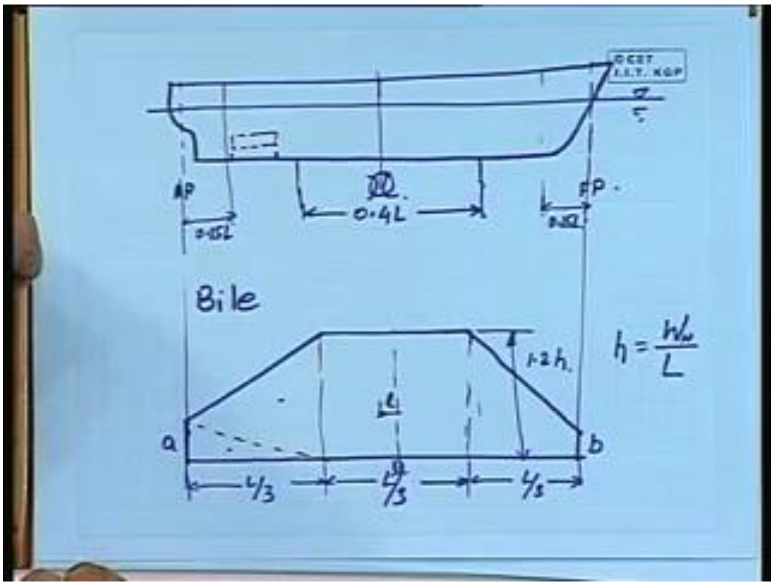

Suppose I take this diagram, and I say that from a particular frame number here to another frame number here, this is the place where my main machinery is being put. So, over this length I have to superimpose this distribution or this distribution, whatever is the actual distribution, is this okay. Now the cargo weight or the dead weight distribution normally one gets from the capacity plan, we have the grain capacity, we have the bell capacity and depending on the type of cargo which capacity is to be taken. So, that how much you load and what is the capacity up to that loading will be known to us. So, that has to be super imposed.

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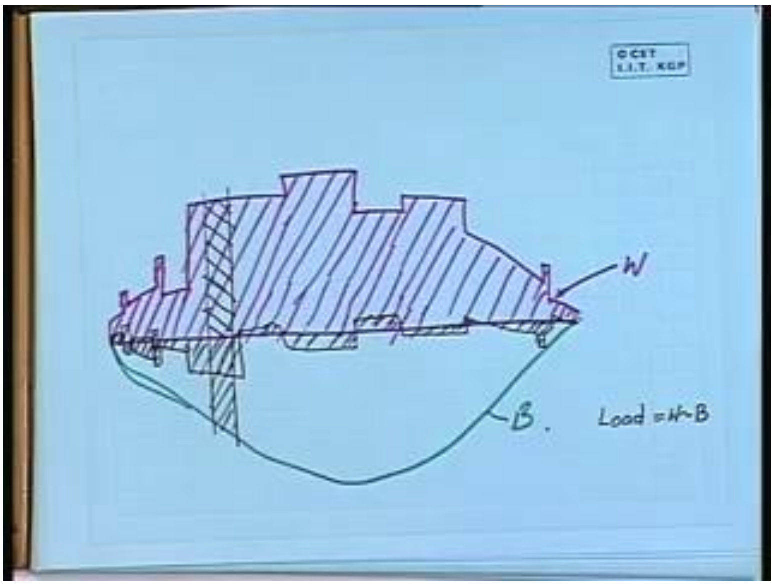

So, once we try to do that, then what we get? We can draw a line here. Some sort of a curve we will get which is very, I am just trying to draw some arbitrary figure here, and I say that this is the weight curve. Now area under this curve it is a very decent curve I have drawn, but in effect you will find very crooked curves. So, area under this curve will be the total weight W light weight plus dead weight. And when it is floating in water, then this weight has to be balanced by the buoyancy.

