Port and Harbour Structures
Module 4, Lecture 22
By Prof. R. Sundaravadivelu
Department of Ocean Engineering,
Indian Institute of Technology Madras
Estimation of Mooring, Berthing and Seismic Forces

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This class we will try to find out how to estimate the berthing, mooring force and about the Seismic force also. I have clubbed these three together because one of them will control the design either berthing or mooring or seismic. If it is a open type structure in Seismic zone less than 3 berthing will govern if it is a vertical face structure along with active act pressure and differential water pressure mooring force will govern. For Seismic zone 5 or 4 Seismic force will govern. Govern means this will govern the design. I will be asking this question so you please try to answer which load will govern the design that will be the question.

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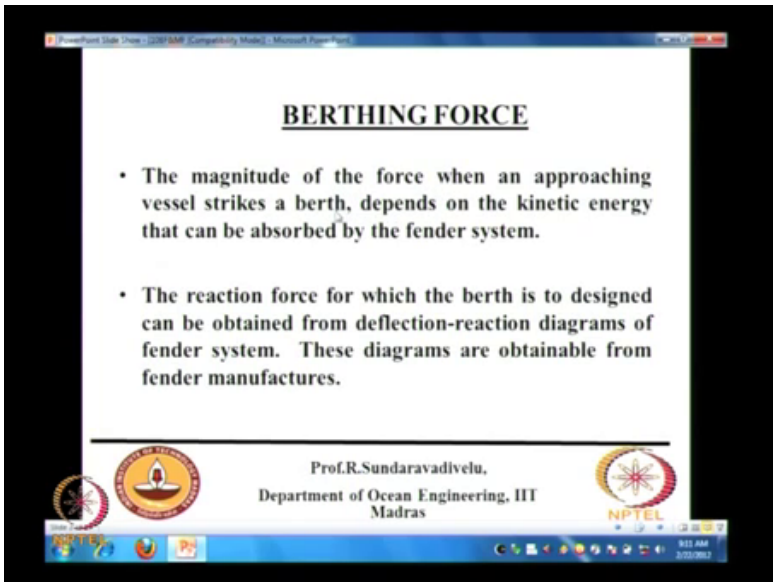

What is berthing force? Berthing force you have to calculate the magnitude of the force when an approaching vessel stress the berth. An approaching vessel takes the berth this depends on the kinetic energy that can be absorbed by the fender system. You know the formula for kinetic energy. What is the formula? ? Potential energy M P H, so we will be using the half m p square formula; m is the mass of the vessel; p is the speed of the vessel. One fellow (()) (02:18)where is he, he has not come today.

What is the speed of the vessel normally, ok what is the speed of the bus? 40, 25 you tell me the range, it is going on a highway from Chennai to 120, and then I want you to give the range of speed 60 to 80, 70 to 90 may be you to quote it between 40 and 100, most probable value is between 40 and 100. You are suppose to answer this question correctly. Yes there is some problemistic probability nature of data is there. So if you are going in a bus you try to find out what are the speed it is going.

Most probably if the road is good and is empty he may go to 100, 120 if he goes there is a problem. What is the speed of the aircraft? ? 750 units, kilo metre per hour any aeronautical student here. There are different types of aircrafts may be from 300 to I do not know 750 may be I was thinking 550 only kilo metre per hour. The speed of the Tsunami is also equal to the speed of the aircraft, ok. From Port Blair to Chennai it takes about one and half hours for the aircraft.

Same way the Tsunami also has taken one and half hours to travel. What is the speed of the train in India? Maximum speed 140 kilo meter per hour, ok. What is the internationally? 250 , 250, 300, 500 depending on various countries. Now you should answer this question. What is the speed of the ship? 20 to 30, units? 15 to 20 knots. First of all you should not tell in kilo meter per hour. 20 to 30 knots. How much is 1 knot 1.5, yeah 1 knot is equal to 1.8 kilo meter per hour.

What is the maximum speed of the high speed boat? 25 to 30, 50 knots 40 , it is about 40 knots high speed boat, normal 25 boat 15 knots, 15 to 20 knots 25 I do not think it is right, 15 knots it is approximately about 30 kilo meters per hour. What happens if the speed of the vessel increases? Resistance increases, resistance increases. What happens when resistance increases the fuel consumption is more.

so it is not desirable to go in a very high speed. Specially if you are conscious of fuel for a ship it is very much required. That is why they do not go. When the ship enters the berth the speed will be less they will stop the engine. They will stop the engine may be at 5 knots or 7 knots. But when the vessel comes inside it will be about 3 knots. It cannot be less than 3 knots because your control is very difficult.

How many of you have participated in slow cycle race? Participated, ok. Is it easy or difficult? Slow cycle what is difficult in slow cycle race? Balance, balance, control, control or balance? Because you are not able to control you are not having balance. Ship also same thing there is a radar which controls the direction the speed is less you cannot control that is why it should not be less. One knot is how many metre per second?

