Port and Harbor Structures
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Module-04 Lecture-26
Fenders

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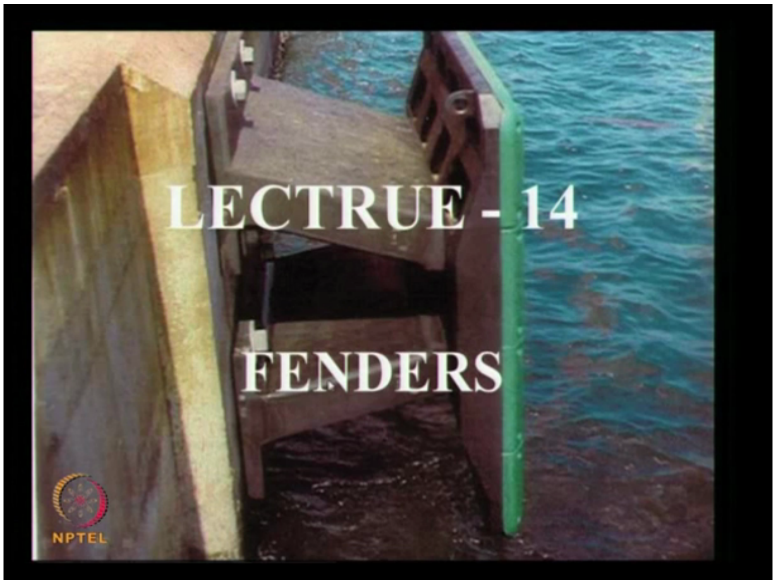

This class, we will discuss about these fenders. This buckling type fender, this fender consists of this rubber component. Then we have a frontal board. This part of the black color is a steel board. And what we see here in this green color is rubber board which will reduce the friction between the vessel and the fender. We are seeing the bolts here which are used to fix the fender to the berthing structure. Here is special design requirement at this place where we are fixing the fender to the structure.

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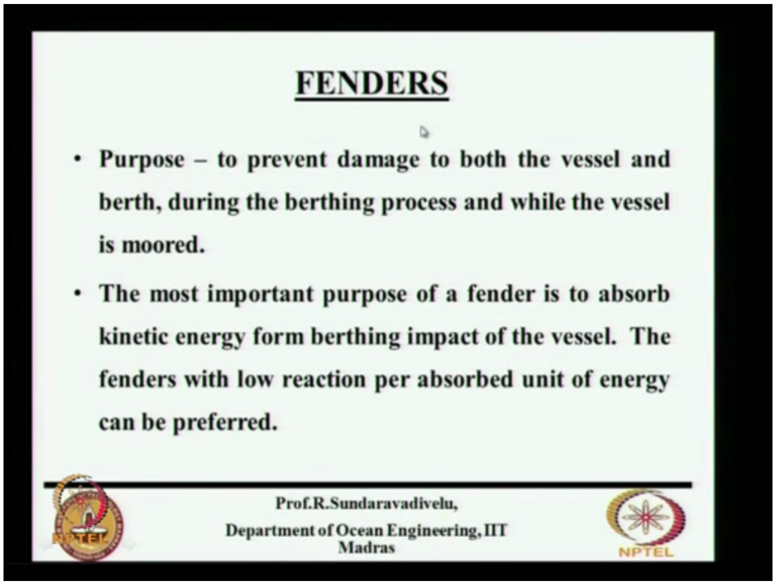

What is a purpose of a fender? Is to prevent damage to both the vessel and berth during the berthing process and while vessel is moored. That is two operations. One is when the vessel comes and berths. Second is when the vessel is moored. When there is a wind, the wind is blowing towards the vessel, it will be berthing and it will be hitting the structure. When the vessel is pulled away by the wind, then the mooring lines will transfer the load to the bollard.

So when the vessel is berthing, the maximum forces will be there. But when the vessel is moored due to the operational wind, there will be some berthing force. The damage should be avoided to both the vessel as well as the berth. To prevent the damage to the vessel, what we do is, normally the vessels are designed for pressure of about 40 tons per meter square. The bigger vessels are designed for 20 tons per meter square.

