Hydrostatics and Stability

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Module No. # 01

Lecture No. # 17

Healing Moment - II

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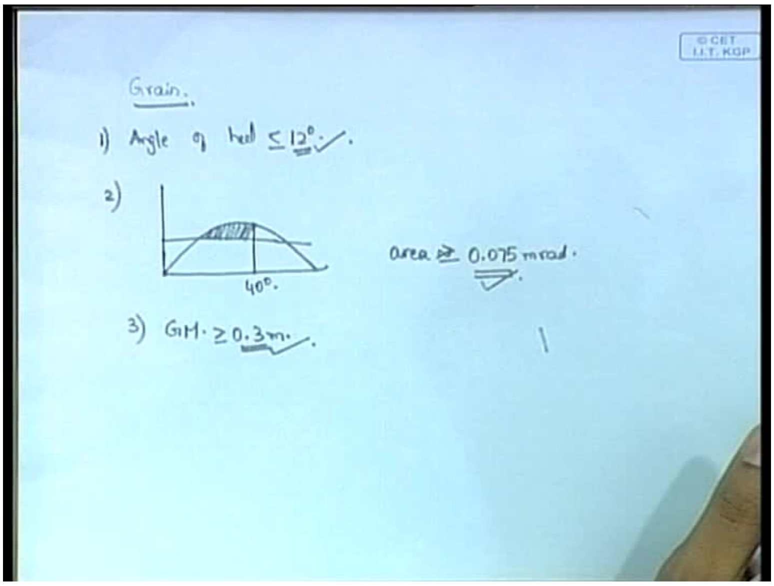

Let us start with the heeling moments again. First of all, we will deal with the heeling moments associated with grain. Grains are contained in the container ships and there are some set of rules that are made in regards to the grains. Regarding the GZ curve, the area and the different stability conditions, I will just state those conditions again. Then we will do a problem.

Now, when grains are put into the container, because of the grain shift there is a heel, let us say of the ship. The rule says that the angle of heel should definitely be less than 12 degrees because of the shift in the grain. This means grain is there and due to some reason it is shifted as a result of which there is a G 0 G 1. G 0 G 1 meaning there is a shift in the center of gravity. As a result of which, there is a heel and the first rule says that the maximum angle of heel due to any amount of grain shift should not be more than 12 degrees, it should be less than or equal to 12 degrees but, not greater than 12 degrees.

Then the second rule is that in the GZ curve - the statical stability curve, suppose this is your righting arm curve and suppose you have a heeling arm like this - the rule says that the area between the righting arm curve and the heeling arm curve up to an angle of 40 degrees or an angle of flooding if it is occurs before - angle of flooding means because of its heeling there is some hole that has come to the water means that hole is actually on the free board but, because of the heeling that hole has come into the water as a result of which water is entering. That is called as angle of flooding.

So, the area in the GZ curve between the righting arm and the heeling arm between the angle of 0 degrees and 40 degrees or the angle of flooding if it is occurs before - this area should be at least 0.075 meter radians or it should be greater than or equal to 0.075 meter radians. So, the area between the curve should be at least 0.075 meter radians. That is the second condition.

Then the third condition is that GM, the meta centric height should not be less than or it should be greater than or equal to 0.3 meter. The GM the meta centric height should definitely be greater than is 0.3 meters. These three conditions are the rules associated with grains

Sometime back I derived some other rules. You have to remember all these rules. Actually, in the later stages after the mid-semester, we will be doing explicitly with a lot of rules. Rules associated with this ship, that ship under different conditions, the wind and heel - all those kinds of rules. There are lots of rules associated with that. You have to by-heart and write as such. But for this mid-semester that is in 2 weeks, this much of rules you have to remember associated with grains and something else I derived sometime back those are rules associated with merchant ships. Vessels should have satisfactory stability that is the area under the righting curve should not be less than 0.055 meter radians up to an angle of 30 degrees. So, those rules also you have to remember. In case you have such merchant ship conditions, the problem will state which rules you have to apply. The moment you see grains which are in container ships, some kind of container ships, you use these rules. These three rules - all three has to be satisfied. All three satisfied means - the question will be - is the ship stable or is the ship likely to be certified something like that.

So, if all the three rules are satisfied, then the ship is stable. Note that even if it is 12 degrees, is passes the test even if it is 0.3 meter it passes the test. Similarly, here 0.075 - it passes - that it is always equal to or greater than not greater than. If it is any of those values, you pass the ship.

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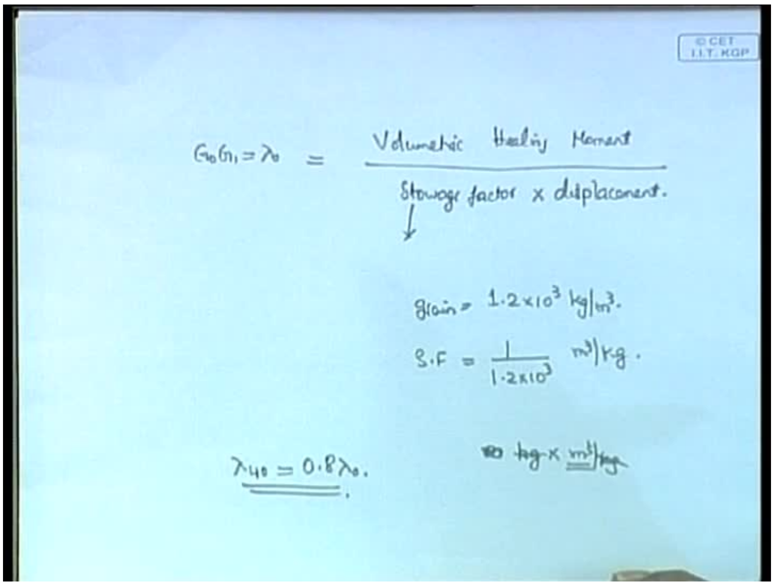

Then, some other things which I did not explain - that is - in case of such grains we use G 0 G 1 is written as lambda 0. It is defined as the volumetric heeling moment divided by stowage factor into displacement. So, G 0 G 1 - that is the shift in the center of gravity of the grain is producing your heeling for the ship is equal to lambda 0 is equal to volumetric heeling moment. Now, this I did not explain properly. What is stowage factor? Now, I think I said something like fraction or something it is not exactly that. Actually stowage factor means suppose the density of that grain is 1.2 into 10 cube kilogram per meter cube.

