Hydrostatics and stability

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Module No. # 01

Lecture No. #31

Bilging – III

So, let us start on, continue with this section on bilging. We have already done some problems relating to bilging. So, in this section there is one more problem.

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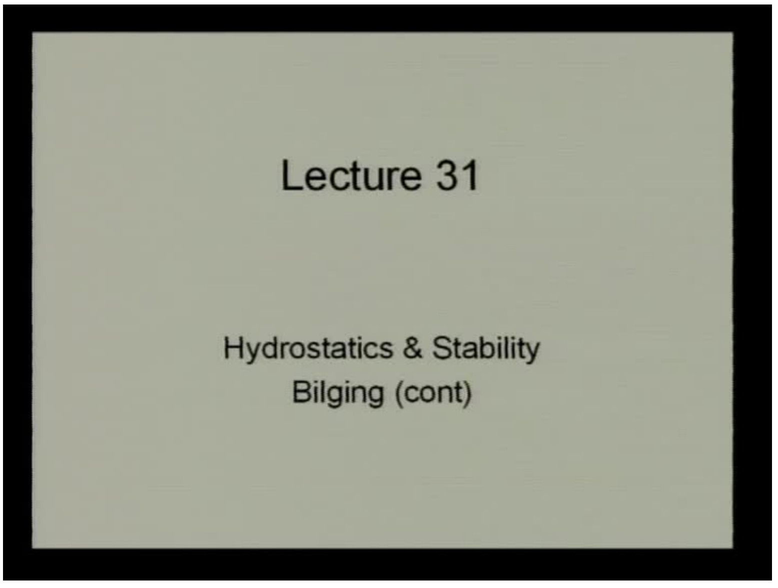

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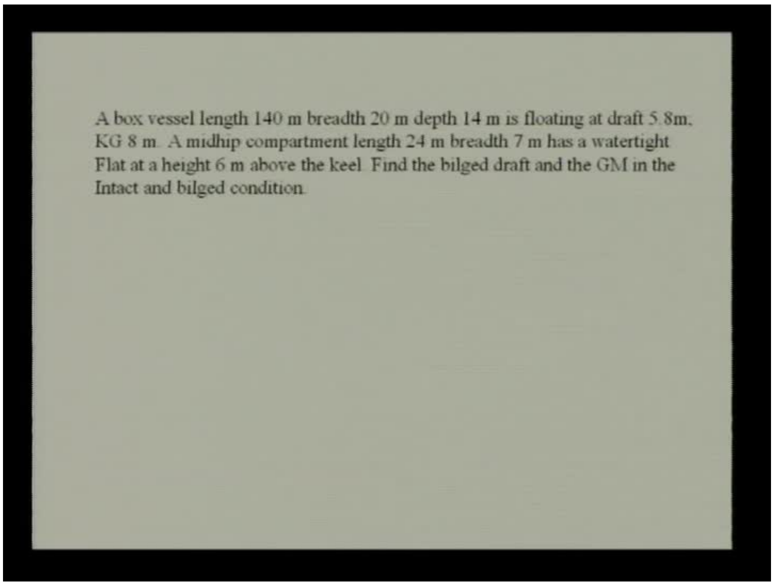

Now, let us look at this problem. A box vessel of length 140 meter, with breadth 20 meters, depth 14 meters is floating at a draft of 5.8 meters. You are given the KG as 8 meters. It is a mid-ship compartment of length 24 meter, breadth 7 meter, has a watertight flat at a height 6 meter above the keel.

Find the bilged draft and GM in the intact and bilged condition. I will explain what the problem is.

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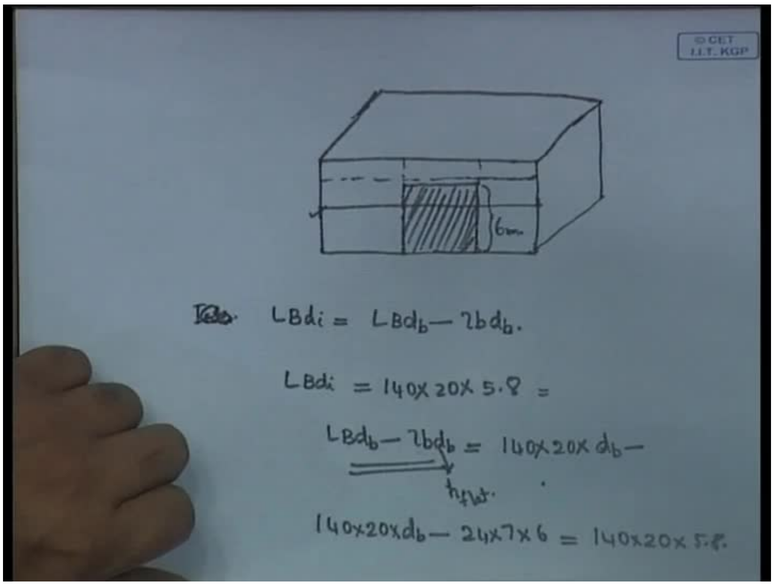

So, just like in the previous, you have a box shaped vessel and you are told that there is a compartment in the middle, this much and let us call this is the water line. So, there is what they mean by a flat is that there is some kind of sealing above. It is like this, so this compartment as such is covered here at some height. So, what this problem is trying to state is that usually we see that when a ship is bilged, it gets bilged completely means this whole region gets bilged whatever means up to the draft. Let us say the draft increases to this in this case.

Let us say, this is the final draft. You know that up to this, in all are problems the compartment gets bilged up to this point that is how we have done. In this problem, the difference is that they have put a flat here means there is some kind of a sealing here such that when this is bilged, it is a watertight flat that means water cannot go above this. So, even though the draft is up to this much in the compartment, water will be only in this region. Water will be only up to this and this region will be just like the other ship which is not at all bilged. That is our difference in this problem.

Just a slight twist, the difference will come into trying to calculate things like I and the height up to which it is bilged, things like that. That is only difference. So, there are two possibilities. As you can see in the first case, the draft is here means it is below the flat. In that case, the problem becomes just like what we have done so far means the problem is where you had some compartment bilged and that whole compartment buoyancy is lost, that volume is lost.

So, it becomes exactly like that but the second possibility in this problem is when your draft is above the flat. This one that become slightly different because bilging, then occurs only up to some point in between and some point in that compartment is still remaining. Therefore, it becomes slightly difficult to calculate the volume etcetera, so that is only thing in this problem. So, let us check that. First of all to solve this we use the formula.

This formula we have done if you remember LBd initial gives you the total intact volume before total intact volume means before bilging and so, this gives you the distance d, b gives this, gives you the formula which states that I told that the easiest way to think of it is the final volume. The final weight of the ship after the water is gone in is equal to the weight initial plus the weight of water. That is the easiest way to look at this formula.

So, in the book it states as you will see that it is the same thing. It says that intact volume before bilging is equal to the intact volume after bilging. You just see that it is the same then. Therefore, in this case LBd let us assume that.

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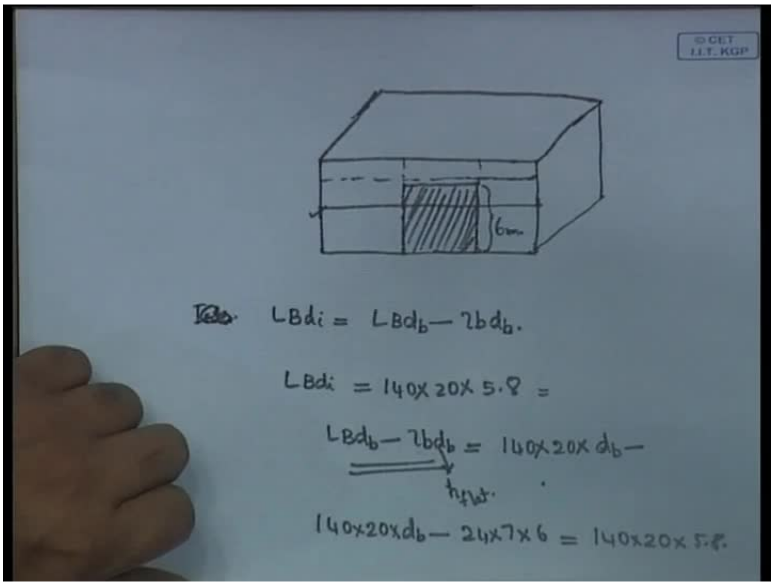

LBd i becomes we have to find the length. Let us look at the problem length is 140, so 140 into breadth is 20 into initial draft is given to be 5.8. So, this is your initial volume before bilging intact volume. Then the volume after bilging becomes LBd b minus lbd b which is equal to LBd, b is 140 into 20 into d b which you do not know minus l b. So, what is subtracted is a volume of the compartment that is bilged. So, you need to know the length of the compartment that is bilged and the breadth of the compartment that is bilged and the height to which it is bilged.