One knot is 1.8 kilo meter per hour both 0.5 meter per second 3 knot is 1.5 meter per second. This is when the vessel is travelling over the entrance channel. What should be the length of the entrance channel. I said about stopping distance. 7 times the length of the vessel, ok. There only this paid but the vessel is controlled by the tuck boats. It pushes the vessel to the berth that time the vessel is hitting. For that the speed is between 0.1 meter per second to 0.7 meter per second. 0.1 for a bigger vessel 0.75 for a smaller vessel.

If you come with a cycle you do not have to reduce the speed you can go and park. If you come with a two wheeler you have to slightly reduce and park. If you are coming with a park you have to naturally reduce the speed. If you are driving a lorry or a container you have to reduce at least 200 to 300 meter before. Then the cleaner has to come down he has to give the

direction then only you can park. Same thing only here, Fishing boats, Catamerons need not have to reduce they can go and park. Oil tankers two or three tuck boats has to come. Some one has to give direction then he has to come and park. It is why it should be at a very slow speed 0.1 meter per second. Kinetic energy is half m p square.

So (we) I have told it is 0.1 to 0.75 meter per second. If you are going for an interview in a port and harbour organisation they will ask this question, what will be the berthing velocity. If you tell in this range do not tell 5 meter per second and all. This mass there is an added mass you know displacement and age that has to be used to calculate the mass plus you have to add the added mass, velocity I set then there are certain coefficients that also you have to use to get the energy.

What we are talking is the energy from this you have to get the magnitude of the force. So if there is a force, force into displacement will give you the energy. So once you know the displacement of the fender you can get the energy. So equate the energy to the force absorbed ny the fender and you should know how much will be the displacement of the fender.

How many are Civil Engineers? Ok, what is the permissible displacement? There is a servisibility criteria, in a structure when you design there is a permissible displacement. How much is the permissible displacement? L by 350 the fender is designated by the size, typically the size varies from 0.5 meter to 2 meters, ok. The force is a compressive force or a buckling force. So how much it will get compress?

Suppose the thickness of the fender is 1 meter you have to get the deflection to get the energy. The thickness of the fender is 1 meter. How much it will get compressed? Guess! The span is 1 meter. How much it will get compressed? 1 by 350 no no it will be 1 by 2. If you are carrying some weight on top of your head there is compression on your it is very less, so in the fender your height will come down by 50 percent. That is what is happening in a fender, ok.

It is a buckling fender the deflection is equal to 50 percent of the characteristic dimension of the fender DB 2, it comes back. That is a quality of fender material, rubber material what we are using. Is it clear? Then only it will absorb more energy. The energy absorption is to be more. The force has to be more and the deflection has to be more if you want to minimize the force your deflection has to be increased. So that is a concept here and it has come back to the original position. There should not be any plastic deformation.

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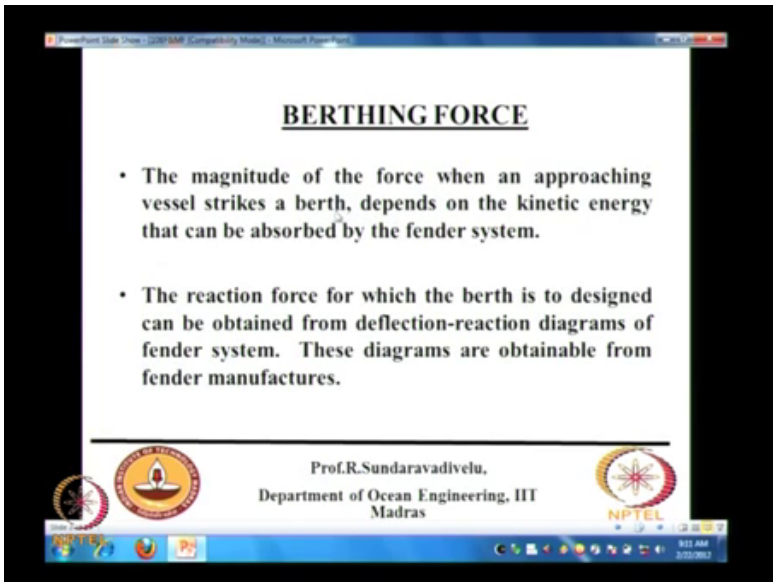

So this reaction force what I discussed this can be obtained from the deflection reaction diagrams of fender system. And these diagrams are obtainable from fender manufacturers.

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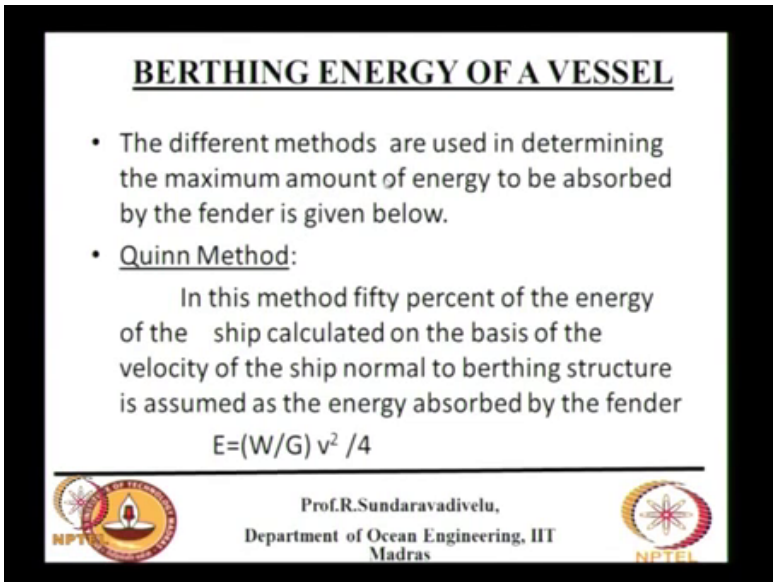