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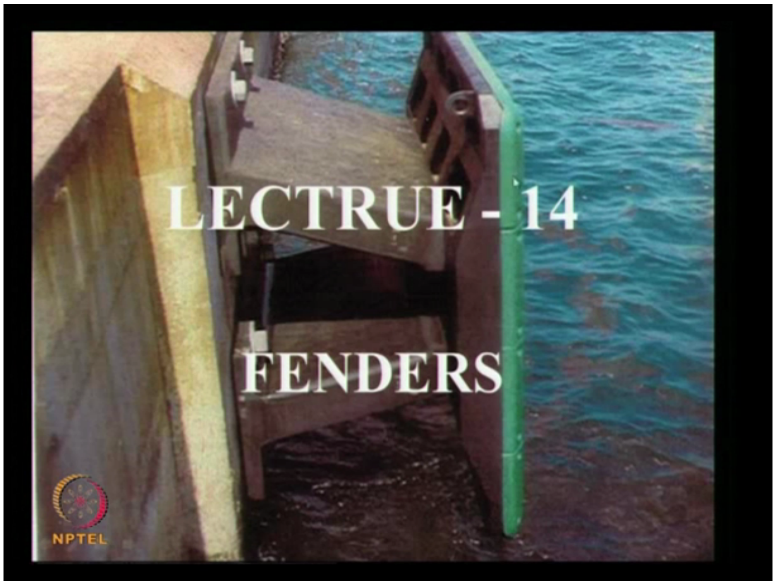

That means whatever the pressure that is coming from the board to the vessel should not exceed more than 20 tons per meter square for a bigger vessel and 40 tons per meter square for a smaller vessel. For the berth we have to design the berthing force, that is a force should be transported, transmitted through this. So this berthing force, we have to calculate and design the berth for that.

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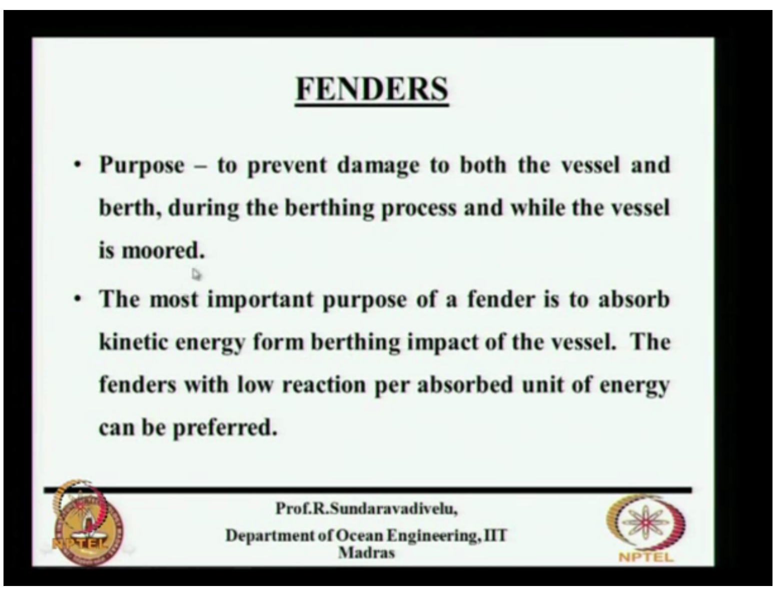

The most important purpose of a fender is to absorb kinetic energy from berthing impact of the vessel. The ship do not have any break, ship is not having a break, so it will reduce the velocity and it will be assisted by tug and it will go on and hit. So there will be an (berth) berthing impact. That time whatever is the kinetic energy, that should be absorbed. For that we provide the fender. Normally we talk about life of the structure. Marine structure life is about 40 years whereas typically the fender life is only 10 years.

It does not come for more than 10 years mainly because of the impact that is imparted on the fender and lot of deflection takes place, that is why the fender's life is only 10 years. The fender with a low reaction per absorbed unit of energy can be preferred. So the kinetic energy is transformed, so the forces to be calculated, that should be very less per unit energy. That is a purpose of this.

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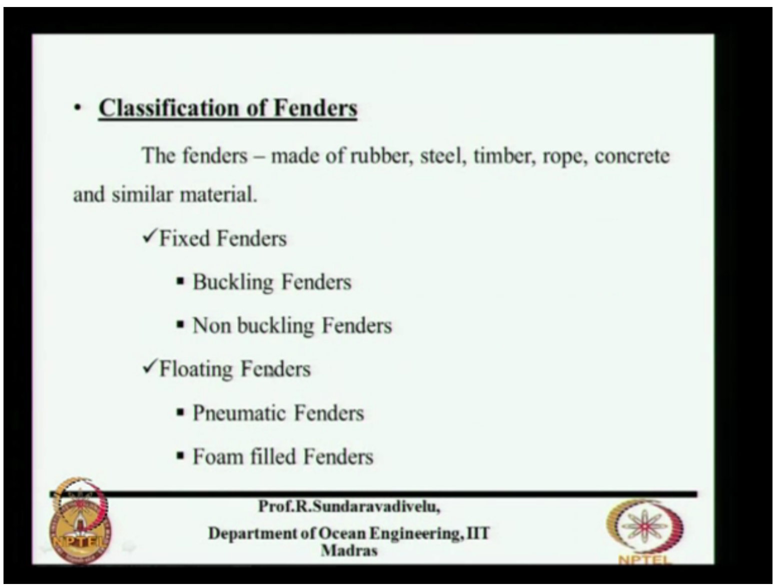