Now, this is the difference in this problem like usually this is the formula capital LBd b minus small lbd, b is the formula. Generally why because when it is bilged, usually in this problem the height up to which it is bilged means the height up to which the water enters a compartment is equal to the height of the water line up to the water line. We assume that the water enters its normal that is the way in which we have done but in this problem there is a slight difference. Water cannot enter up to the water line because at some point in between there is a water tight flat. They have said flat means just a sealing such that water cannot go above that.

So, whatever happens water enters only up to that point, so the height up to which the water enters or to get the volume of water its one length of the ship of that compartment b breadth up to which the compartment is filled up into the height up to which the water can fill up which is actually the height of the flat. It does not dip up to the total height of the water line because height of the water line comes up to this.

In this problem initially, it is at 5.8. Then when it sinks, it goes above 4. The height of the flat is said to be 6 meters. At 6 meters there is a water type flat, therefore this is not d b. In this problem that is the only difference. It becomes some h which is the height of the flat.

So, this is the height up to which the water can flood the compartment. Therefore, it will become 140 into 20 into d b minus 24 into 7 into 6 here. l is the length of the compartment which is flooded, 24 is the length of the compartment that is flooded, 7 is the breadth of the compartment that is flooded and 6 is the height of the flat. That is height up to which the compartment can get flooded. So, this is equal to the initial volume that formula. Please as I told you, it is very important.

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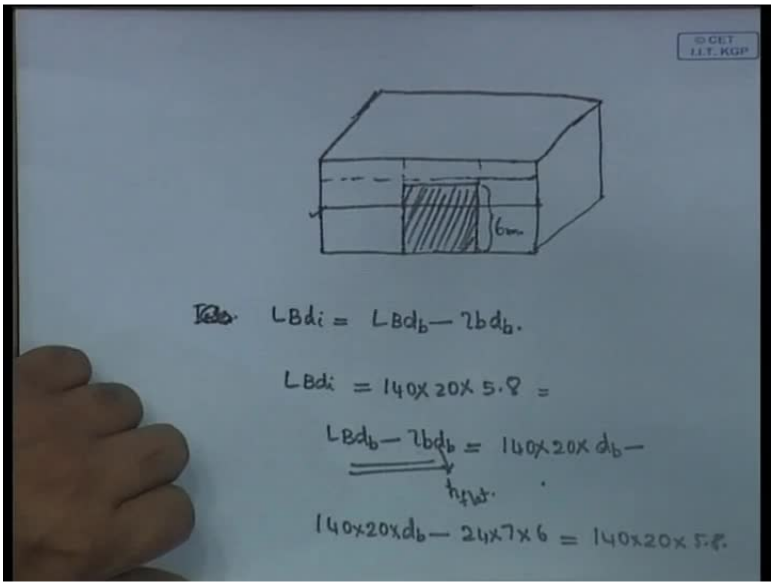

Yes, no you are assuming but that is just intuitive. See initial draft is 5.8 meters; the height of the flat is 6 meters. Now, when water enters I think it is reasonable to start with assumption that it will go above 6. If you do not assume, you will see that your answer will come above 6. Therefore, your answer is wrong but you can easily see 5.8 to 6 meter will definitely go above that, so that is why we have directly assumed that it does definitely go above that. Otherwise, yes you are right. Then but I think you might get end of getting d b as negative are something in that you will have to do that and see when you if you assume that its below you might get d b negative which means that is actually gone above the flat. That it would not match, it would not be able to solve it. So, this minus this becomes equal to the initial volume which is 140 into 20 into 5.8.

So, when you do this, you will get d b as equal to 6.16 meter. So, this much the height of the water line has gone above the height of a flat. Therefore, that is the slight catch in this problem. So, you see that this is the height up to which the ship sinks d, b is the final draft the bilged draft it is called.

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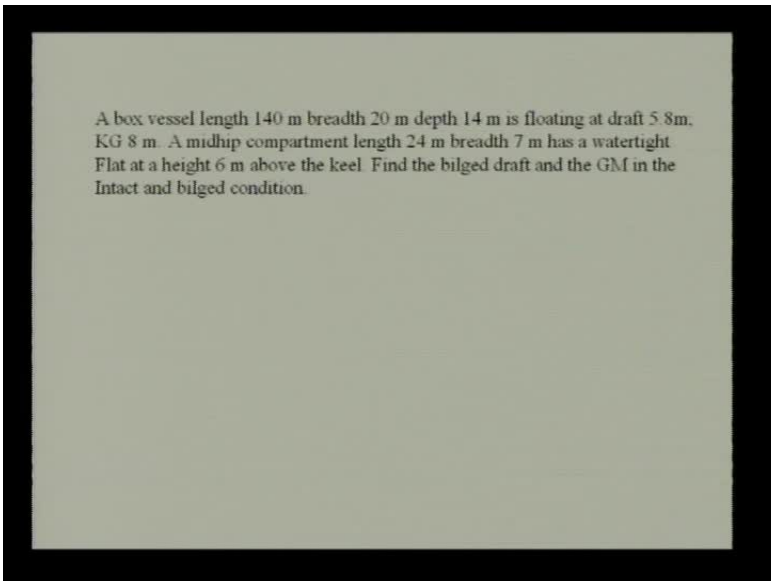

Now, the other thing you are going to calculate is to you are asked to find the bilged draft and you are asked to find the GM. Therefore, to find GM, you need to find KG and KM.

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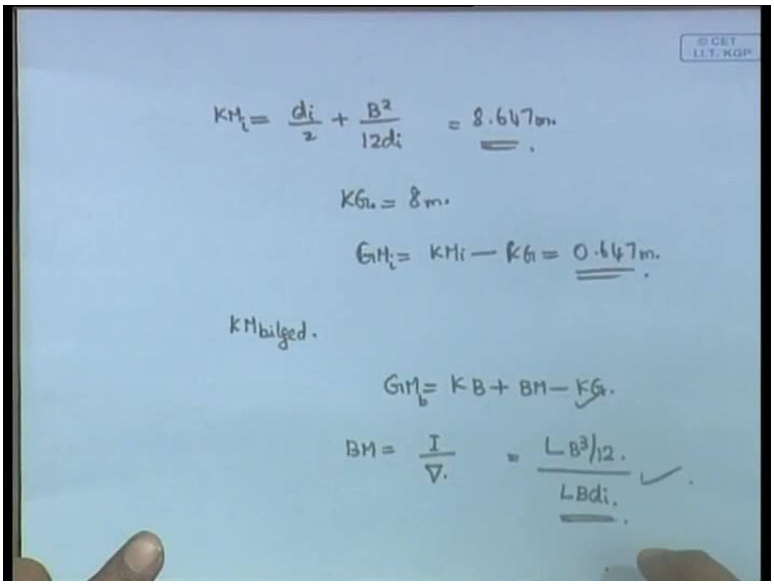

Now, KM remember this is a box shape vessel we are talking about intact condition. First, it will be very straight forward formula. You have the box shape vessel; you have the KM given by this formula. You do this; you will get it to be. So, this becomes the KM of the vessel, then KG is given in the problem itself. KG is given to be 8 meters. Therefore, GM of the vessel in the intact condition is KM in the intact condition minus KG in the intact condition. KG does not change. In this case it becomes 0.647. So, this is your GM in the intact condition, then you need to find the KM in the bilged condition.

Now, we can use the formula GM is equal to KM. This is in the bilged condition, KB plus BM minus KG. Note that we are doing everything using buoyancy. So, KG does not change. KG is still 8 meters, so this we know. So, you need to find BM and you need to find the KB.

Now, BM can be found as I by del. Note that in this case, lb the water plane rather the water plane area does not include. It is just like an ordinary ship means it does not have a lost volume or anything. Therefore, it is just an ordinary ship. So, it becomes LB cubed by 12 divided by del will be LBdi. This because it is a method of loss buoyancy, the volume is the same as before. So, this is BM. This you can directly calculate very straight forward, so this will give you your BM.