So this is the berthing energy of the vessel. So when you do your classical study on berthing energy you have to go through the various methods. This is M, m square by 2 is the kinetic energybut we take only 50 percent of the energy. This is by Quinn's method and there is a text book after Quinn also just go through that text book. The reason for it is when the ship is berthing there will be the first contact at that time 50 percent of the energy will be dissipated then the vessel will go back then again it will hit then the balance energy will be dissipated.

It is not the first contact in which the total energy will be dissipated. There will be number of contacts 5 or 6 contacts will be there after wards only the total energy will be dissipated. That is why they take 50 percent of the energy. Then there is a wood rough method, this is a empirical method you have to substitute w in tonn and you will get the energy in, I think there is some mistake here it should be w, where w is in tonns and e is in ton feet. So your energy will be in ton feet.

Because this coefficient depends on the unit what you are using. This is very important for you to learn. When you go to an equation like this we have not given any unit. So you can use consistent units. G is acceleration due to gravity instead put small g w is the displacement tonnage of the vessel or sorry this is displacement tonnage plus sorted mass. So here you can put whatever unit you want and then you can get the consistent unit energy. Whereas here it is not like that.

Because this is a analytical formula there are no coefficients in this half ME square you are taking 50percent of that, that is why that is ME square by 4 so you can use any unit. If you use kilo newton and meter per second square you will get the energy in kilo newton meter. You can put kips and foot per second square then you will get the corresponding unit. You can do that here.

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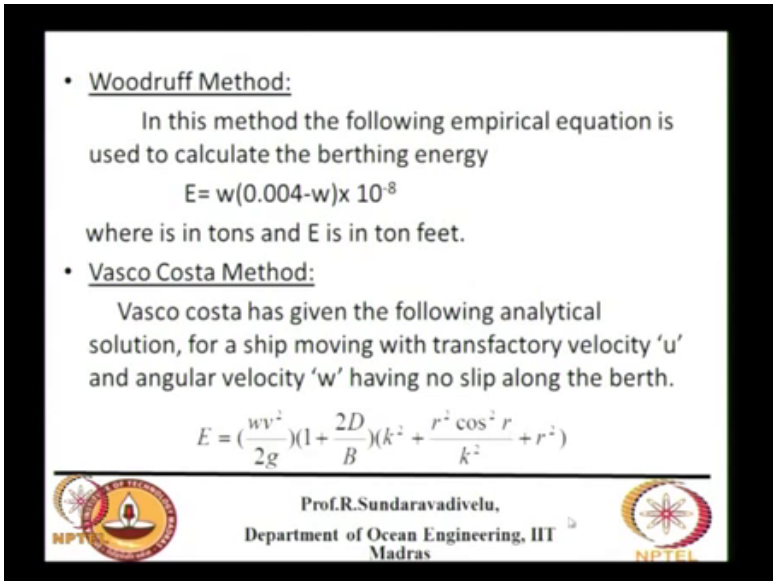

But you cannot do it here. This is most commonly used method this is analytical solution based on first principles there is a derivation for this to get this energy equation. Our IS code

is using this equation to give the various parameters but if you want to know the background for the IS code formula you have to go through this there is a general paper where they have given, how they have derived the formula for this?

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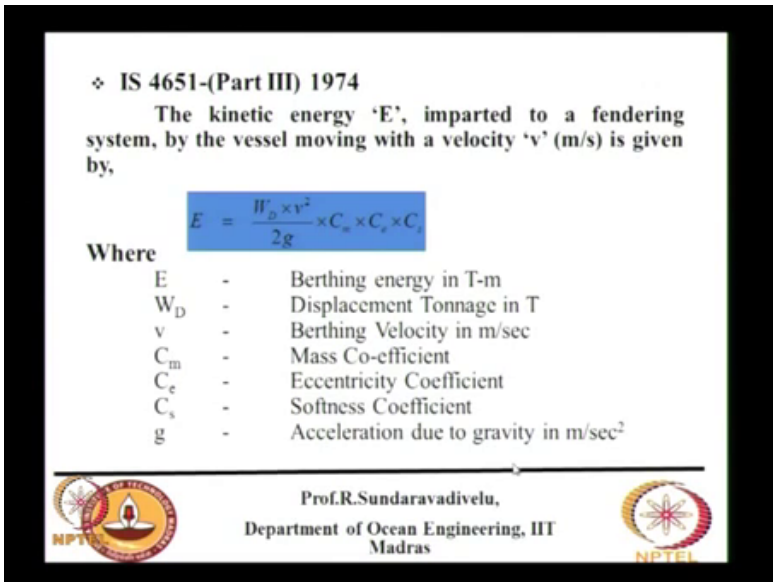

So this is the equation what you are doing that is energy is equal to w d that is displacement tonnage v is the velocity G is the acceleration due to gravity, C m is the added mass coefficient, C e is the Eccentricity coefficient and C s is the softness coefficient. So you have to find out this coefficient to get the value of energy.