We can classify the fenders based on the material. Earlier days we are using timber as a fender. Nowadays mostly we use rubber. We have also used steel rope, concrete and other materials also but most commonly used is rubber fenders nowadays. Timber also is nowadays being used. There are two types of fenders. One is called as fixed fender, another is called as floating fender.

The difference between the fixed fender and floating fender is for a floating fender, the weight of the fender is taken by the buoyancy of the fender. And when there is a tidal variation for the floating fender, the fender goes up and down. Okay. That is a purpose of the floating fender. Two advantages, one is the weight of the fender need not have to be transferred to the structure. The second is we do not have to have a big frontal board because the floating fender, it is low tide level, it goes to the low tide level. If it is a high tide level, it goes to the high tide level. So that is the purpose of the floating fenders. Whereas in a fixed fender, you have to have frontal frame.

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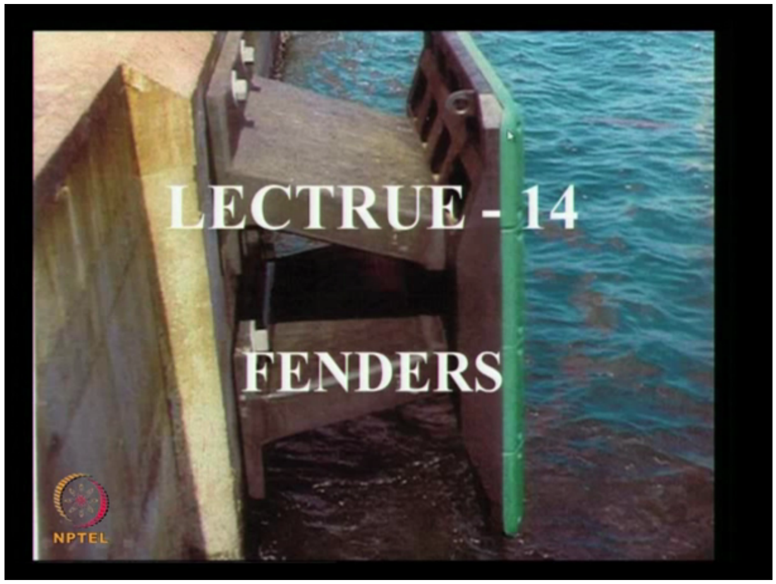

So if you see this particular slide, we have the frontal frame like this. This frontal frame should be very close to the low tide level and this top level should be above the high water level. So that is main purpose of this frontal board height. So this height will increase when tidal variation is very high. That is in case of fixed fender. The weight of the fender also should be taken by these bolts, so the weight also should be taken.

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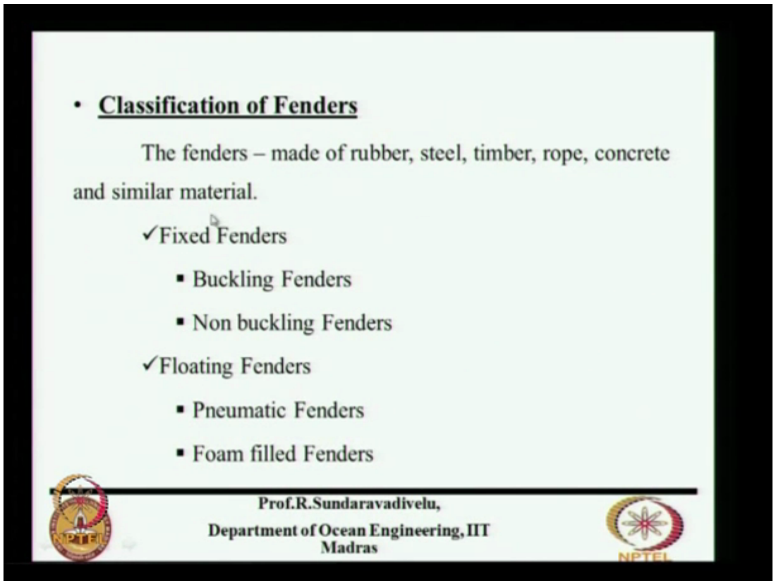

But mostly we use nowadays only fixed fenders and there are two types. One is called as buckling fender, another is called as non-buckling fender. And in floating fender we have two components. One is called as pneumatic fender, that means there is a pressure inside the fender tube. And there is a foam is also filled, in that case there is no internal pressure.