Now, the next thing to calculate is your KB that is the slight problem in this KB is the centroid of the volume. Now, what are we doing? We are using the method of loss buoyancy which is saying that it is the method of lost volume. Some volume is lost from the ship and so, you know the initial volume its Kb you know the lost volume I will tell you what it is there is the how much the volume of the ship is loss because of water has entered rather it is the volume of water enter and you need to find its Kband using a resultant of these two you can find the net Kb like this

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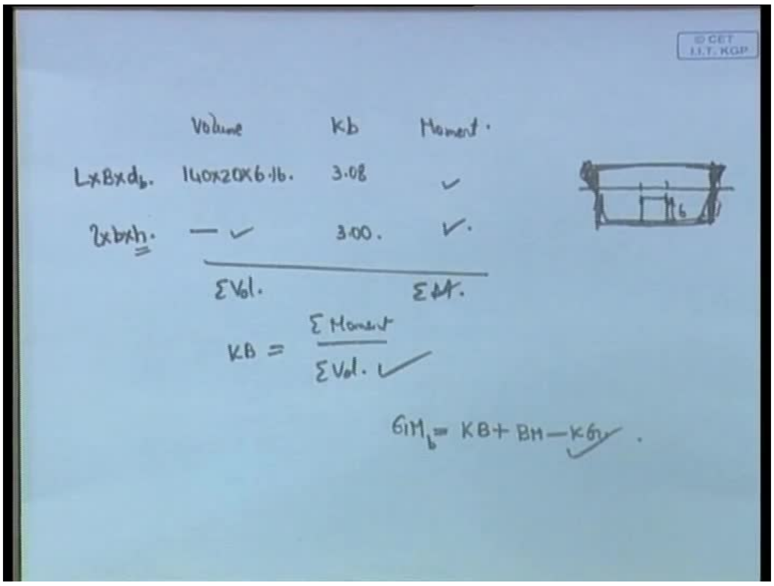

That is the first one is to find the volume of the ship. Therefore, volume KB and moment if you write like this L into B into d b, so it will be 1. What is L? L is140 into 20 into db. We have calculated d b 6.16, so this gives you the initial volume of the ship or that is the ship is like this. Now, this is the water line and this is the compartment and this is the flat. Therefore, this much volume is lost from the ship. Now, what we are doing right now is the easiest way to do is you find the KB of this. How do you find the Kb of this? It is a box shape vessel, so you note the KB. You need to find db, db is given as 6.16. So, its Kb is 3.08, it is not a ship as such. It is a box shape vessel in this case.

So, in this case it is a box shape vessel, so it is a Kb. Therefore, you just multiply these two. You will find the moment, then you have this volume. This volume is a volume of water entered; it is equal to the volume loss from the ship.

So, this which is l into b into h, h is height of the flat. So, that you do and the best way is put it as negative because this volume is loss from the ship. So, this becomes negative. In this case, whatever it becomes and the height of the flat, this height we have just seen. It is 6 meters, so its Kb is 3 meters. Then you find its moment and you do sigma moment means this is sigma moment, this is sigma volume. So, sigma moment divided by sigma volume will give you the total net moment. This will give you the net KB. This is the total KB of the box shape vessel after the water has entered up to the flat.

So, once you have that you get the KB. So, KB I have already told you, how to get BM and KG is already given. Therefore, GM of the vessel finally in the bilged condition becomes KB plus BM minus KG. So, this is the final KB. This KB BM KG, the thing is you cannot we had a formula KM minus KG equal to GM. You have a problem calculating the KM for such a bilged condition because this is not an ordinary kind of ship.

First of all it is not an ordinary box, a vessel that is what I mean it is a box, a vessel in which you have loss some volume and it is not even lost up to the water line. So, that direct formula of KM is equal to d by 2 plus b square by 12 d cannot be used here. That is why this formula always holds good that is GM is equal to KB plus BM minus KG. It is true always, so whatever be the shape of the vessel or whatever be the condition, you can always use this formula GM equal to this.

Now and note that in as for as this course is concerned, you are always going to do problems wise. I mean theory wise you need to know the method of added weight as well in which that we have done. So, need to know the method of added weight as well but as far as problems are concerned when you are doing the problems, you do it using only the method of loss buoyancy. That is what I have done. All the problems I have done so far is using the method of loss buoyancy. So, the things that you need to remember. Again, I am stressing one is that that volume which is filled with water is loss from the ship.

So, that volume is not a part of the ship anymore. So, as a result of which as a result of losing that volume, the net KB of the vessel will change the KB because the volume is loss from the ship will change but KG does not change means whatever is there in the ship, the part of the ship as which is there is still there weight we are not changing. As far as method of loss buoyancy is concerned, the weight is not at all changed. Therefore, the total weight remains the same that is del delta remains the same. The total weight of the ship KG also does not change.

So, otherwise it is very difficult. You would not be able to do these problems because you will be searching for KG i and KG b means you have gone. You would not able to solve it.

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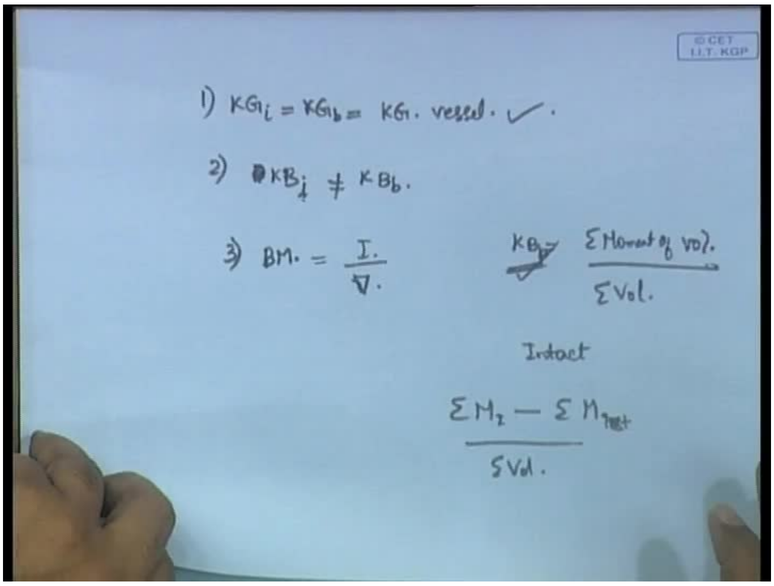

So, do one thing. Some simple things I will tell you, so KG in the intact condition or KG in the initial condition is equal to the KG in the bilged condition is equal to some fixed KG which is the fixed KG of the vessel. So, do not get confused at all. Never change the KG, do not search for KG. It will always be given in the problem. Also, KG will be given then KB will change KB initially and I think all your problems will be box shape vessel only because KB for other vessel becomes little more complicated.

KB initially you will have something KB. It would not be equal to your KB in the bilged condition because some volume is lost directly. It assumes the KB is changed because KB is the centroid of the volume. So, if KB volume is loss, KB is loss, so KB is decreased or it is changed. So, KBi is not equal to KBb. You have to find the KB. The best way if you want to find the volume, always use this way that is KB is always equal to a sigma moment, moment of volume divided by sigma volume.

So, if you have some volume, you take the intact ship, so sigma moment for the intact ship minus sigma moment for the lost volume divided by sigma volume. This will give you the KB for the bilged condition which is your distance of the center of buoyancy from the keel that will give you KB and that will be different in your bilged and in your intact condition because under water volumes are different.

So, KB will be different. Then your BM also will be different because the position of b is changing, so BM will also change. Only thing that one changes your G position of center of gravity does not change but BM changes because b changes. So, BM you will have to calculate it as I by del. So, this will change, so this you have to calculate.

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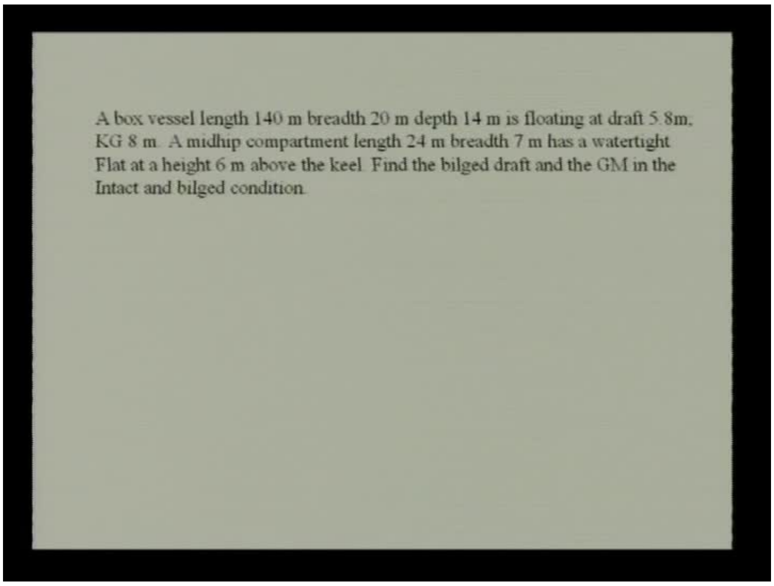

Then these are things you need to remember in doing these problems.