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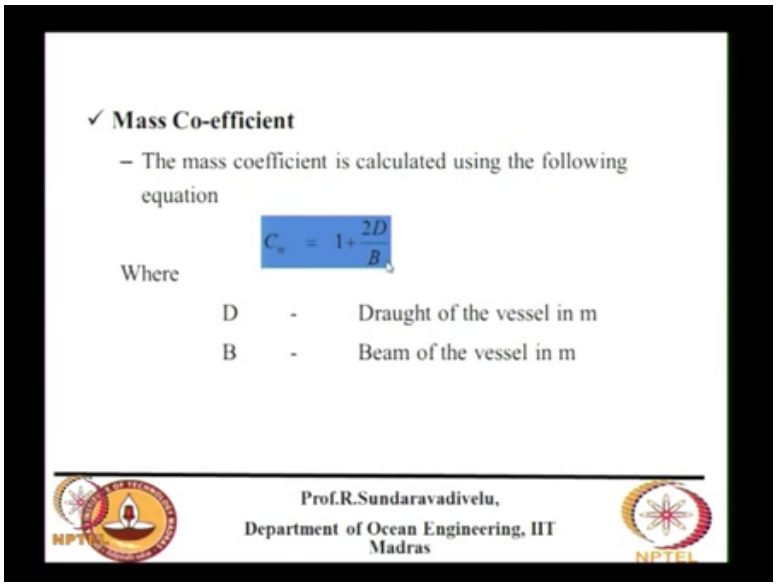

So the mass coefficient you can calculate using this formula 1 plus 2 D by b where D is the draft of the vessel b is the beam of the vessel but this equation is only valid for smaller vessels.

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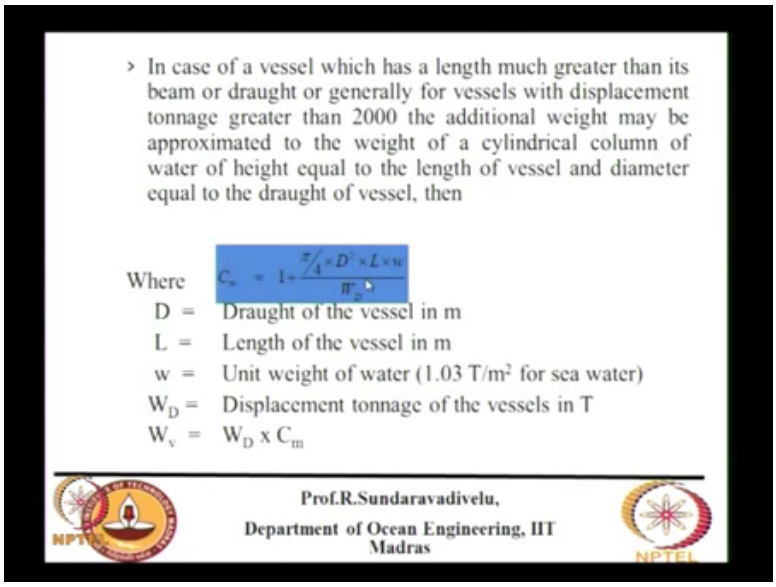

It is a larger vessel you have to use this formula it is given here pi by 4 D square L into w L divided by the displacement tonnage of the vessel, so this gives the ratio. So added mass of the vessel for I do not know whether this is correct or not. I thought it is 20000 tons it may be wrong I will check and let you know. For vessel greater than 20000 tons the additional weight.

Suppose the vessel is moving or accelerating in water the force will be mass into acceleration but when you measure the force you will get the force more than the mass and acceleration. So that is contributed by what is known as added mass. This depends on the acceleration of the body around the weighted perimeter. So there is lot of numerical solution as well as experimental curves available from which you can get.

Simply the added mass is equivalent to the volume of water displaced by equivalent cylinder whose diameter is equal to the draft of the vessel and length is equal to length of the vessel. So the volume of water displaced by equivalent cylinder of diameter and length L is pi by 4 into d square L. So you calculate that multiply by the density of the water you will get the weight of water displaced divided by w d you will get the ratio.

Typically added mass ratio is between 1.5 to 1.7 that is the ratio. Whenever you do the calculation if we get 2 , 2.5 and all you do not use that use only you please recheck yes you cannot get that value. You should only get between 1 .5 and 1.7, 1.4 is ok, 1.8 is ok, 1.1 and 2.9 is not ok. Okay whenever you study engineering you please find out what is a probable range do not go purely by mathematics do not substitute the formula and say that my formula is right.

As all students know correctly. May be you have done some mistakes. This is a density of a water unit weight of water you take it as 1.025. So whenever your vessel approaches a berth it approaches at an angle that angle is called as theta it varies from 0 to 24 degrees. So this also has some contribution. The formula is given by this 1 plus L by r whole square sin square theta plus 1 by 1 plus L by r where L is the distance from gravity of the vessel to the point of contact and r is the radius of gyration.