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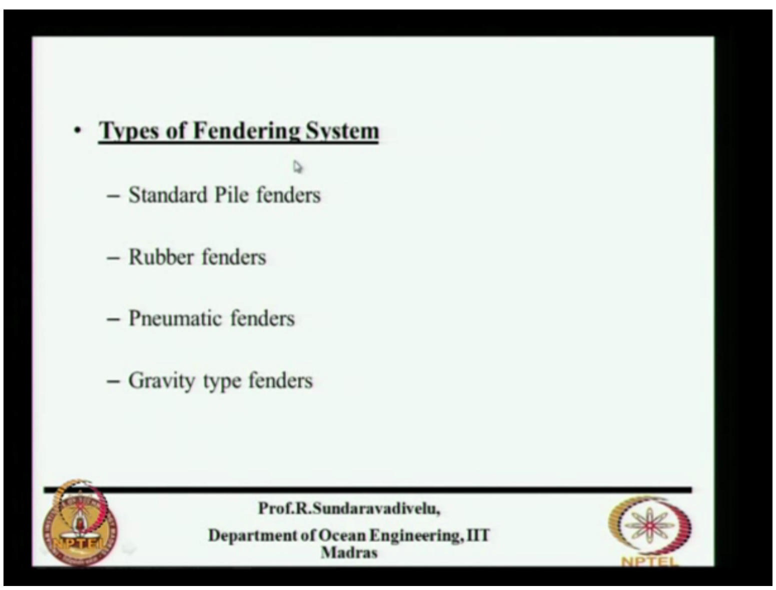

The fendering system, we can have different types: standard pile fender, rubber fender, pneumatic fenders, gravity type fenders. Rubber fender is what the first slide what we have shown. Pneumatic fender is this one, that is the floating fender with pressure inside. Then we have standard pile fender and gravity type fenders. So gravity type fender is nowadays not being used, I will not discuss much but standard pile fender I will explain later.

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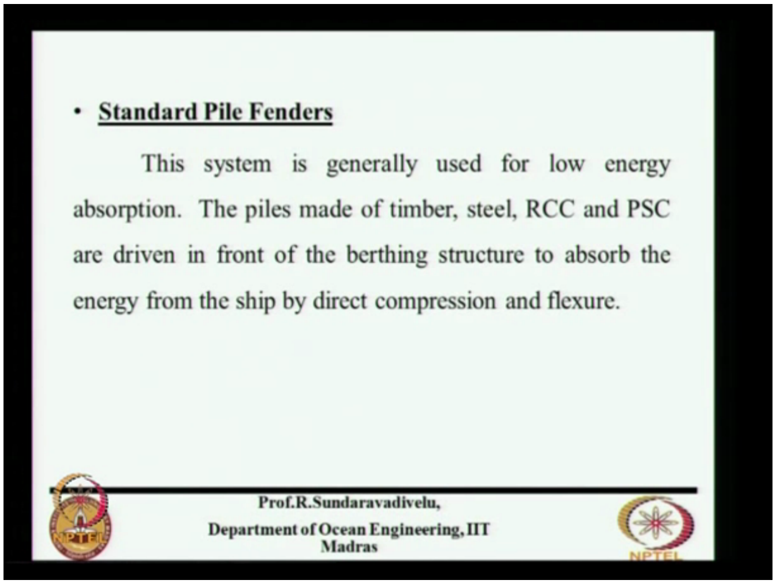

This system is, this is used for low energy absorption. This is not for big vessels, small vessels. We simply drive a pile made of timber, steel, RCC or prestressed concrete and driven in front of the berthing structure to absorb the energy from the ship by direct compression and flexure. That is the purpose of this standard pile fender. This is most commonly used for very small vessel less than 1,000 dwt.