Now buoyancy is in a very smooth manner; let me draw the buoyancy in the other direction, and I say that starting from 0 depending on the shape, I think I should have taken something like this. This is the B curve; that is the W curve; this is the B curve which we say. Take a section somewhere, take a small length here. Now what we find that the weight here is this much and the buoyancy here is this much acting one against the other. I will come back again to that diagram because of this nature here.

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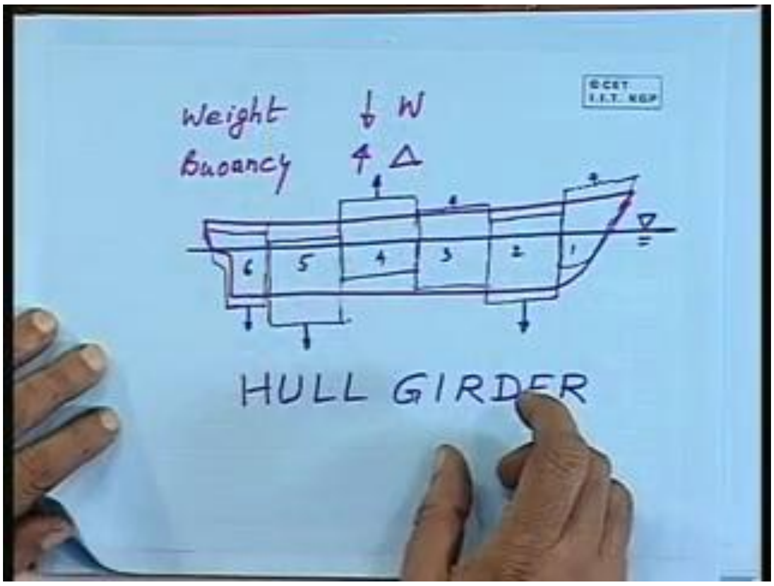

Because of this nature here this part will either go up or down, okay. So, the difference between the two is basically the load which is acting on to the hull girder. Now it all depends that what we consider positive or negative. So, I will simply say that that is up to the analyst whatever he wants to use. I simply write that W minus B is the load for this portion. And for each individual such small sections if I get this load W minus B if I consider W here is positive and B is negative, then this part if W is greater than B, then it is a positive load; that means acting downwards. If this is negative; that means it is going to act in the opposite direction. So, if that can be found out, then we may get a curve something like this. I think I am drawing in the opposite direction; whatever it is say something like this. Now this is the load, which is acting on this girder, okay.

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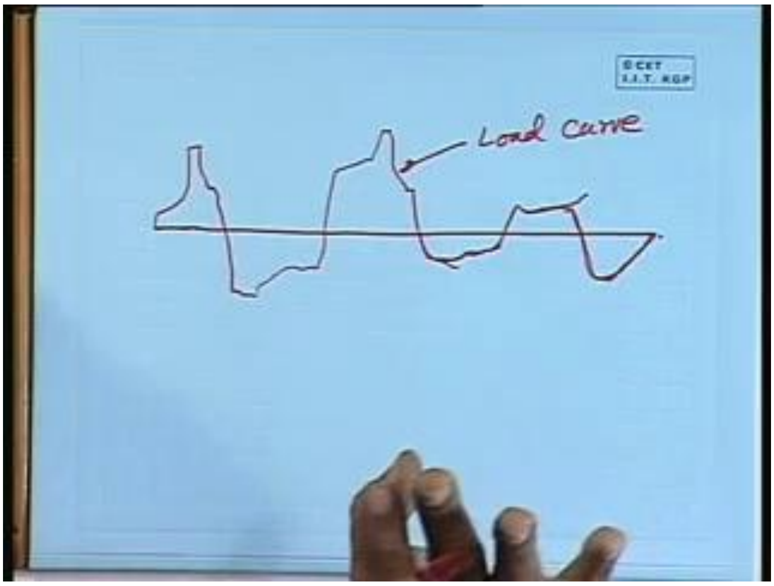

I think still I can continue, okay, and I will stop it and I will just complete later on.

Student: You have to stop sir; you have to stop here.

I will stop it; I will just complete drawing.