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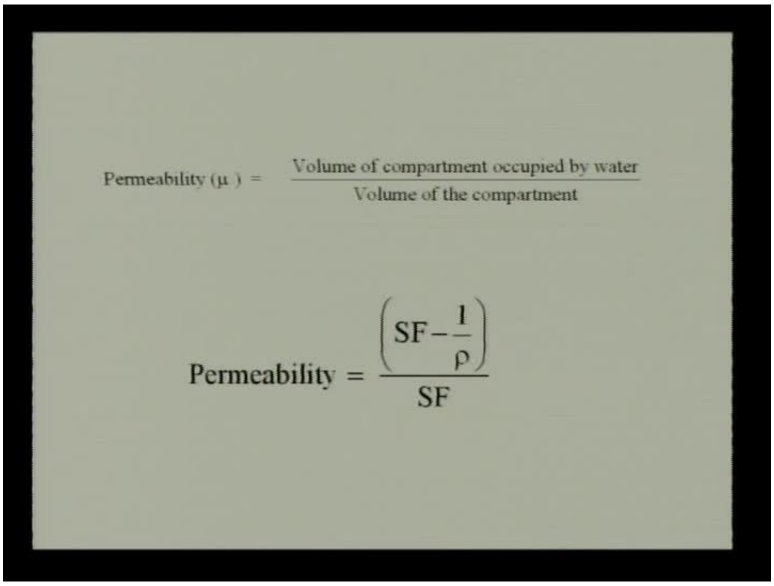

Now, I have already defined you something known as permeability. I said that it is the volume of the compartment that can be flooded with water divided by as you can see there. It is a volume of compartment that can be occupied by water divided by the total volume of the compartment. Now, note that it is because of this. First of all, there will be volume of the compartment given by l bd means length, breadth and draft or depth whatever is that size of the compartment.

So, we talk about one compartment. Now, so there is a volume. First of all given by length into breadth into the height of the compartment that is one volume, then there will be different kinds of solid stuff in it means like anything. Whatever you have solid other than such that the total volume decreases from your l b into d to something else decreased to a smaller value because for instance some very big some shape something is there. So, different kinds of things will reduce the volume further from l b into height of the compartment. It will decrease to something else and then again further if there is cargo in the compartment, if you put cargo in the compartment, the total amount of volume that can be filled with water decreases further.

Now, what we really call as permeability here is first in the numerator you have the volume that can be filled with water means cargo is there and then what the volume that can be filled with water is. The denominator is without the cargo. It is still is not equal to l b into height there still might be very solid constructions which will reduce it from l b into height but it is a volume with cargo divided by the volume divided by without cargo. So, that gives you the permeability and usually, you will see that the permeability is around 95 percent 0.95 rough value of permeability. So, this is what you define as permeability is equal to about 0.95 roughly for ships. This is the value.

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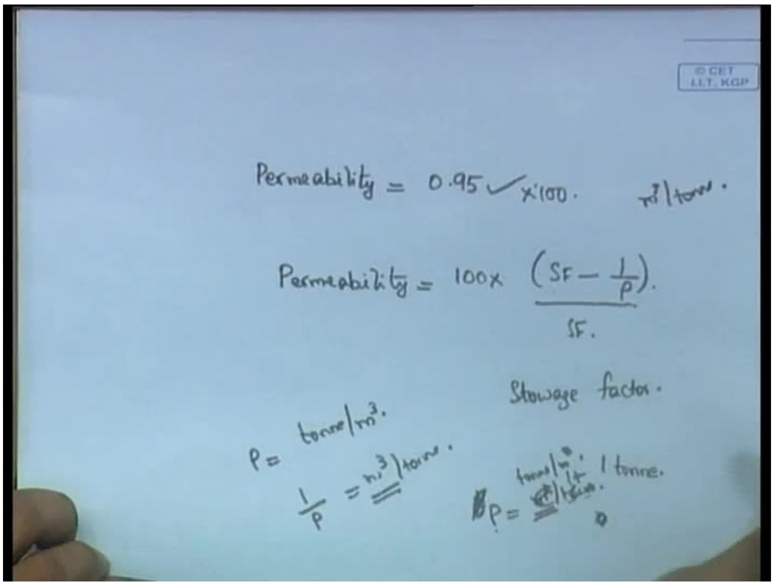

Now, permeability can be defined as to do it mathematically. It is usually expressed in percentage, so it becomes 95 percentages. So, 100 into now this is how this SF is what is known as a stowage factor. The meaning of stowage factor is this. It is the volume with these things different construction in the room means you have a room. Let suppose there is a small very thick pillar here that will reduce a volume, in fact so that much pillars volume is lost.

So, that is one construction possible. Something else here like that different columns here, different things will reduce the volume. So, that volume is roughly what you call as stowage factor. It is the amount of cargo, really that you can put. Then 1 by rho, so this is SF. This represents the volume of the compartment and minus 1 rho. Rho is the density of cargo that is put and therefore, 1 by rho means you assume that 1 ton of cargo is taken the whole that is how stowage factor also defined. So, if you have 1 ton of cargo, the volume now you always express rho in terms of meter cube per ton.

In hydrostatically, not meter cube per kilo kilogram, you write it as meter cube per ton. So, whatever is the density of cargo and if we assume 1 ton that will give you the volume means this is 1 ton, you will obviously get 1 by rho to be the volume. No, rho is tons per meter cube. Sorry, I made a mistake not in meter cube per rho is always given in tons per meter cube instead of kilogram per meter cube. Therefore, if 1 by rho as you can see will give you in meter cube per ton and if you take 1 ton of cargo, this obviously gives you the total volume occupied by that and stowage factor is also given in terms of meter cube per ton.

Therefore, the whole thing is defined in terms of per ton. So, you can assume, so this is a meter cube minus meter cube divided meter cube that gives you the permeability. The total volume that can be occupied by water that is roughly the meaning of permeability, how much volume can be occupied by water this is written as mu that is the permeability. Then this is permeability SF minus 1 by rho by SF.

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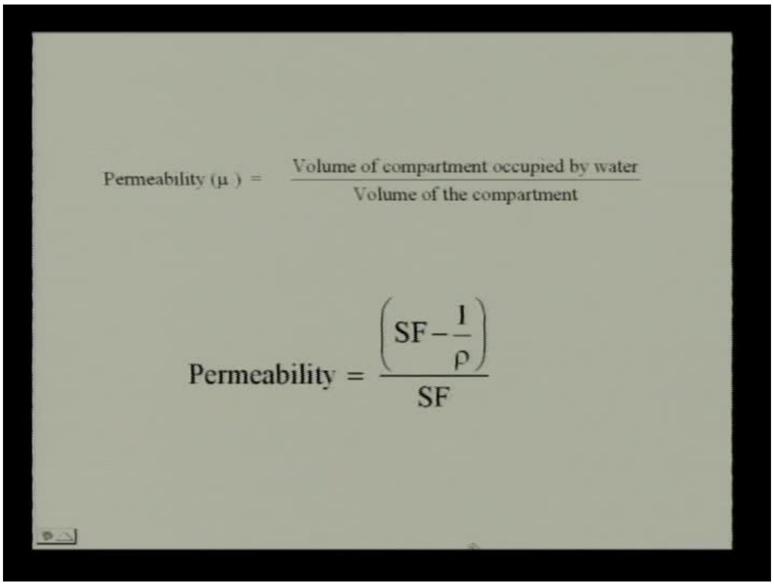

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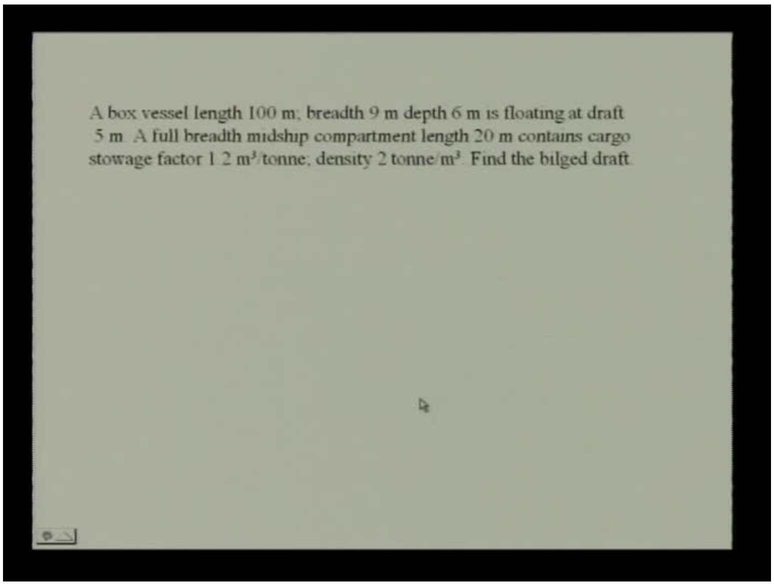

Then that is this problem. It says that now there is the box vessel of length 100 meters, breadth 9 meters, depth 6 meters floating at a draft of 5 meters.

Now, a full breadth mid-ship compartment of length 20 meters contains cargo at a stowage factor of 1.2 meter cube per ton. It has a density of 2 tons per meter cube and you ask to find the bilged draft. This is the problem. Now, first of all in this problem directly you can find the permeability.