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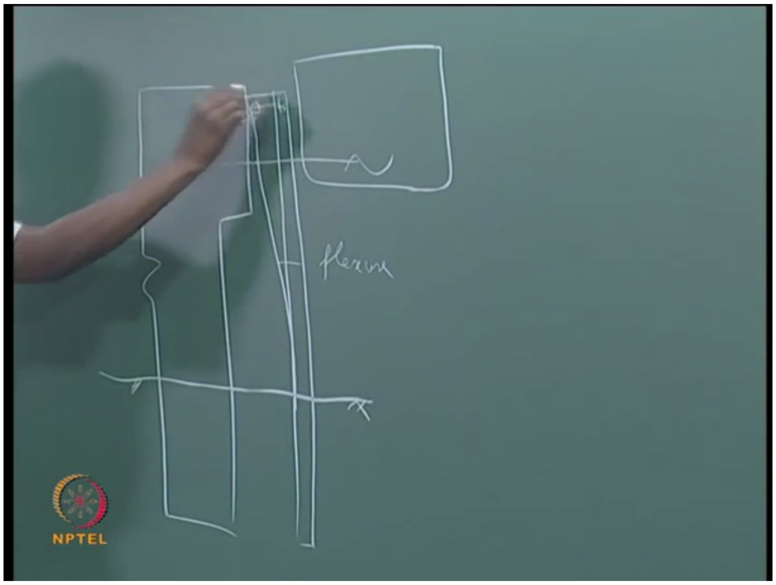

Suppose you have a berthing structure like this. This is a water level here. What you do is you drive one fender here. It can be very close to the structure also. So whenever a ship comes and hits, there will be a deflation of the fender and it will go on and hit, that is direct compression. And then is deflecting now, you will have some deformation. This is flexure. So if you plot the load versus deflection, suppose you call this as horizontal load.

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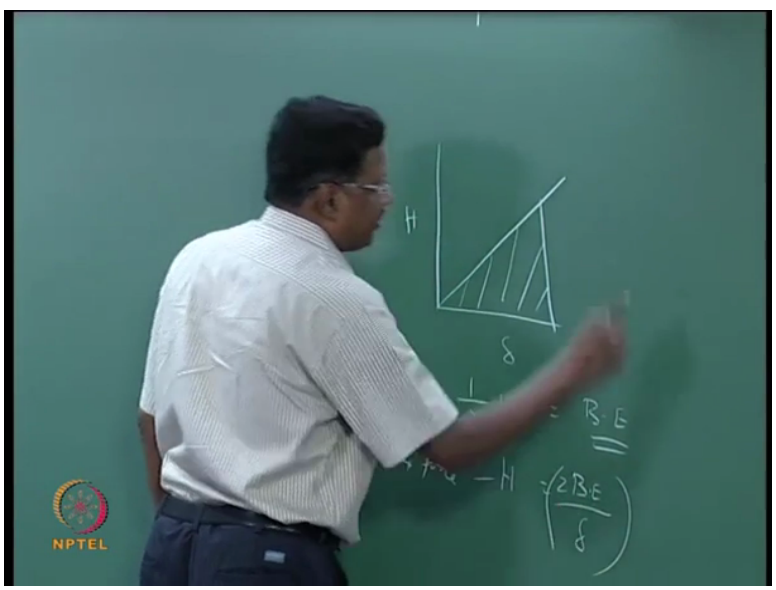

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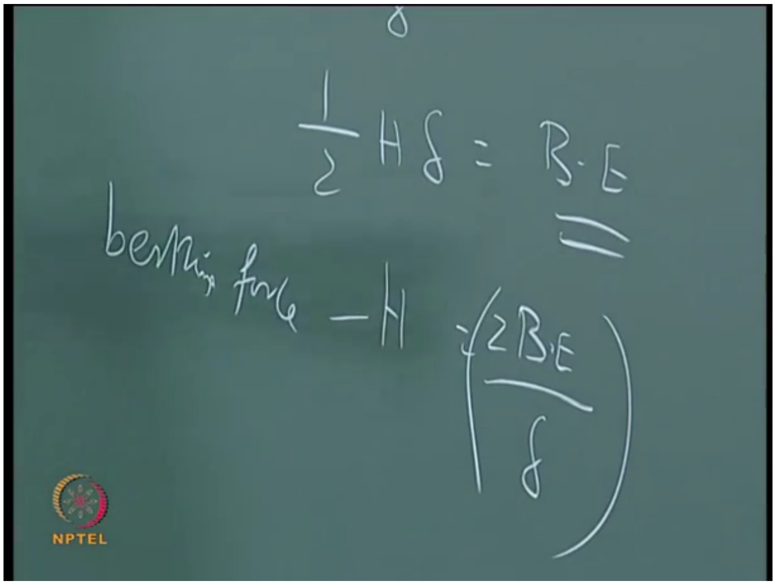

This is a deflection. Suppose you assume this is a linear relationship. This area under the curve, this is half H into delta equated to berthing energy. So this side is, H is the force, this is your berthing force, that is equal to BE, berthing energy multiplied by, total berthing energy divided by delta. Depending on the deflection, what you are getting here.