Suppose, I have drawn this curve here and I say that this is my load curve. So, this I call is load curve, okay; I do not know whether still time is there or?

Student: You can stop sir and then restart the lesson.

I think that is an accepted norm all over without saying, unless otherwise stated one takes it for granted that once a ship is designed, launched and put it in service will last for 20 years. It will try to earn revenue for the organization for the shipping company for 20 years without failing. Now during these 20 years of expected life, it will undergo different types of loading conditions, which are market driven, seasonal and so on, so forth

So, one particular loading condition we do not know, what is that loading condition, but we know one thing that the total weight component which we have talked about the two of the weight component that is the hull and the machinery and semi concentrated items that is light ship of the vessel; it can never come down below that. So, that is one which is constant throughout the life. Cargo, yes, it will keep on changing. Depending on the availability of cargo, the type of cargo, the type of pattern of business and so on, so forth.

So, that part we will keep on changing. Depending on that, the buoyancy distribution will also change, because weight has to balance by the buoyancy. And therefore, the buoyancy will be changing. Now how the buoyancy distribution will change?

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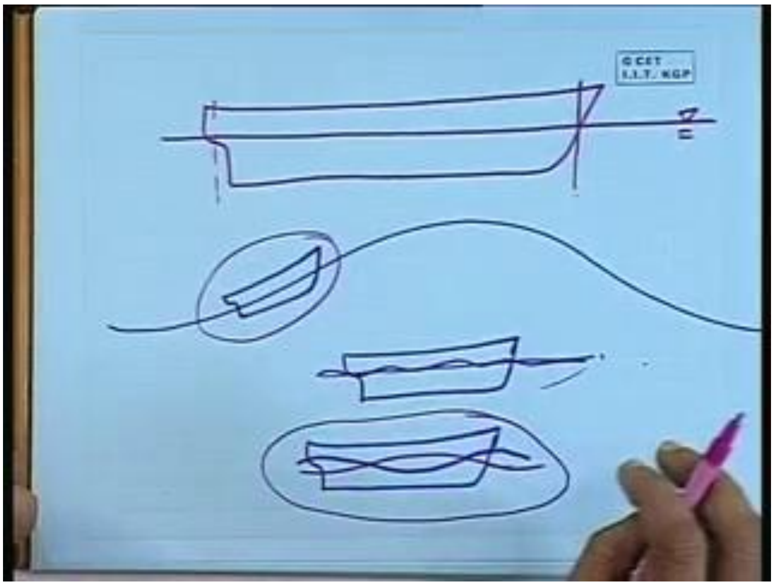

Now the ship can be considered to be floating in calm water; when do we see the calm water? In actual operation you people will know better than me that there is no situation when you can consider the ship to be sailing in calm water.

Student: At times.

Very rarely, even I would not say that is a calm water condition.

Student: Yes

And moreover when the ship is sailing, the surface is never calm because the ship generates its own wave pattern. So, it is never a calm water condition. So, what is the wave condition we should consider in which the ship is floating. Now the sailors have designated right from calm condition buffet number 0 to 11 or to 10; whatever it is to cyclone or hurricane, okay. And according to the definition, different wave patterns can be seen in these conditions, and we have also studied and we say that the ship should be in position to even sail during the hurricane condition.

It may be tough for the sailor; it will be tough for manning the vessel, but still you should not try to disturb the route and follow the predetermined route to go to a destination even under adverse condition. Ship should be still in the safe floating condition. Keeping that in our mind, what type of forces will be generated? Now I can consider this particular ship to be floating; I will just try to draw few diagrams here. One is that is a very big wave is there with wave height, and the ship is floating something like this. This is one condition; it is moving in a big wave.

There can be a condition when the ship is something like this and the waves are like this. There can be a condition when the ship is something like this, and this may be a wave pattern, or this may be a wave pattern. You see the second diagram which I have shown the ship is floating in waves which are very small wavelengths having very small wavelengths. That the picture down below is a ship more or less floating in a wave, the wave length of which is more or less equal to the length of the ship.