Let us suppose that the density of the grain is this- 1.2 into 10 cube kilogram per meter cube. Then, the stowage factor is defined as 1 by 1.2 into 10 power 3; it becomes meter cube per kilogram. This is the meaning of stowage factor; it is something like 1 by density.

It will become something like 10 power minus 3 kind of thing meter cube per kilogram. That is the meaning of the stowage factor. As you can see here, this will be - displacement is in delta, it is not the volumetric displacement; it is the total displacement of the ship which is the weight of the ship, so, it will be in mass. Displacement will be in kilograms and stowage factor is in meter cube per kilograms. When you do that, you get something like volume meter cube which is the dimensions of volume. Therefore, you can look at your expression for G 0 G 1 which is lambda 0. So, it is a volumetric heeling moment divided by a volume. That is a arm only; it is a distance. That is why it is something like a center of gravity or G 0 G. That is the shift in the center of gravity - that is what gives you G 0 G 1.

Then, lambda 40 means - lambda at 40 degrees is defined as 0.8 lambda 0. This is the second expression. This too you have to know. Let us do a problem probably this will explain.

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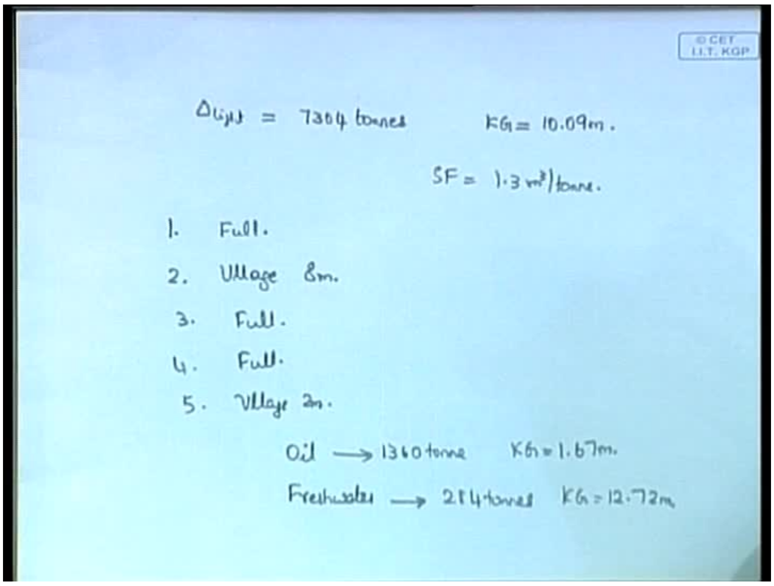

Now, you are told that there is a ship which has a light displacement. This is the light displacement of 7304 tons and you are told that its KG is equal to 10.09 meters. Now, this is the ship in which grain is added. First of all, the moment you see the grain make sure the question is going to be - will the ships satisfy the IMO criterion? First of all, you have to remember the rules. Then, we will see how to do the problem.

You are given that the stowage factor is 1.3 meter cube per ton. These things you have to change. It is 1.3 meter cube per ton. Ton - you change into kilogram - it will become 1.3 into 10 power minus 3 meter cube per kilogram. Do not forget that; you have to change that.

Now, you are told about the different compartments. The figure that I showed you applies to all compartments, which means all compartments are exactly identical; there is no difference. Whatever is a Ullage, we can directly read the volumetric heeling moment from that. This is the way in which the different compartments are filled. First compartment is filled fully, second compartment - it says Ullage is 8 meters, third compartment - it says is full, fourth compartment is full, fifth compartment - the Ullage is 2 meter.

Then it says that below that you are going to add oil which is 1360 tones and KG equal to 1.67 meter. Somewhere you are adding fresh water which has 284 tons and it has a KG of 12.72. Actually, when you do such a problem there is one additional thing you might get confused; that is, when you are having water and oil, you might have to take the free surface effect as well. It becomes a very complicated problem.

But in this problem, for the oil, they have not given the compartment size and all that. So, if you are not given that obviously means you neglect the free surface effect of fresh water or the oil, because this problem is just for sand. We are not doing the other part.

In a complicated situation totally you really have to consider that. In this problem, we are not going to consider free surface effect. Nothing about the fresh water tank size or anything is given; otherwise, you have to find i for the tank. If you remember for the free surface effect, you have to get i of the tank. We are not given anything about that, so, we will neglect those things. This is the data. What is this for then? Why is this oil and fresh water given? What do you think it is given for? What does it affect?

KG exactly. It is just for calculating your final KG of the ship. It is just a measurement for KG and not for the movement of G in the horizontal direction not for that. Just for the vertical movement of G, that is the only thing. What you first have to do is you have to find the net volumetric heeling moment. You have to find the net KG and net displacement of the ship, because remember we have to find G 0 G 1 which is lambda 0.