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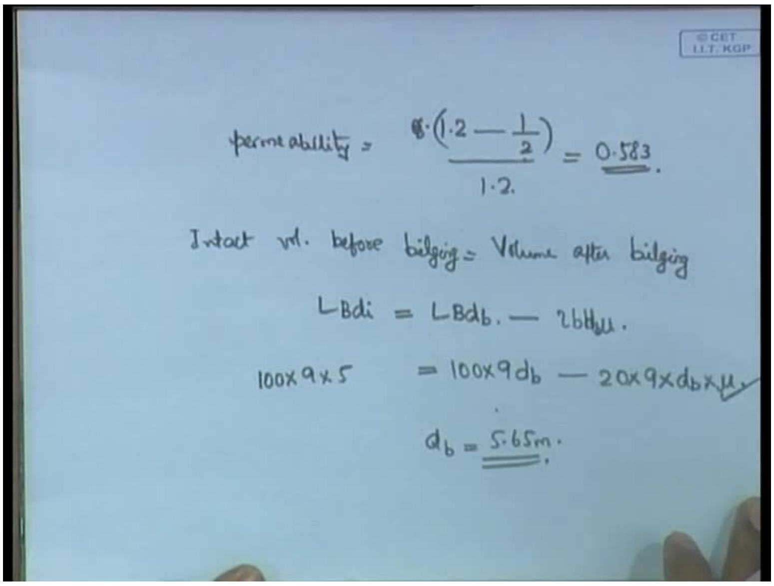

So, permeability is in this case given by stowage factor is given to be 1.2 meter cube per ton. Density is 1 by density is given to be 2 tons per meter cube 1.2 minus 1 by 2 divided by SF which is again 1.2. So, this is about 0.583, this is your permeability.

Now, what you need to know here is remember that equation I wrote. In that equation which said that intact volume before bilging is equal to intact volume after bilging. It was like saying that the volume or it was like saying that the initial weight of the ship or the final weight of the ship minus the added weight is equal to the initial weight of the ship. That is that equation.

So, it is like this. Now, what I am trying to say is that when you take that intact volume before bilging is equal to the volume after bilging or the volume before bilging is LBd i. This is the underwater volume before bilging equals LBd b. This gives you the volume after bilging.

Now, you need to subtract the volume of the water. Now, what is to be used to do? We usually use to find the volume of the compartment. Now, what you are saying is that is not enough to find the volume of the compartment. You have to multiply with permeability because only that much will be flooded with water. So, this is actually, this derivation came from getting the weight of water.

So, to get the weight or mass of water, to get the weight of the water that mu has to be multiplied because only so much of the volume will be flooded. So, that is needed in this case if it is lbh. You have to multiply that mu. The whole volume of the compartment is not flooded with water only, the volume of the compartment into mu that much of volume is only flooded with water. So, that is only difference. So, you are told that the length of the vessel is 100, 9 is the breadth, 5 is the draft initially.

So, 100 into 9 and you do not know what is your db minus. You are told that is 20 meter length, 9 breadth is flooded into d b. So, the problem there is nothing different except that in this equation which said that the volume of the water which is entering. Initially, for us the volume of the water that entered was L into B into d b LBd b. Now, we just changed that slightly, LBd b into mu that is the volume of water that has flooded.

So, in this problem that is only difference you multiplied with the mu here. So, once you do that, you will get your d band. In case you are asked to find KM, you do d i by 2 plus b square by 12 d and that is all. That will give you your KM and that is one part of it.

Now, we will derive a particular kind of a problem. Particular kind of that is we are going to now do. You have a ship. Now, what this section deals with is so you have the ship of length here and in this middle, suppose that there is a small region on. Let us say that this is the center line. Let us suppose that some distance from the center line somewhere towards the edge of the ship, small region there gets flooded in the mid-ship part of the whole length. Mid-ship means middle of the length, not the middle of the breadth. Not this view from this view. In this point somewhere at the middle at some distance some region gets flooded.

Now, what will happen is that ship is like this. This is the whole length of the ship, this is the center line and this region is flooded. Now, what we are going to do is if this region gets flooded like this, it will sink. First of all, one more thing is happen, it will heel like this. Now, we can find out by mathematics how much will be the angle of heel? What is the final list angle? What is the final heel angle? We can find, so that is the section.

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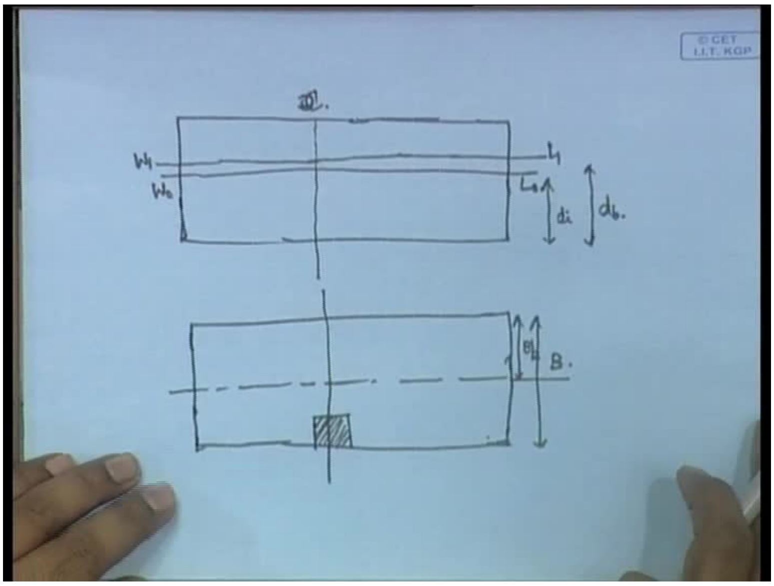

So, this is your initial water line, W0 L0. Let us call this di and now some region, this is the mid-ship, this is what we are calling as mid-ship. Now, at the mid-ship the sin says the mid-ship there is the meaning of that sin. We will look at the plane view. So, this is the plane view, this is the breadth of the ship B. So, this is equal to B by 2. This is also B by 2. Now, the problem is defined like this. This is the center is like, now some region here a small compartment here gets flooded, this region. So, this compartment region gets flooded. So, what happens is the ship will first of all sink and its waterline is now here, W 1 L 1 and let us say that the water line has gone up to db. This is your final draft bilged draft.

Now, what we have that is the first thing that happens is that it sinks and this cond part of the problem is that start heeling. Now, because it is only on one side the compartment is not on the center line. If it is at the center line, there is no heeling but it is now at a one corner, as a result of which the ship heels.

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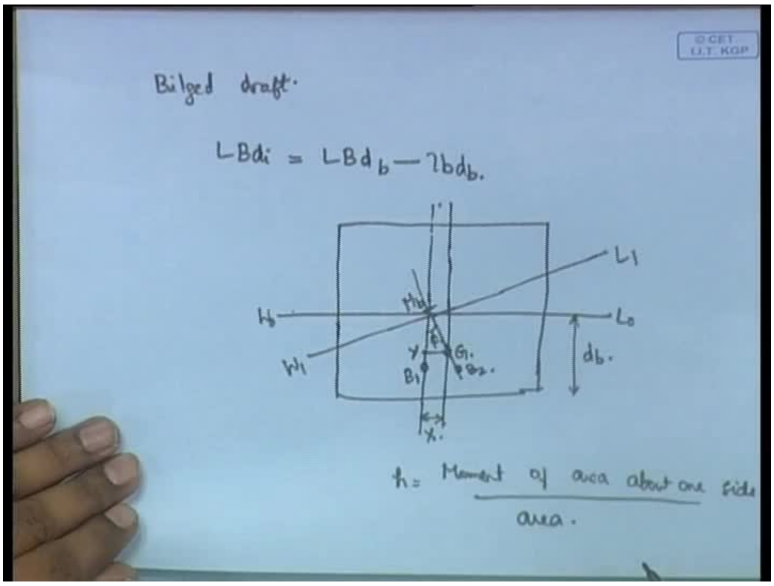

So, we need to find the angle of heel. So, first we need to find the bilged draft, so the bilged draft is given by the formula weight balance. We can do this is the initial weight of the ship is equal to the final weight which is equal which is LBd b minus lbd b. This will give you the bilged draft. This directly you can calculate.

Now, the next one let us look at the ship from this point of view from front view. What we usually do when we find the metacenter and all that?