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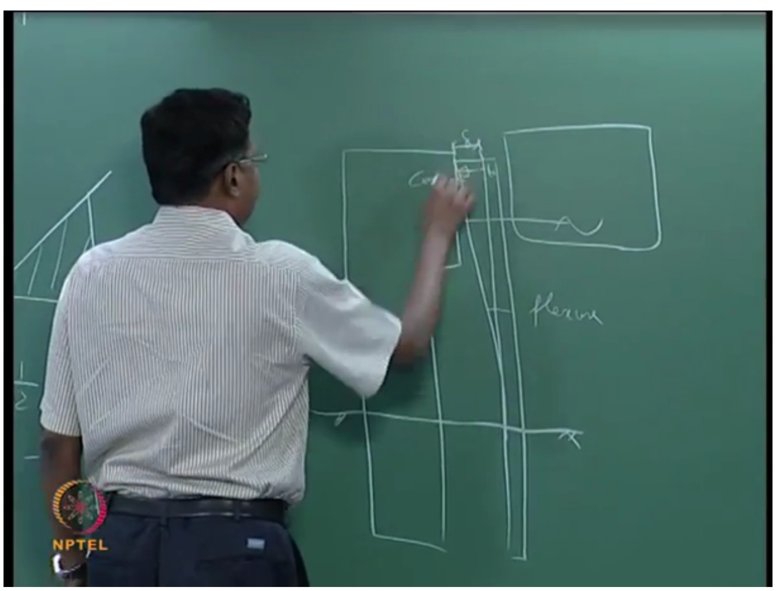

This is your deflection. You calculate the energy and find out. This used only for small type of vessels.

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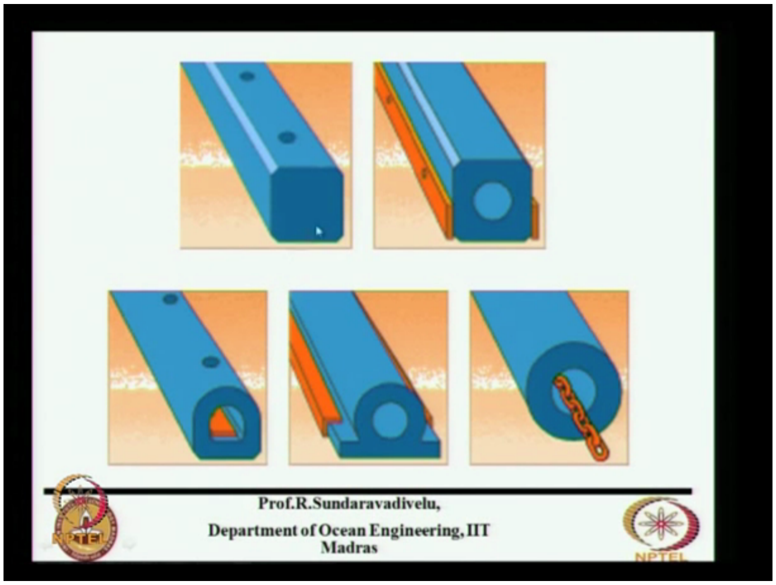

So these are rubber fenders of different shape. Square shape, square shape with a hollow. This is a D type fender. This some other shape, this is a cylindrical fender with a chain inside. These are also used for smaller size of vessels.

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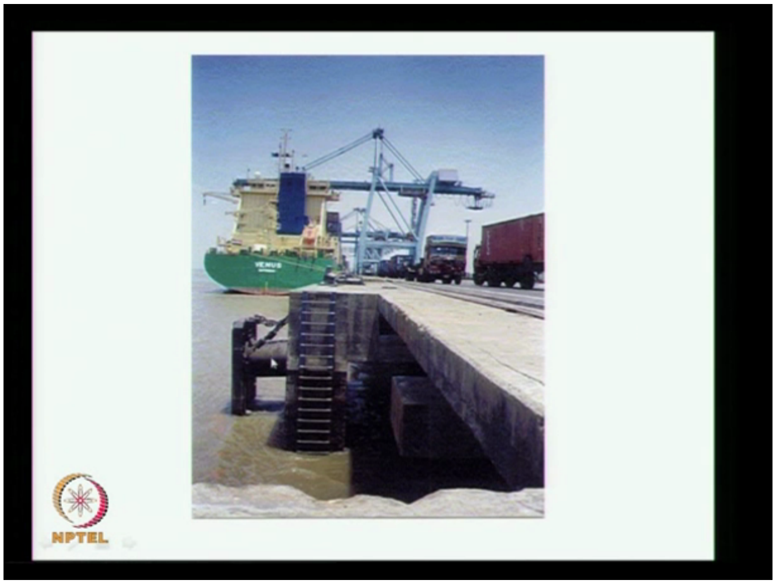

These are most commonly used fender. This is called as a cell type fender. This photograph what you are seeing is for the port at Mumbai, Jawaharlal Nehru Port Trust. You can see the vessel here. This is called as a cell fender. This dimension will be about 1.5 meter. Then you have the frontal board, this is top level of the frontal board. This is bottom level of the frontal board. This may not be low tide level. If it is low tide level, you can see the bottom of the frontal board, this may be in between this.