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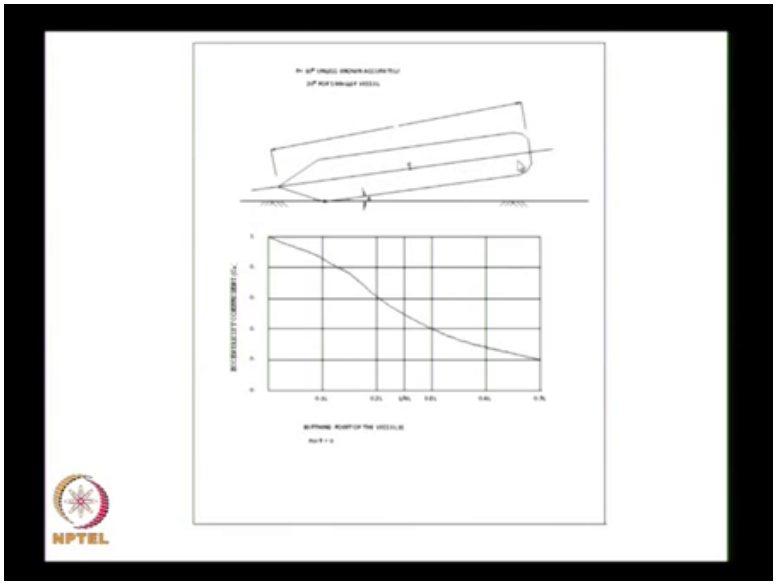

So when the vessel is hitting the berth it does not hit at the central point it is not preferable it hits at quarter point it is called as a quarter point berthing. So what is shown here is the x axis we have given the berthing point the berthing point is 0 means it is along the middle point of the berth middle point of the ship quarter point means out of this total length at L by 4 from either bow end or the stand end it is hitting.

Preferred is quarter point berthing. The Eccentricity coefficient is 0.5 so what is shown here. The vessel hits first then it rotates then hits here then it rotates hits here. So after 5, 6 contacts it remains stationary. Hello you come here, come here you are reading something for the next

case you go do not sit here please go you are not concentrating you please go no point in sitting here.

So this is Eccentricity coefficient. What is the ya radius of gyration there are 6 motions what are the 6 motions? For a floating body there are 6 motions what are the 6 motions? Ocean Engineering students ?

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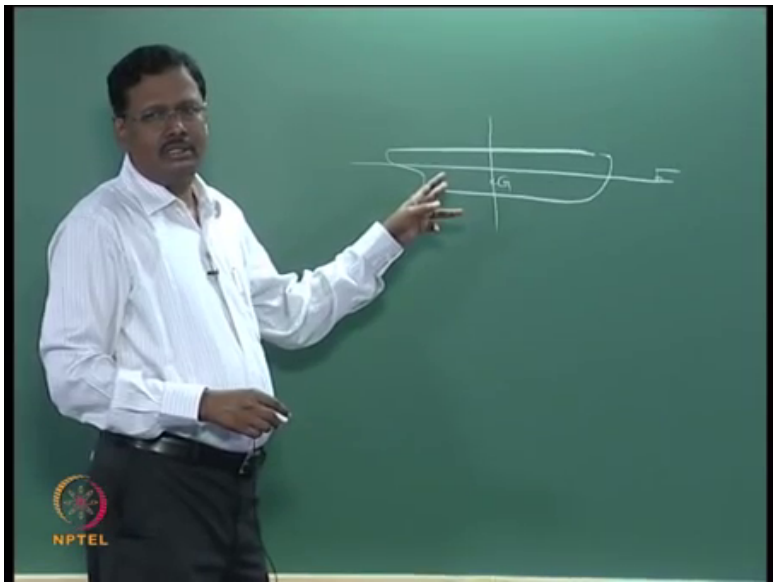

These motions are with reference to the centre of gravity of the vessel. So this is very important where you are giving the motion the motion is at the centre of gravity of the motion.

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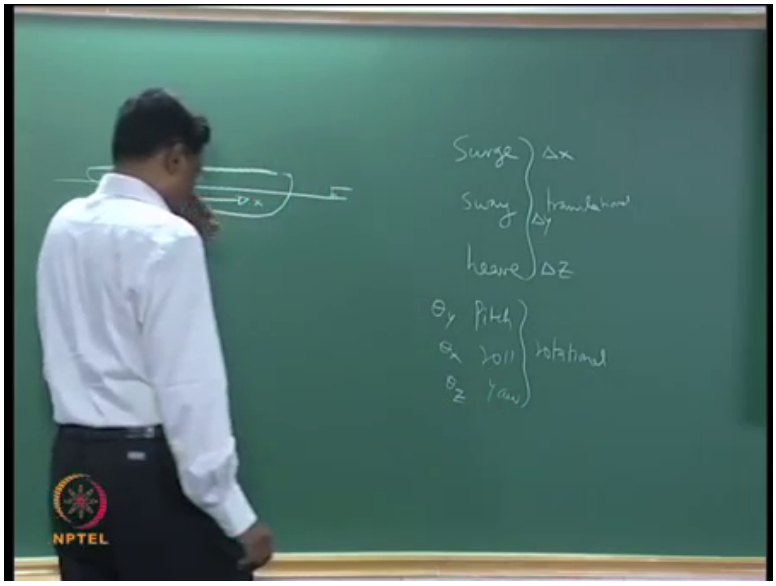