In our definition, lambda 0 is equal to G 0 G 1 is equal to volumetric heeling moment divided by stowage factor into displacement. What do you need? You need the volumetric heeling moment. You need the displacement. Two things, that means you have G 0 G 1, then you need to calculate GM. To get GM, what do you need? One more thing - KM is given as 11.3 meters. What do you have? What are you supposed to find? Remember, the 3 rules imply you need to find three things.

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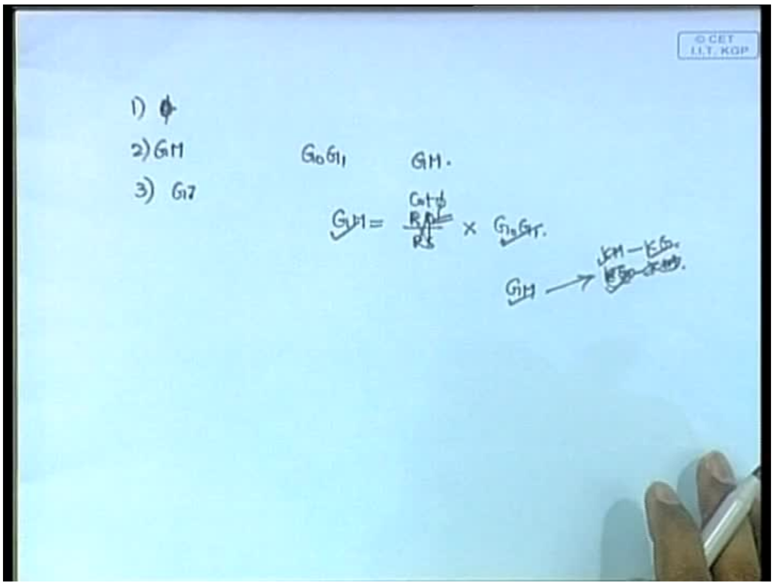

There are 3 rules associated with grain; the first is the rule associated with theta, the phi- the angle of heel - that means you need to find the angle of heel. Now, what do you need to find the angle of heel? To find the angle of heel, if you remember - we are going to use the equations associated with the inclining test. To do the inclining test, you need two things, G 0 G 1 and you need GM. There are a lot of formulas we have derived so far in this and they are they are interrelated but, you have to remember them - all those formulas.

So, you have a G 0 G 1 and you have GM. So, G 0 G 1 and GM are required in order to calculate the theta. This is the formula - R0 by RS becomes cot phi. So this is the formula. If you have to find your phi, this is the expression. Please remember this expression. First of all, the question something to do with the derivation of inclining test is sure, because it is a very important thing - inclining test. That means you will remember. That method of derivation and the experiment is to be remembered definitely and this final expression you just keep it by-heart. GM is equal to cot phi into G 0 G 1. This expression is needed for a lot of such problems and without that you will get totally stuck.

Therefore, what we need to find here is phi. We need two things, G 0 G 1 and GM. To get GM, what do we need? GM is equal to KM minus KG. This expression is to be remembered. KM is given; that is fixed. There is nothing to do. KG of the ship has to be found. This is important. From that, you will get GM. What have we found? First we need to find phi. There is a rule associated with phi, it says that phi should be less than or equal to 12 degrees.

Number 2 - it says that GM should be greater than or equal to 0.3 meters. So, these two are required. Then, three - you have to find the area under the GZ phi curve between the heeling moment and that area should be greater than something.

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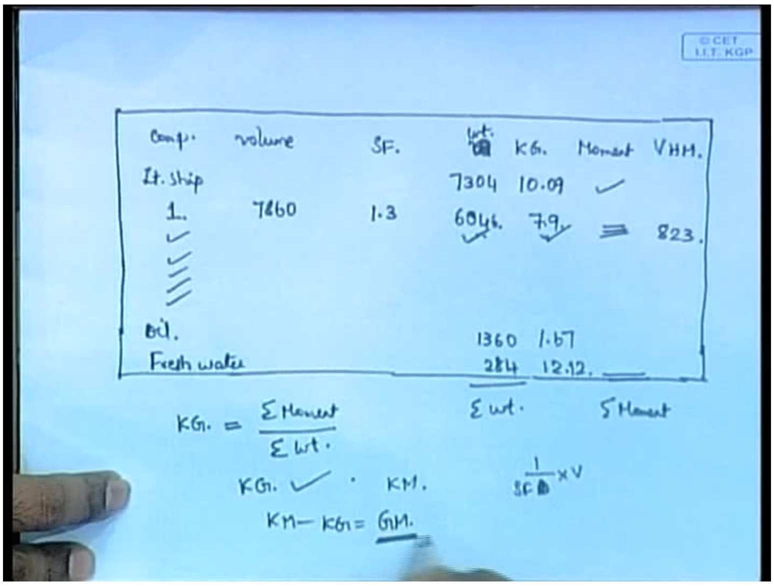

So, we will go step by step. The first thing is - to find in one table itself; we can do most of it. Let us say this is the component, then the volume, then stowage factor, this is the weight, KG, moment VHM.

Now, we make a table like this. This table should be able to calculate everything that we need in regards to this problem - that is we need to find the KG and lambda 0. To do that, this table should be enough. Let us take the first one - component is the light ship. Light ship - there is no volume or stowage factor, the weight is given 7304 tones and its KG is given 10.09 meters.

So, you find the moment. Is there any volumetric heeling moment associated with the light ship? Note- Volumetric heeling moment is the heeling moment associated with the shift of grain in a compartment. The light ship itself has no volumetric heeling moment; there is no grain there, so, the light ship has no volumetric heeling moment. So, this is not there.