As you see here, this side and this side we compare. This side is more compared to this side. Normally it is fixed like that only. So this is the central line of the fender. The board which is above the central line is about one-third. And the board height which is below the fender is about two-third. Mainly we want to fix the fender somewhere here which is the average between the mean sea level and high water level.

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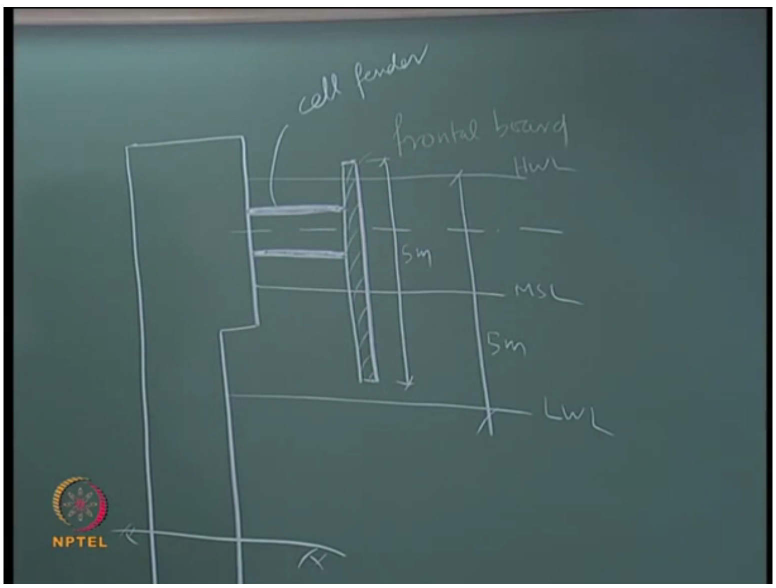

The distance from mean sea level to high water level and mean sea level to low water level is almost the same. This point is in between high water level and low water level. The central line of the fender we normally fix between mean sea level and high water level. And typically the frontal board is slightly above the high water level. And bottom level of the frontal board is slightly above the low water level. This is how we fix. In (())(11:32) this variation is about 5 meters. This frontal board also be about 5 meters. This is how we fix.

Why do we fix the fender slightly above and not to fix at the mean sea level? What could be the reason? See the, for fixing the fender we need some time which is water should not be there. So above mean sea level at least 6 hours a day in two slots it will be available. If you are fixing at the below now, fixing of fender will be very difficult. That is one of the reason why we want to, see we have to fix the fender here with the concrete structure, some bolts added. That fixing is possible only there is no water. Underwater fixing is possible but it is very difficult and costly also. That is why we fix it here like this.

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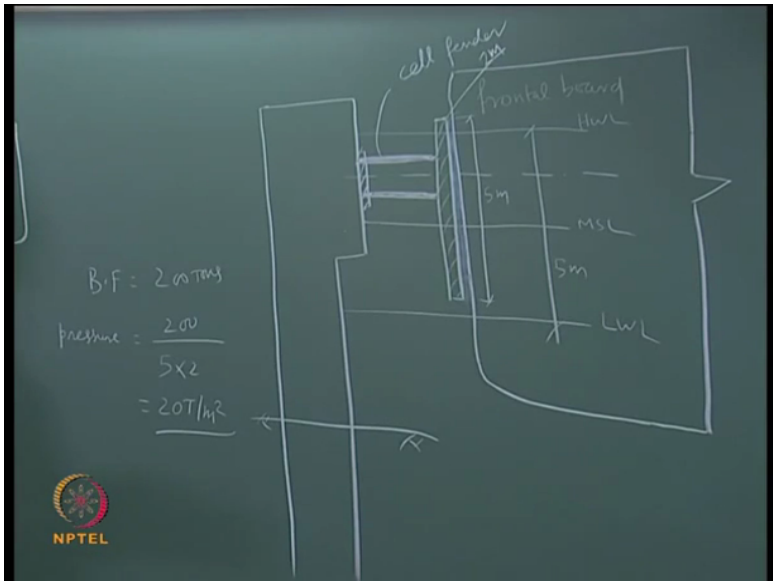

So when a vessel comes, suppose the vessel is coming, the vessel will be, so this will be the, this portion is a contact area for the vessel. This, whatever is this, this is a place where the fender will be in contact with this. Typically the other dimension for the fender is about 2 meter or let us take it as 2 meters.