What are the six motions? Yeah, Surge, Sway, heave, Pitch, Roll,(())(21:24) motion, so these three are rotational motion these three are translational. So you have to draw the axis here normally they mark this as x this will be z and y. So your displacement in x is surge y is sway and the z is heave. Which is the motion about rotational motion about y. This is 1 is theta x this is theta z.

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Civil Engineering students what is radius of gyration? Pi root of L by i this i is area moment of inertia a is the area here the radius of gyration is mass moment of inertia divided by mass. What is a probable value of radius of gyration in pitch, ? What does it relate to? Suppose I give the dimension of the ship will you be able to tell what will be the radius of Gyration, how much? Length is 230 meter width is 25 meter raft is 10 meter approximate values are required. Which is between 0.2 to 0.25 times L roll yo also is between 0.2 to 0.25 times L. Roll is 0.2 to 0.25 times B.

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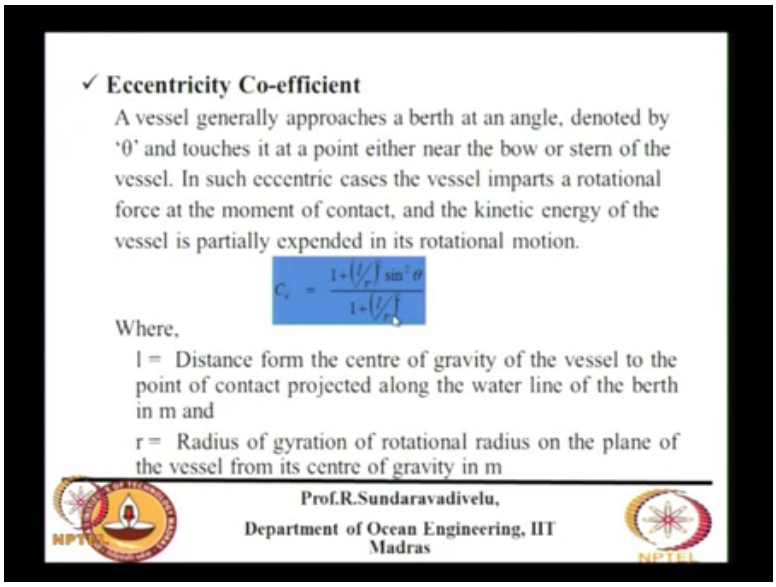

So I will not get into the theory it is very simple only theta is the angle L is the that whether it is quarter point berth and all or is the ya radius of ya we are giving because the vessel is rotating about the z axis. The energy is spent by the rotation. So the ya radiation of gyration comes into picture.

Then softness coefficient that is the relation between the rigidity of the vessel and that of the fender and also between the energy absorbed by the vessel and fender. So we normally apply 0.9 and maximum is 0.95. If you want a higher safety margin. So this is how we calculate the berthing force.

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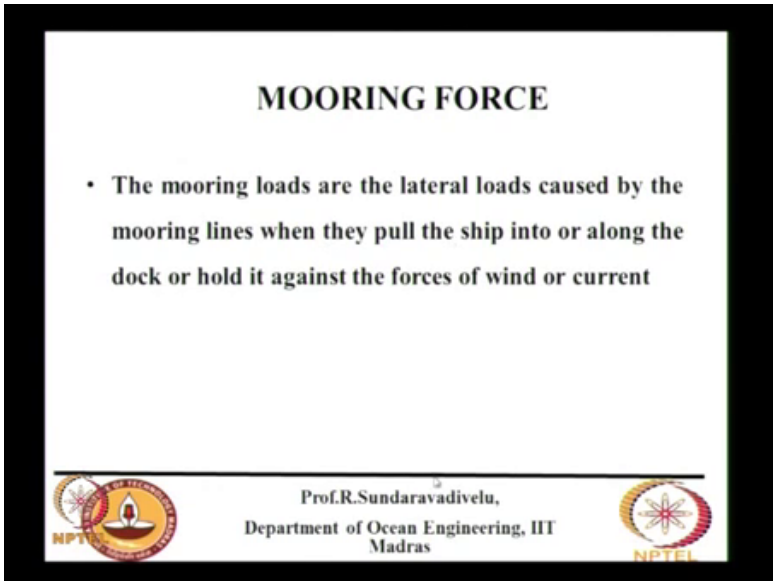

The mooring force are calculated these are the lateral loads is crossed by the mooring lines when they pull the ship into or along the dock or hold it against the forces of wind and current.

Suppose the ship is near the berth the wind is blowing it can blow towards the berth or away from the berth when it is towards the berth the ship is pushed to the berth and you will have a berthing force due to the wind it will be very less, less than the first impact what you are getting. Whereas when the vessel is moved away from the berth the mooring lines will get tension. So that we have to calculate due to wind or current.