Then, you consider the first compartment in which grain has been added. They have told. How do you find the volume of the first compartment? This is the first compartment. First compartment is full. In this way, you complete the table. You do it for all the components and finally, in the end, they have said oil. All the different compartments are done. 1, 2, 3, 4, 5 – so, all the compartments are done and then you have oil. For oil, there is no volumetric heeling moment. Volumetric heeling moment is defined only for grain. It is a particular property of grain. As you might imagine oil also shifts like grain. No such thing. It is defined like that. Volumetric heeling moment is defined only for grain.

Therefore, forget about it. There is no volumetric heeling moment as far as the oil is concerned. This is not there but, this oil is given just for the sake of its weight and KG. Therefore, here only two things are important. Weight is given 1360 tones. This comes and its KG is given 1.67. Similarly, fresh water is given -it says 284 tones and its KG is 12.12.

Now, we have the complete table. What do we find out from this table? See here, we have the total moment - which is weight into the KG - that moment sum up the total moment, sigma moment. This, when summed up will give you the sigma weight and therefore, your net KG of the ship after all the heeling everything is over, the net KG of the ship will be given by the sigma moment divided by sigma weight. This will give you the net KG of the ship. Now, you have the KG. That is solved. That is a very important thing. One important part is over.

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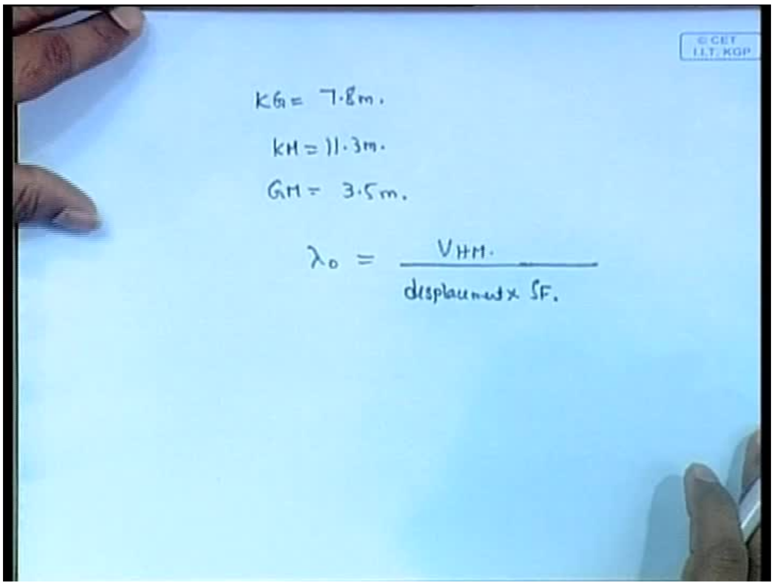

Now, you are given your KM. KM value is given and note that these KM values are not going to change because of the shift of grain or anything. KM is fixed. Therefore, you do KM minus KG - you get your GM. In this particular case, when you do that you end up with the KG equal to 7.8. KM equal to 11.3 and you end up with GM equal to about 3.5 meters.

So, this is the first thing you have to check. It says that GM should be greater than 0.3 meters. That is the first condition. So, in this case, you are getting GM to be 3.5 meters. So, you have no problem as far as that is concerned. That is the first check.

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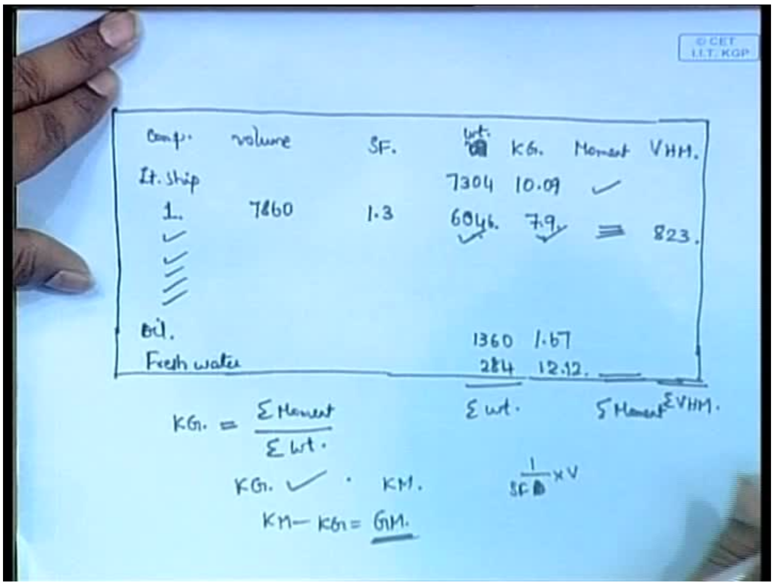

Now, that is satisfied. Next, you have to calculate lambda 0. Now, lambda 0 is given by the formula - volumetric heeling moment divided by displacement into stowage factor. We will look at this table. You have the total volumetric heeling moment as your last component in the table as your last column in the table. Sum up those volumetric heeling moments, you will get the sigma volumetric heeling moment. That is your total volumetric heeling moment.