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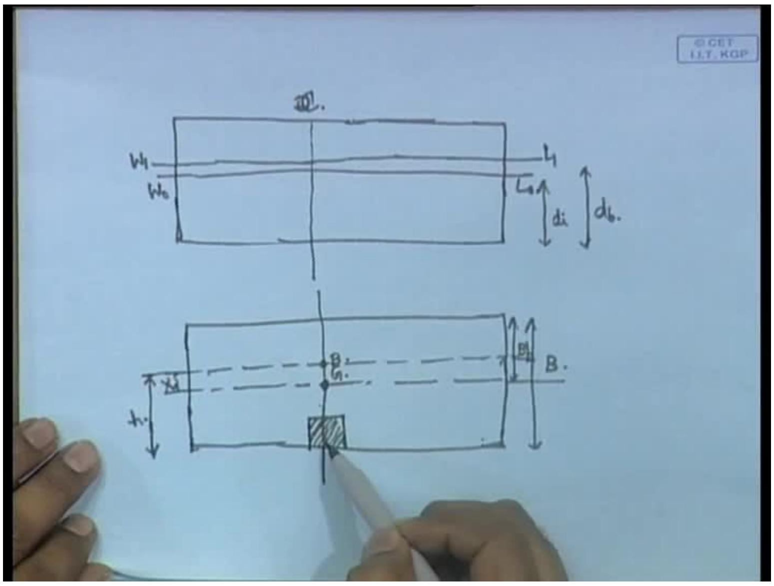

So, this is your waterline and this is after bilging. So, this is water line and now this becomes a problem. See that is this region, is this is again we are doing this problem, is all very small. We are doing for box shape vessels such that your Gb everything is very simple. You can directly calculate it from rectangle square, all those kinds of volume, so the G of these vessels.

Since, it is a perfect rectangle; it will be a center here. G will be here but the problem is, now this region gets bilged, G will not change. I have already said that G does not change in any of these problems. In bilging, we do not change G at all but your B is changing. So, this much volume is lost. Therefore, your B will initially when the vessel was upright and it was having no bilging, nothing. It was upright vessel G and B where in the middle from when you look at in this top view G and B where exactly in the middle because there is no volume. Here is equal to volume, there that concept we have assume that the volume is in a middle but the moment this part gets bilged, some volume is lost. Here B moves, here B somewhere, here B is shifted. Now, this we draw it here, so let us assume that this is your G.

So, this is your position of G. Now, as you saw in that figure B was not at that point B was somewhere slightly away. So, this is your B1. We will call it B1. This is the center of buoyancy after the ship will bilged but before it has heeled the ship, has not heeled. Now, it has just sunk and it is bilged but it is not heeled and that is third condition and now, it heels. So, this is your G and this distance let us call this position as Y. This distance is Y; it is the distance between G and B which is your center of gravity and center of buoyancy.

Now, what happens? Why is that ship trying to heel? First of all, so the ship is trying to heel because G and B are now not in a same vertical line. When G and B are not in the same vertical line, there is moment acting and the ship will heel to such an extent such that finally G and B will come in the same vertical line. Then the moment becomes 0 and the ship is more or less stable in that condition. That is why the ship is trying to heel.

Now, ship heels W0 L0. It heels to W1 L1 such that B1 moves to a point B2 center of buoyancy is now B2 and this somewhere here is your metacenter Mb. Everything same as in the previous sections where we are dealing with the metacenter, the sealing part.

So, I would not go into that same thing that is vertical drawn from B which crosses through G crosses the initial vertical at the metacenter. That is what this is, so this is head at the metacenter. So, that is a M b and the ship is heeled through an angle let us say phi. So, this is d b that means it is the draft after the ship as bilged, then this distance this is not y. It is in this book, it is written as X. So, this distance is X, the distance between G and Y is X.

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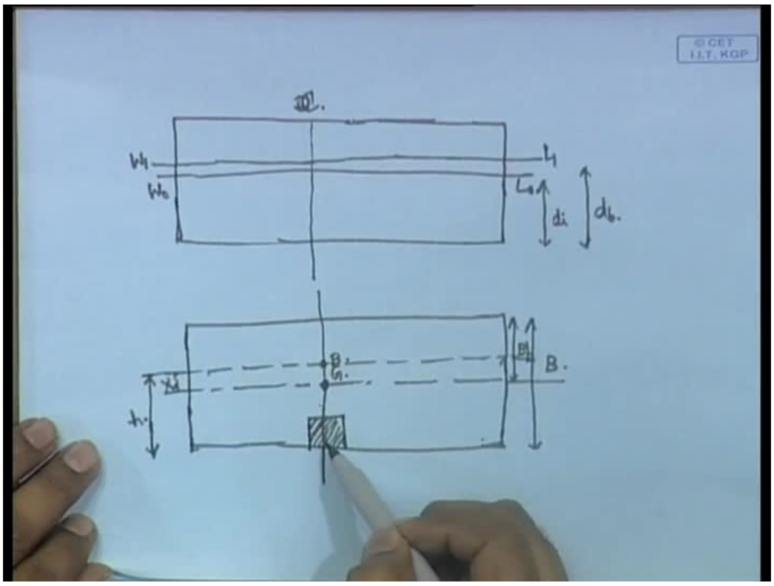

Then this distance is now what is h. H is the center of buoyancy of the bilged volume, h is the distance of the center of buoyancy from one edge from this edge. Let us take this edge fixed everything. Let us calculate from this edge distance, so from this edge, this distance B you need to calculate or the distance of the center of buoyancy from this edge needs to be calculated that is given by h.

Now, how do we find the centroid of center of buoyancy? Centroid of center of buoyancy is always calculated as sigma moment of volume divided by this sigma volume. So, sigma moment of volume now in this case, since is the box shape vessel we can just calculate area. You do not need to calculate volume. Everything is the same draft, everything is a d b.

So, what you need to calculate is this total volume. Instead of taking the volume, we take the area because draft is the same in all cases. It is just constant, so sigma moment of area divided by sigma area that means this whole area moment minus moment of this area divided by the total area. It will give you the net centroid of this area. That will give you the net position of this B from this end. So, this edge will be given by the moment of area to find the below straight area which is below the water line.

What has happened that is correct but what I am doing is there is a box. Now, what I need to find is the position of B, not the height. I am not trying to find KB here; I am trying to find position of B. So, I need to find this distance. Now, you have a whole box up to some draft, some volume inside. Now, in this edge some volume is lost that is a condition. Now, how do you find the position of B? You find the moment about the whole box minus the moment of this box that is lost volume divided by the net volume that will give you the position of B volume under water not total.

So, that we never talk total volume. Whatever is a volume under water intoposition of B minus the volume that is lost here, position of its B divided by the total volume that will give you the position of B that is what we are doing. Now, everything is this area divided by this height and anyway, we are trying to find this coordinate of the center of buoyancy. So, what we are done is we are taking only that water plane areas moments instant of multiplying with the height also.

So, that will give you the position of this position of the center of buoyancy, not this. This we are not needed this anyway. I do not think there is anything to do because even if this volume is lost fired, this height will still be with its d b by 2 because you have a box. Even if you remove one section from here, vertical position will still be at db by 2 that is not going to see. It is only the horizontal position that will change because some section is lost here. So, to find that horizontal section, you need to take the horizontal moment means moments like this, you have to take not vertical moment.

So, we will take it from one side right. Now, so moment of area about one side divided by the net area, you can take area at the water line. So, this will give you if you just look at this figure, it will become very clear what area we have to take.

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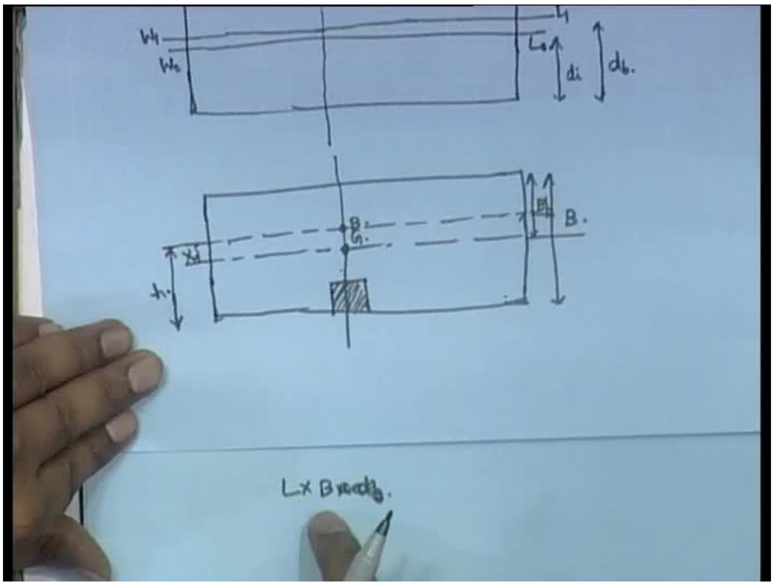

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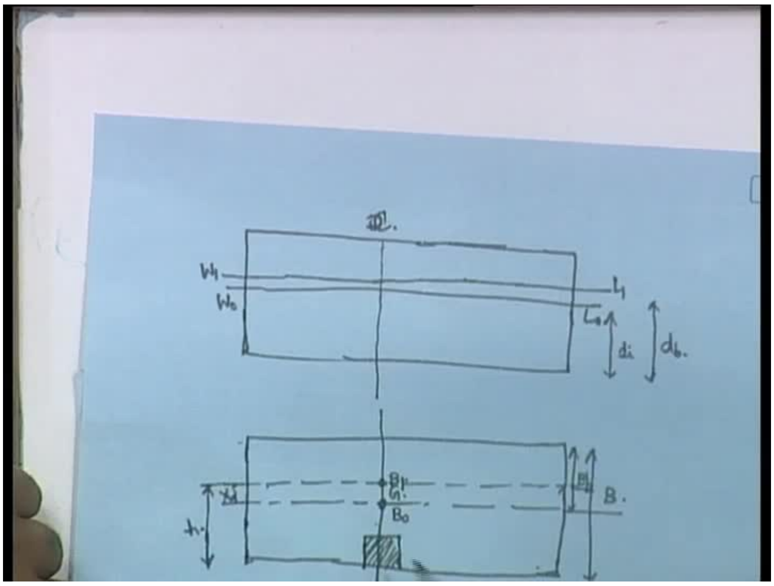

For instance, it will be LL is this length into B into d b. This gives you here not db. We are trying to find the moment of area L into B is the area into what do we need. We need the centroid of its, we are finding the x coordinate or this coordinate, this distance this is x. Let us call this x or y. Usually, it is y, so we are trying to find the y coordinate of the position of B.