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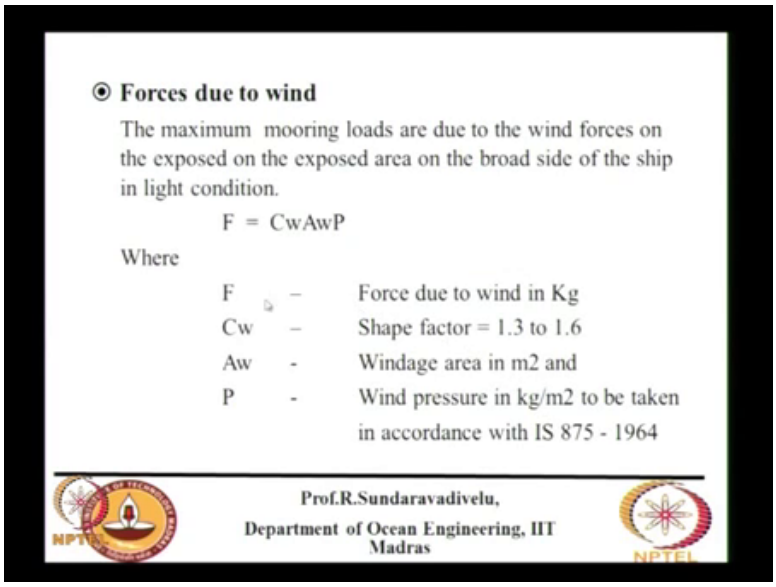

So it is given here the wind force is calculated using this formula using some coefficients the windage area and the pressure. The pressure is to be taken from IS 875. I will give a calculation, how to use this formula? So windage area is area of exposed to wind.

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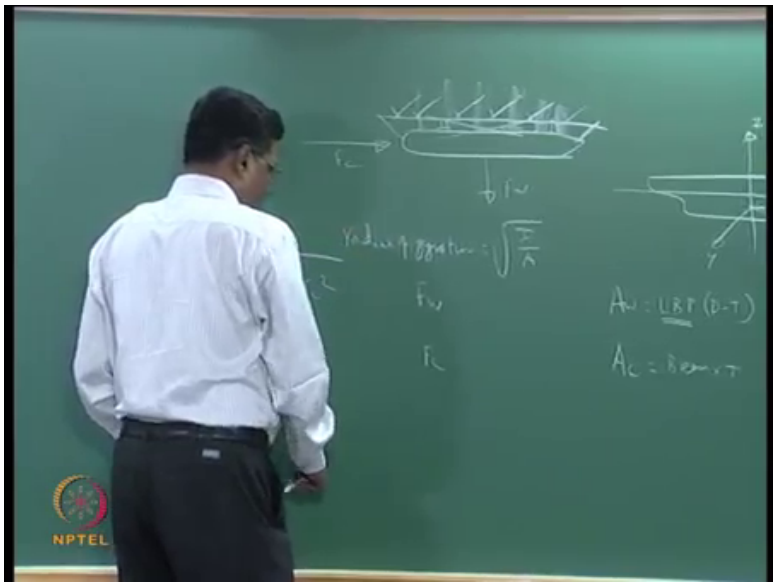

Typically this equal to the suppose wind is blowing in this direction, so the windage area is this is your moulded depth this is your draft and this is your area of width D minus t multiplied by length of the ship. So the length of the ship and d minus t depending on the shape it varies.So we give a shape factor to this they will use the perpendicular distance for the length, length between perpendicular that is why you put a shape factor and we calculate the pressure.

The pressure is a function of the speed of the wind. So we will have two forces the first force is due to a wind the other force is due to the current. Suppose there is a vessel here like this and there are fenders to absorb the energy there are bolars to connect the fender so vessel is moving away due to wind acting on this face the lines will get tension. But we know the current direction we always the worry on the vessel in a direction of current.

So the vintage area will be area due to wind is length between perpendicular d minus t the length between perpendicular this length in it area exposed area due to current will be beam of the vessel into draft. So you calculate the wind force calculate the current force you calculate the resultant force is equal to square root of f w square plus f c square. Because you will have this force which is equal to this force which is equal to current force.

They are not in the collinear same direction if it is collinear you can calculate f w plus f c. The one of the measure point which you have to consider is do not put the ship in any direction do not worry on the berth in any direction you know the current direction either in a

canal or in a (())(29:10) worry on the berth parallel to the current, if not plus minus 10 degrees is ok. Do not put it in the beam sea condition then the current force will be enormous.