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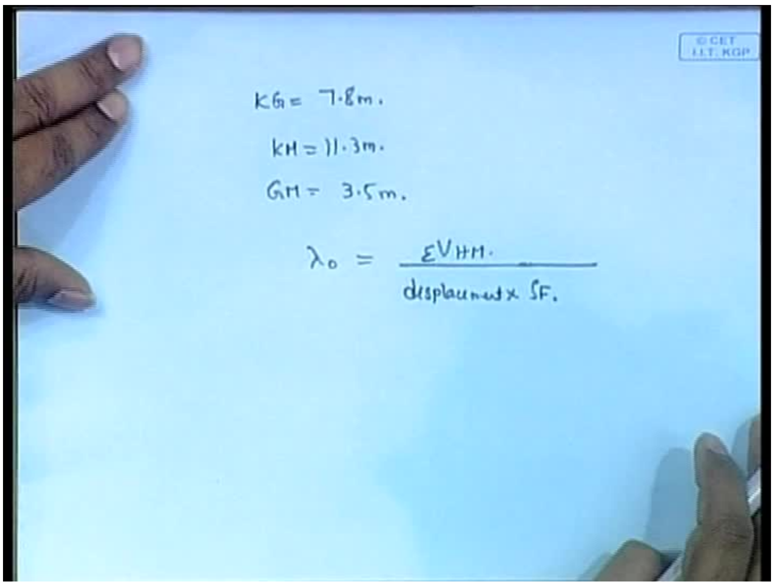

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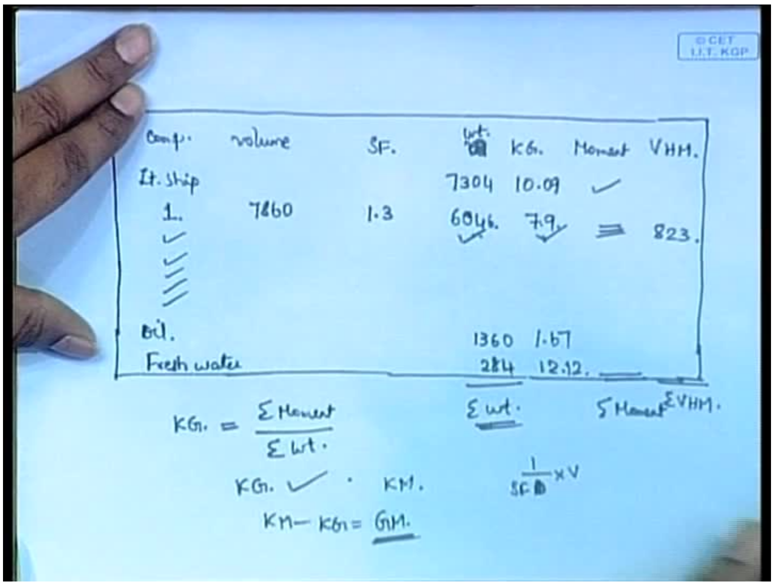

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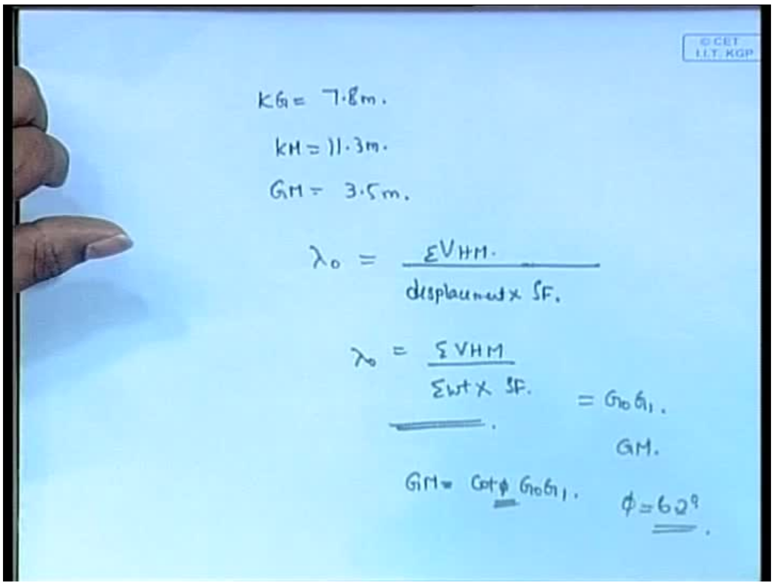

This is what it is - lambda 0 is equal to sigma volumetric heeling moment divided by displacement into stowage factor. So, sigma volumetric heeling moment I have told you that is the last column. Then, this displacement is this sigma weight. So, you have sigma volumetric heeling moment divided by sigma weight into stowage factor. Stowage factor is a constant; some 1.3 meter cube per ton. That is given. This gives you lambda 0.

Now, this is equal to G 0 G 1. Now, note that you have already have GM. Therefore, GM is equal to cot phi into G 0 G 1. Use that formula and find phi. If you have phi, in this case you will get phi to be 6.2 degrees, it should be less than 12 degrees. So, that is also satisfied. That is the second criterion. So, two criteria are satisfied.

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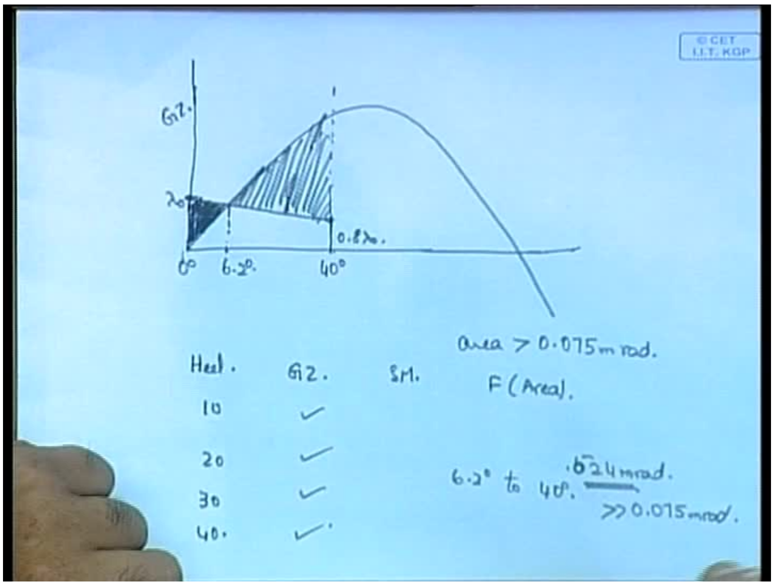

Now, the third thing is to find the area under the GZ curve. To do that, you have to be given the GZ curve, otherwise, you cannot do that. That will be given and either a GZ curve or a GZ table will be given to you. The rest becomes very simple. You are given your GZ table.