So, we multiply the whole area which is L into B into its center of buoyancy. What is it? It is B by 2 for the whole, it is B by 2. When it is lost, it when this section is lost from it, it goes here. Let us I would not call this B. Then I will call this B1. Initially, B is here, only B0 is exactly at the center because it is just a box. B will be exactly at center for the area B1.

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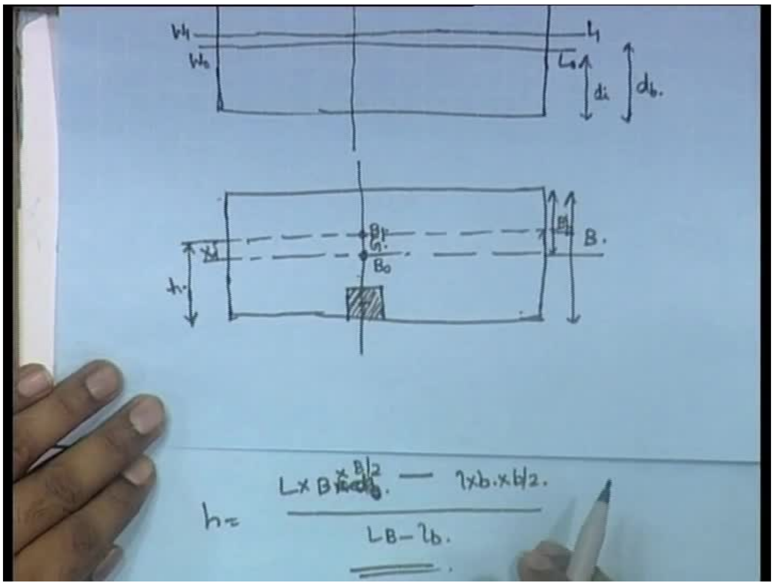

Therefore, L into B into B by 2 minus this small volumes or the small area into its centroid small area is l into b, whatever it is. This length into this breadth that gives you its area into its centroid, it will be small b by 2 divided by the total area. This will give you h this distance.

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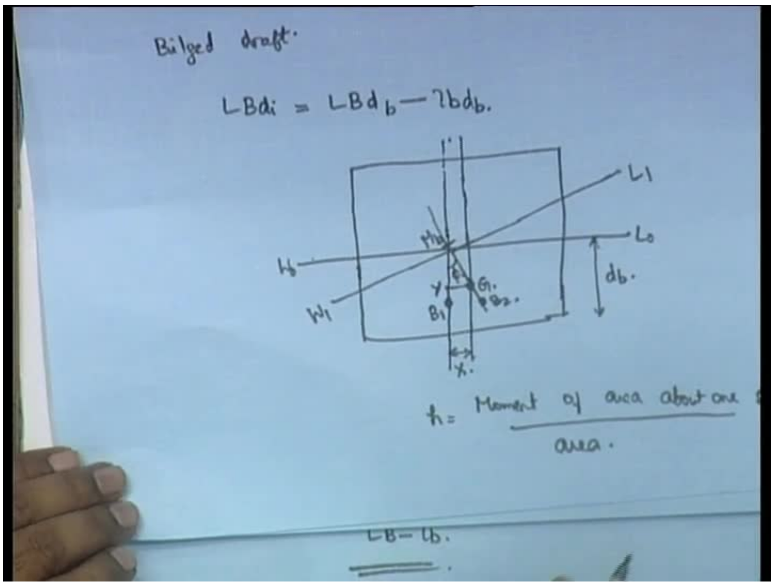

Now, what we need here is another thing. Actually, it is very simple. When you do, when you read the book and when you see the derivation, it become very simple. Actually, when you are listening itself probably it is becoming very clear.

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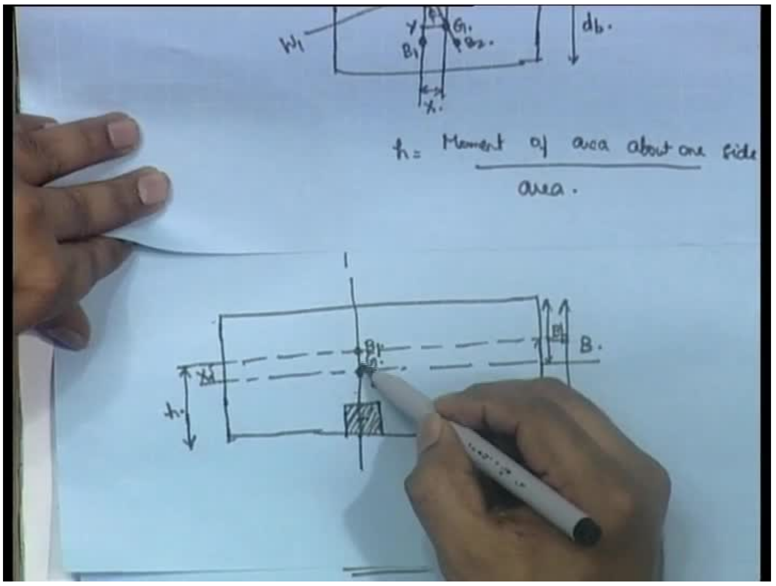

That is this distance sh is this distance and it is the distance between this edge in this figure. It will be here. See it is the distance between this edge and B1which is the center of buoyancy after bilged condition and this is your G. In this distance is GB1 or it is the horizontal distance between, note that G and B would not be on same vertical level. They might be different.

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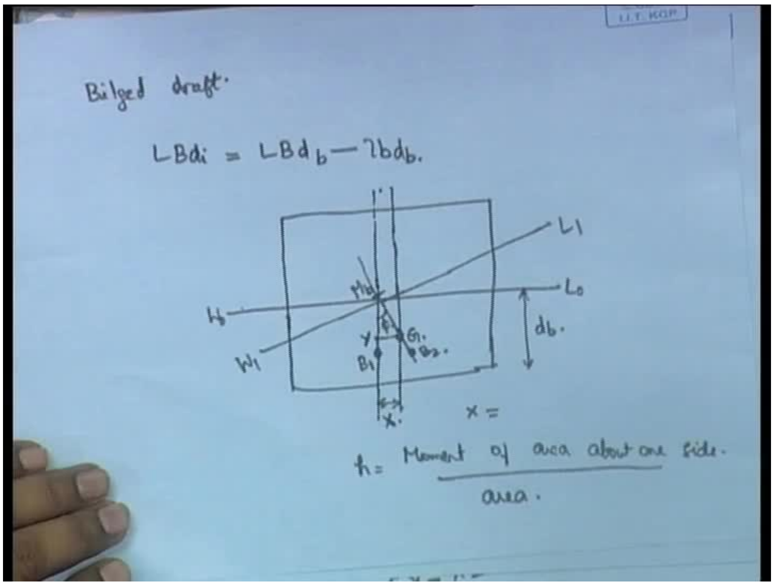

So, this horizontal distance between G and B is what we call as X. In this it will come like this, this distance is X, the horizontal distance between B and G is X. It is this. Therefore, this X as you can see from this figure is equal to h minus B by 2. This is h, this is B by 2, so h minus B by 2 will give you this distance.

Therefore, GY will be equal to X will be equal to h minus B by 2. This is your GY in this distance. G Y is now calculated using this formula.