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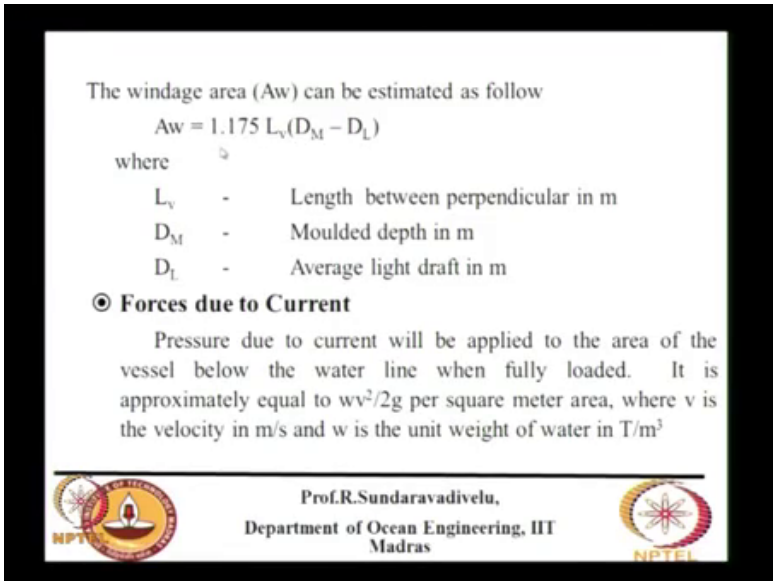

So this is for the vintage area this is depth moulded and life draft. So depth moulded is full depth and depth less average life draft then the current force is calculated w v square by 2 g where v is the velocity of current in meter per second w is the unit weight of water. Typically the velocity of the current in tidal flow is between 1 knot to 5 knots. Generally it is between 1 and 3 more than 3 very difficult to design. So this is your f c and this is your f w.

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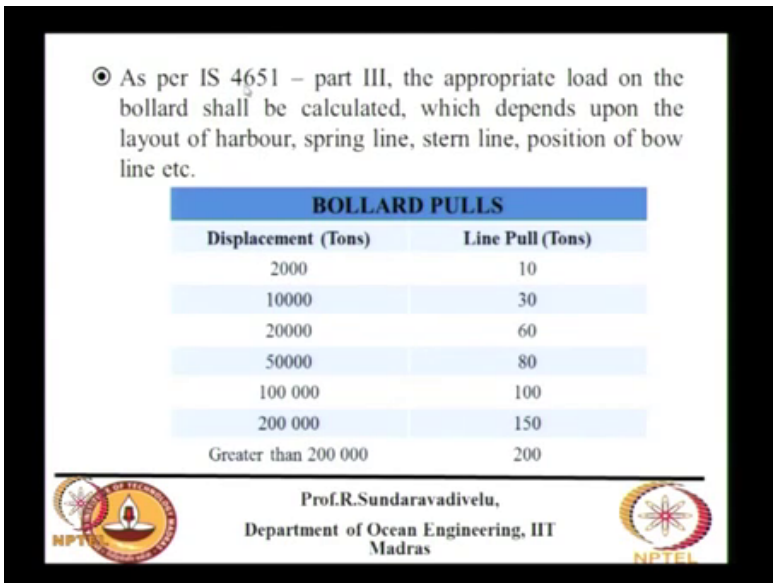

But there is a code given in IS 4651 which gives for different displacement tonnage note this is not d w t b for different displacement tonnage what is a line pull so you do the calculation it is giving what we have calculated is the resultant force but if you want to calculate the mooring force on the mooring line.

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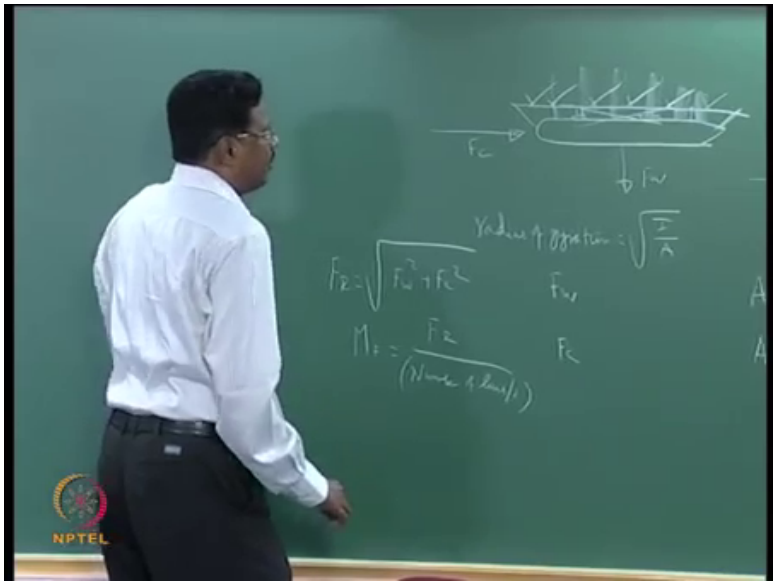

So this is the resultant force the mooring force on the mooring line is resultant force divided by number of lines divided by 2. So if you have 1,2,3 ,4,5,6 lines you calculate the total resultant force divided by 3 that will give you the resultant force this is the approximate value. If you want to do the exact calculation you have to model the whole thing and then do the analysis . In the absence of that you can take the force in the each mooring line tension is equivalent to the total number of lines by 2.

This is because when the ship is moving like this this will be TOT, TOT means there will be a tension in this whereas this line will be slack. All the lines will not be tension some lines will become slack. That is why we take 50 percent of the line.

Ok we will continue in the next class.