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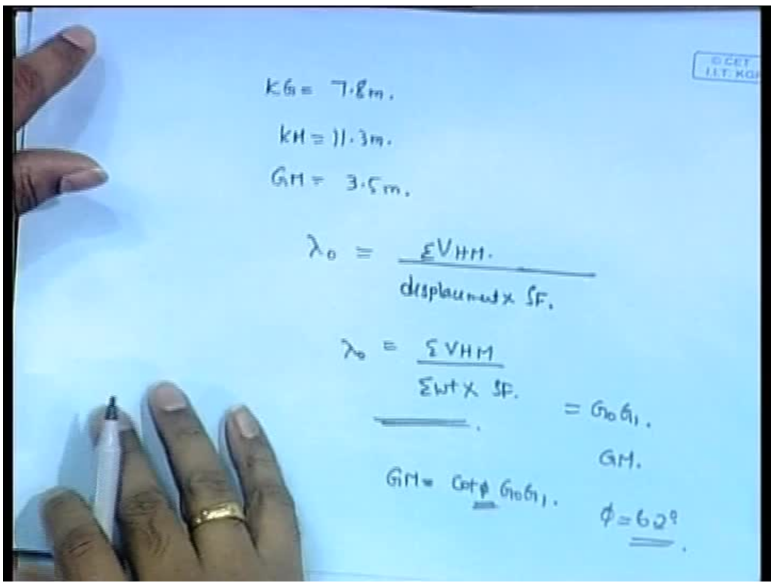

As you just draw the curve, how do you draw the heeling moment? The heeling moment is drawn like this. Remember, you have drawn lambda 0. Here somewhere around this point, you mark lambda 0. You have calculated lambda 0 as sigma volumetric heeling moment divided by displacement into stowage factor. Lambda 0 is like a heeling arm.

Therefore, this lambda 0 is showing your heeling arm. Now, lambda 0 the heeling arm slowly changes, when the ship heels, that heeling moment changes. The method that is adopted is lambda 0 is marked here; then 0.8 lambda 0 is marked here at 40 degrees. Let us assume this is 40 degrees. This is 0 degree. At 0 degrees, lambda 0 is marked. At 40 degrees, you mark 0.8 lambda 0 and draw a straight line through these two; this will give you the heeling arm.

So, this is your heeling arm curve and therefore, your objective now becomes to find the area between the heeling arm and the righting arm curve which is this - between 0 and 40 degrees. Between 0 and 40 degrees, this is the angle between the heeling arm and this is the total area between the heeling arm and the righting arm curve. This total area is what you have to find out. This area should be greater than 0.075 meter radians.

So, in this problem how do you find the area under the GZ? You have the heel angle then you have your GZ then you will have your Simpson’s multiplier, then function of area. So, heel of 10, 20, 30, 40 this and so you have your different GZ. You read from the graph or you will be given the GZ table from which you write these values. Simpson’s multiplier is put here; 1 4 2 4 you put that Simpson’s multiplier or trapezoidal multiplier. You put that here. You find the area.

So, you find the area up to 40 degrees. When you find the area under the GZ curve, you are actually finding this area. You will be finding the area under the righting arm curve. Then, you need to find the area under this trapezium made by lambda 0 and 0.8 lambda 0 and you have to subtract that. That will give you the area between the righting arm and the heeling arm curve.

That is a good question. I do not remember right now. Let me think I have to check that I cannot recall it now. They have chosen 40 degrees as the limit at which this area is. There is some reason for that - I will tell you.

If you look at the equation, one of the rules always in the ship design is that the GZ curve the maximum should always occur less than 40 degrees or 35 degrees or something. That is the rule. The maximum should always be less than 30 degrees. We have given always some safety factor to it and then we are making the rule; that means the GZ curve maximum will never be greater than 40 degrees.

So, this is why the area should be less than 0.075 meters radians. You find this area between the two curves.

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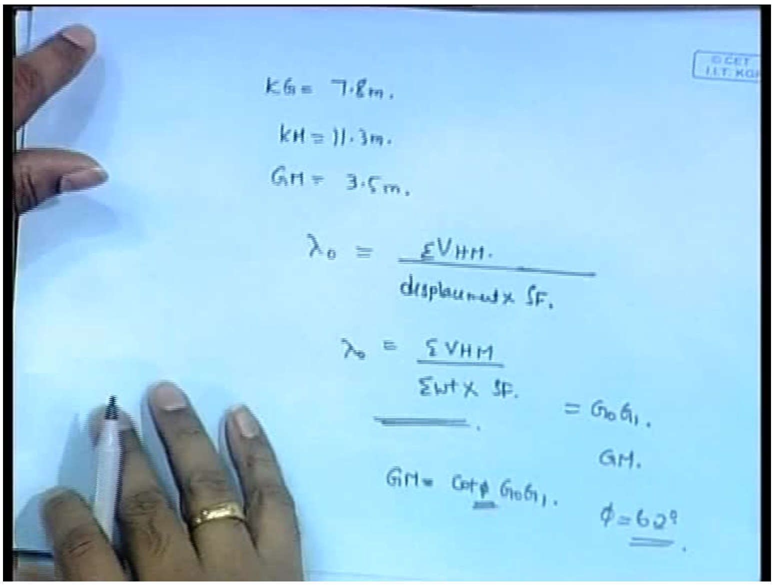

In this case, you will get it something some 0.524 radians meter radians. The residual area between the heeling arm curve and the righting arm curve up to the angle of maximum difference or the angle of flooding should not be less than 0.075 meter radians.