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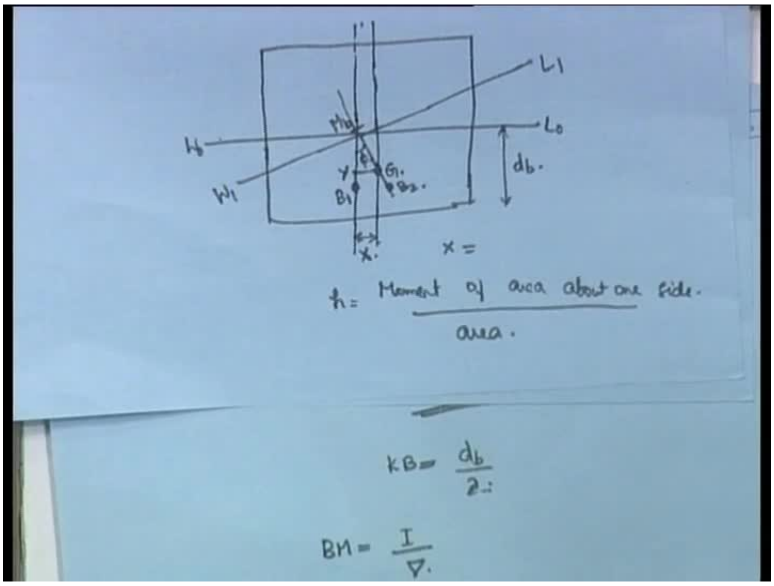

Now, what will be your KB? Then KB is always equal to db by 2. This does not change whatever happens. The bilged draft divided by 2 gives you the KB of the final. This is KB, then we need to find BM. BM is equal to I divided by del. Now, note that usually you always find I about till now this problem has not arisen. So, we have not dealt with it. You usually find the I of the ship about the central line. We have done it about the central line. It is actually that center line, we did not define it very clearly.

It is actually the centroid of the volume. The line through it is the volume, it is associated with the volume means this volume is equal to that volume. That is how it is considered as a centroid. That is why it is called a central line means the volume on left side or a port side is equal to the volume on the star board side and that line was center line. Now, that means it is actually the line through the center of buoyancy. In fact, that Y coordinate of the center of buoyancy is what is required.

Now, this problem it becomes slightly more complicated. In that you see that the volume on one side is not equal to the volume on the other side. Therefore, when you define really central line, it is centroid through B means it is that line that will pass vertically through B. So, it is not the exact center because one side some volume is lost. It goes slightly towards the other side.

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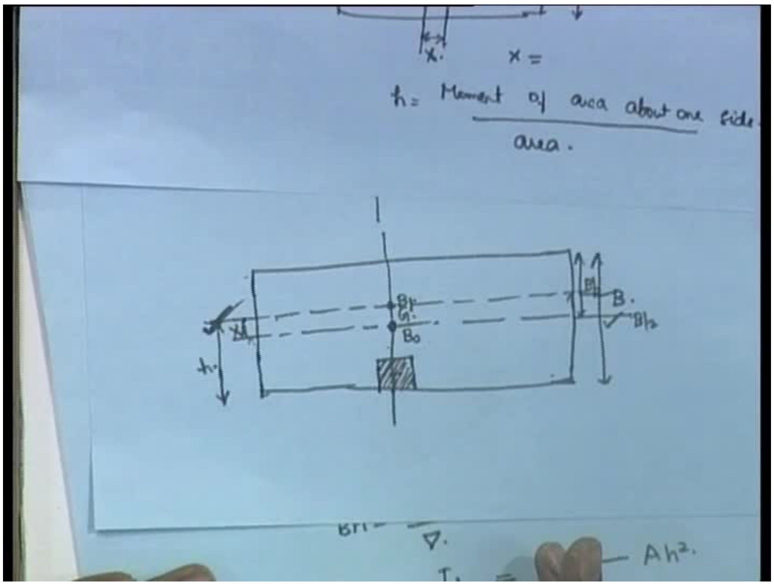

So, that is a point through which you have to take I, so in this case, this I always you are doing. So, in this problem, it becomes I about which point this line this is the line not about B by 2. This is B by 2, this was your central line ordinary case but in this problem, it needs to be redefined. You have to do this volume about this line. You have to take I about this line, the moment of inertia about this line h.

I has to be calculated about this edge now. This is probably the only problem. The way to calculate there are different ways to do this. You can do one thing. You can calculate I about this point B by 2 and minus A y square. You know that formula I about 1 point minus A y square where y is the distance between the two or if you take what they have done is you can do. I about this side, you can take the moment of inertia about this side minus A into h square h is the distance, this distance.

So, that will give you the moment of inertia about this point. It is moment of inertia about this minus A into this distance square.

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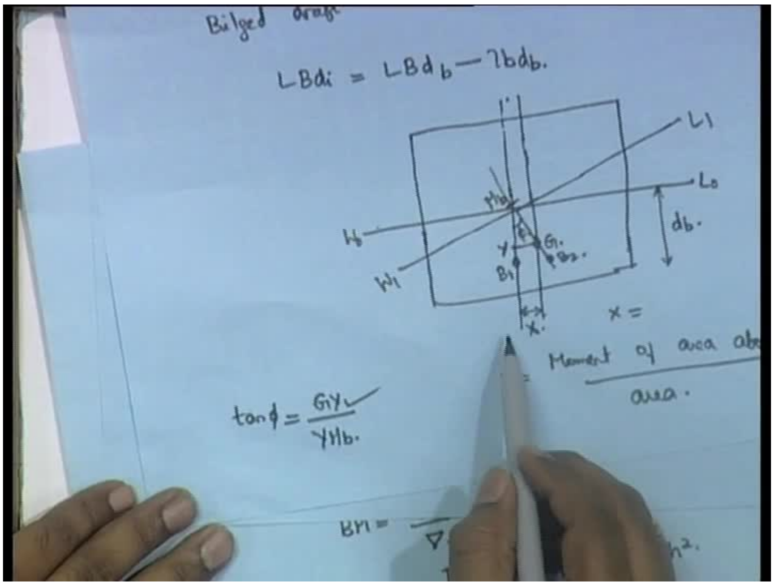

So, this is what needs to be done. This will give you your I about the point hand, then you get BM is equal to I by del and then if you look at this figure, you will see that. In this problem, our concern is to get tan phi. We have to find the list, the angle of heel.

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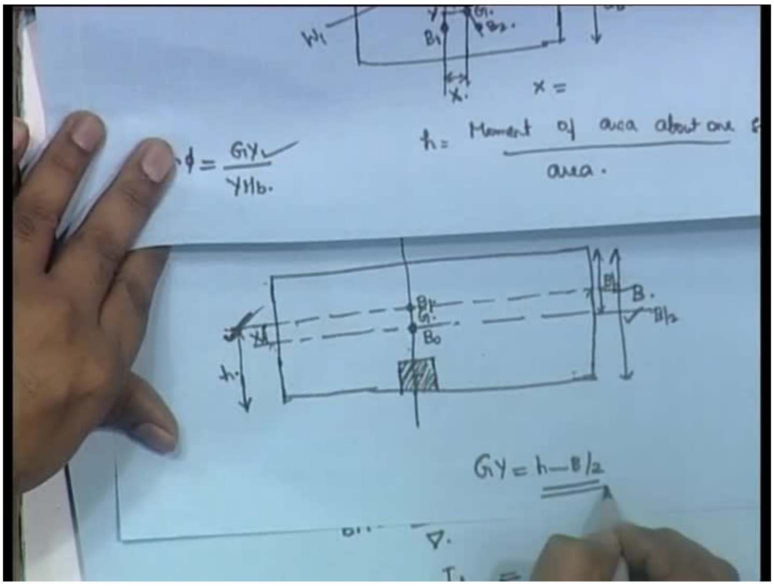

So, tan phi if you look at this problem, it will be equal to GY divided by YM b and now, GY we have already calculated using this right. Now, here GY as you have seen GY is equal in this case h minus B by 2. This was the formula for GY we just got.

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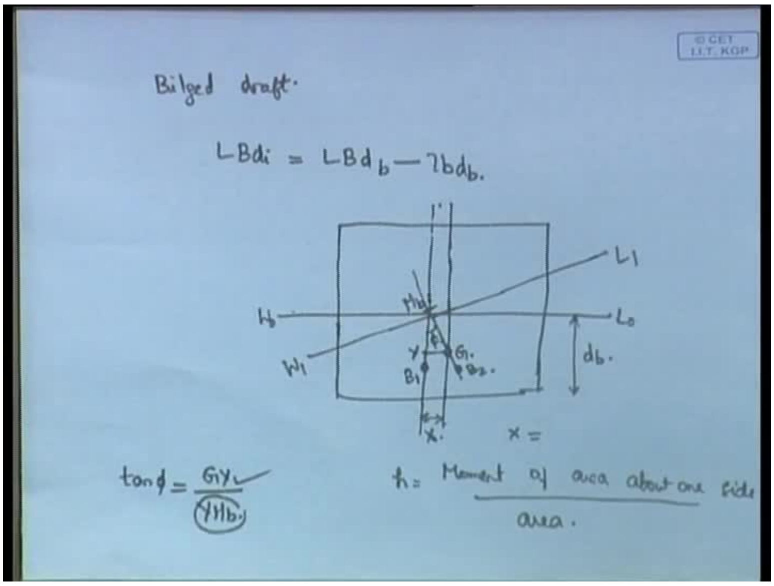

So, therefore tan phi is equal to GY by YM b. We will see how to calculate YM b in the next class. We will stop here.

Thank you.