What is this point? This will be the point where the heeling arm curve equals the righting arm curve. In this case, we have got it as 6.2 degrees. This is how we have defined it. So, the area from that angle up to 40 degrees should be greater than 0.075 meter radians is the rule. This area should not be taken. You have to take the area from 6.2 degrees to 40 degrees. It is not the whole area; that is the rule.

So, first you have to find area of the GZ curve between 6.2 degrees and 40 degrees. That will give you this whole areas - this area plus this area; subtract the area of this trapezium from it and therefore, you will get the area between 6.2 degrees and 40 degrees. That area should be greater than 0.075 meter radians. In this case, it comes to 0.524 meter radians. Therefore, this is much greater than 0.075 meter radians. Till now we have 3 conditions; all three conditions are satisfied by this ship.

I will repeat this; because it is very important. I told this wrongly. First GM should be greater than or equal to 0.3 meter. That is the first condition. Number 2 is the maximum angle of heel. How will you get the maximum angle of heel? You will get it from the heeling equation for inclining test. GM is equal to cot phi into G 0 G 1. GM you have; G 0 G 1 is got using volumetric heeling moment divided by stowage factor into displacement formula. From that, you will get G 0 G 1. With that, you get the value of cot phi; you get the value of phi. Once you have phi, you make sure the value of phi is less than or equal to 12 degrees. That is your second condition of stability.

Then the angle between this value - that is this phi - in this case, 6.2 degrees and 40 degrees. It is not between 0 and 40 degrees. It is the area between this angle and 40 degrees should be greater than or equal to 0.075 meter radians. That is the third rule.

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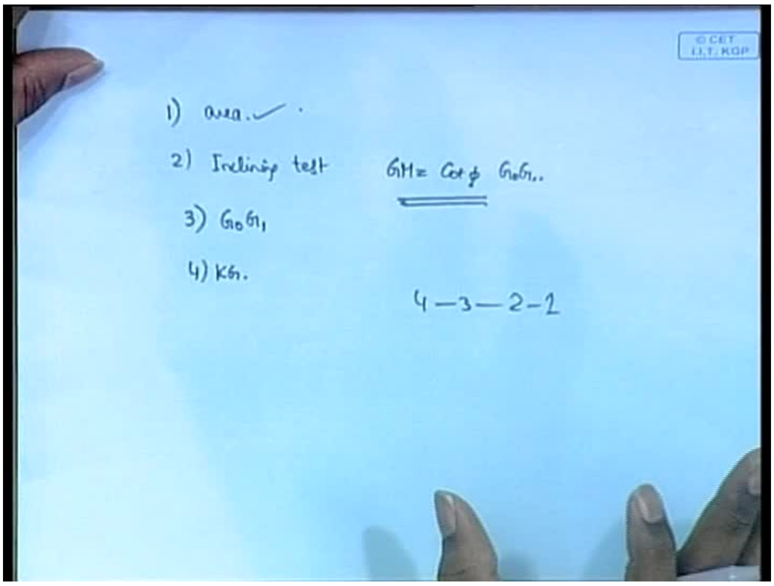

So, couple of formulas that you definitely able to do is - first given the GZ table or the GZ curve, you should be able to find the area under the GZ curve. You should know how to do that. It is very simple. You are just going to simplify the thing and you get the area under the GZ curve. That you should able to do -that is the first thing.

Second thing - remember this expression of the inclining test GM is equal to cot phi into G 0 G 1. This definitely has to be remembered. If you do not remember this, you cannot do anything. Once you have that, you have to get phi and then the third thing is you have to be able to find G 0 G 1. Actually, we should be going in this direction back up. So, first we find the KG, then you have KM given, so, KM minus KG will give you GM. You have the GM, then you find G 0 G 1 using the volumetric heeling moment which is lambda 0. Once you have G 0 G 1 and GM, you can get phi. Then you are going to step 2. From that phi up to 40 degrees, you find the area. So, you go like this 4-3-2-1 like that you go up and the problem is solved. All the 3 criteria should be checked. To do one problem like this, I think will take one hour, 45 minutes atleast.

So, I might not give you a problem as such because that is too difficult; but, I will ask you the steps to solve the problem. That you can write in 15 minutes. These steps you should write. Suppose, if such a problem is given, how do you solve it? You should be able to do it.

The next one- it is very long. I do not think we will be able to finish this in this class. We will start with it; now, it is due to the wind. We are going to find. Right now we found the heeling due to grain. Next is the heeling due to wind.

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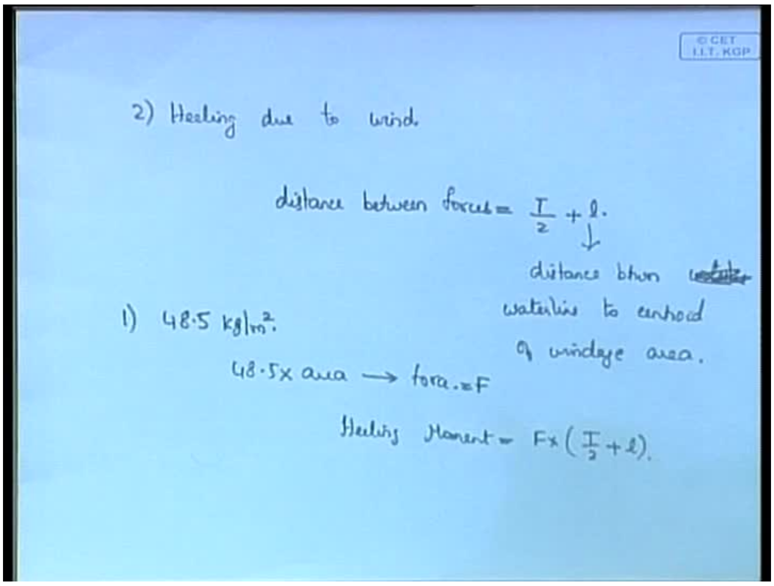

Our purpose is now to find the heeling due to wind. The way in which we define the problem is like this - Suppose you have the ship here, part of the ship below the draft is under the water part of the ship above the water is known as -let us call it is the freeboard, that is called windage area. This is the amount of area that is open to the wind. This is the ship; this is the longitudinal direction of the ship and at this point we have the waterline; so, this much is below the water and this much is above the water.

This area is the windage area; this plus this plus this plus this that is the total windage area. Now, the way in which we define this problem is like this. The wind acts let us say wind acts like this causing the ship to heel here. What we assume is that wind provides some force to the ship. That force acts on the centroid of the windage area. That means the distance between the draft and the top most point of the ship, half of that distance we will call it as the centroid of the windage area. There the force due to the wind acts. This force tends to actually push the ship like this. Water here will prevent the ship from moving. Therefore, water will provide a reaction force.

Now, we assume that reaction force to act at the centroid of the water region under the water; that means at draft by 2. So, whatever is draft, draft by 2 at that point, the reaction from the water will act which is equal to the wind force. Why do we say that? We assume that because if the ship is like this, when the wind acts we assume that the ship does not move like this in any way. It remains there only. So, this force is equal to this force. This force acts at the centroid of this windage area. This force from the water acts as the centroid of the water; that is logical assumption only. This acts here; this acts here. So, there is a force acting here, there is a force acting here as you can see there is a moment produced. One force like this; one force like this and this moment tends to heel the ship like this. It comes from logic when the wind acts, the ship should heel like this but, from the pure force, balance, moment kind of view this is how it acts; there is a force there is a force, this distance into that force that will cause a moment. So, what exactly is the distance between the forces here.

The top - that is what the top of the ship, top of the super structure. Even if you really want to make the problem more complicated, you will see the super structure does not really extend whole of the ship. So, windage area becomes a slightly difficult thing. To find the centroid becomes slightly more difficult. It is the actual centroid; it does not matter. It means this distance - the vertical distance you find the centroid.

So, roughly we can say the distance between the top of the super structure to the water line, half of that distance will be the centroid of the windage area. So, there one force, here one force, the distance between the forces therefore, becomes something like - if T is the draft T by 2 plus l where l is the distance between the water line to the centroid of the windage area. This is roughly like your heeling moment. This is what is causing your heeling moment. So, this is your heeling moment.

Now, how do we solve the problem? When you are designing a ship, note that you will not be knowing what is the wind acting on it. So, the first step is to assume the worst possible and wind design it like that. So, that is what they do. During the design stages, what they do is assume that the windage area is subjected to a steady wind loading of 48.5 kilo gram per meter squared, so, 48.5 kilo gram per meter square of this is the maximum kind of wind which can come anywhere. That is why its wind force is the maximum you can get. It is not even the maximum; it is maximum plus some safety factor.

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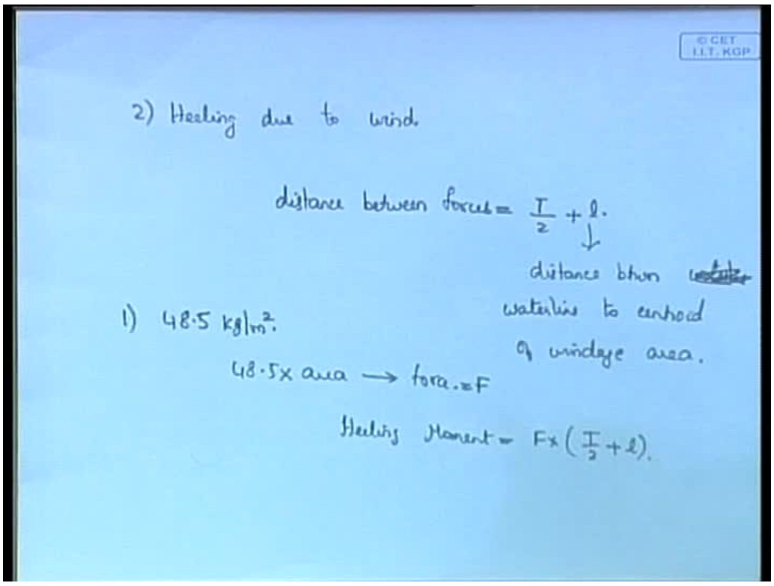

So, that is the limit. Assume that 48.5 kilogram per meter square of wind is acting and as a result when multiplied with windage area; windage area will in turn depend upon the ship. It is the area of the ship. This 48.5 is the maximum wind loading per windage area; so, multiplied with the windage area you will get the force.

So, 48.5 multiplied with the area will give you the force. This is the total force due to the wind. Same is the force acting as a reaction from the water because the ship as such is not moving horizontally means the ship is only heeling. Therefore, this force is equal to this force and that is given by 48.5. This is the force acting.

Therefore, what is the heeling moment? Let us call this F. The heeling moment will be F into T by 2 plus l. This will be the heeling moment. We have a set of rules which tell you how you have to solve for this - wind case. This is a long process. This is how you start with the wind. There are a set of assumptions basically. This is how you check if the stability is satisfied. It is like an algorithm - a series of steps you have to follow and then you decide whether the ship is stable or not. We will do that in the next class. We will stop here. Thank you.