Suppose your berthing force what you are calculating is about 200 tons. Your pressure will be this 200 divided by 5 meter is the height of the fender. 2 meter is in other direction, so this will be about 20 tons per meter square. So this is what is permissible for bigger vessels. Okay. I was discussing about the pressure. The pressure exerted should be between 20 tons to 40 tons per meter square. This berthing force I am giving is 200 tons, this we have to calculate. We have discussed, we are calculating the berthing energy and from berthing energy we can calculate the berthing force.

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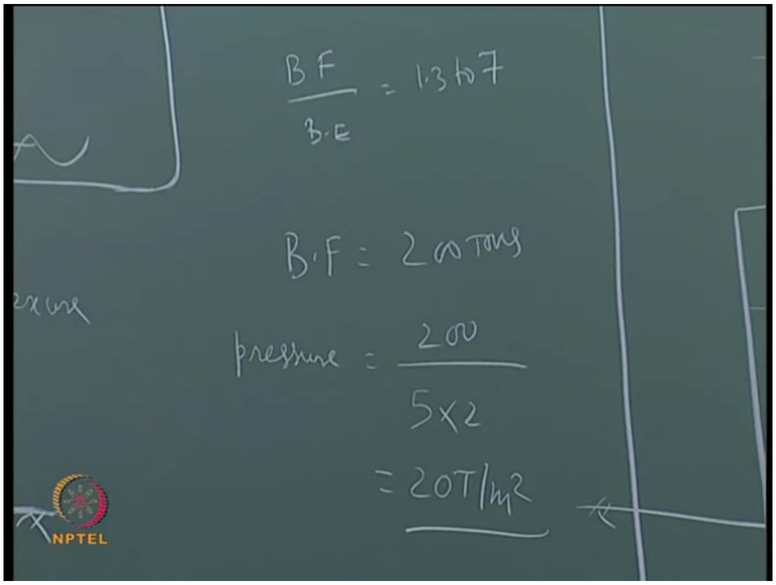

So this ratio of berthing force and berthing energy is equal to 1.3 to 7. So once you calculate berthing energy, from there you can calculate berthing force. Then you can calculate the pressure.

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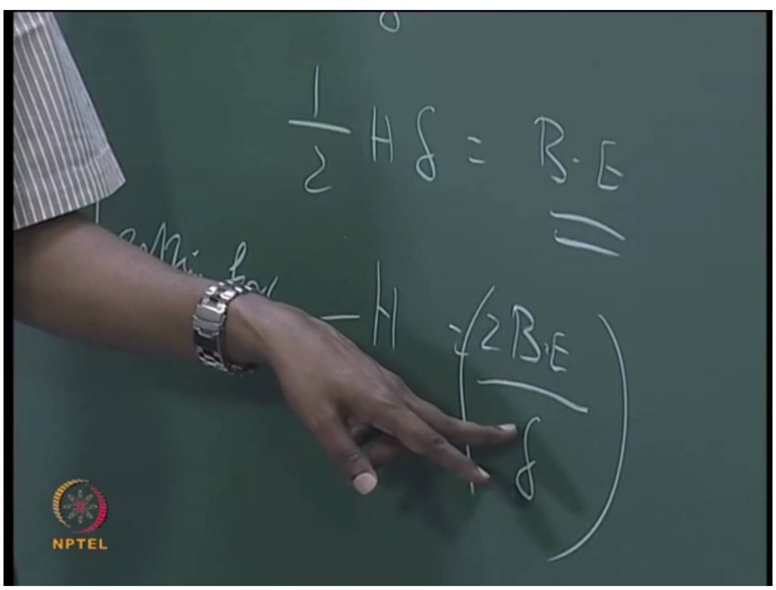

So if delta is equal to 1 meter, this berthing force to berthing energy ratio is 2. The delta is equal to 0.5 meter, ratio is 4. If this is equal to 0.25 meters, ratio will be 8. Okay, this is having in the higher range only. 1 meter deflection for the pile (())(14:53) is very high, maybe 0.25 meter deflection is appropriate. So we put 0.25, berthing force to berthing energy ratio will be 8. Okay.

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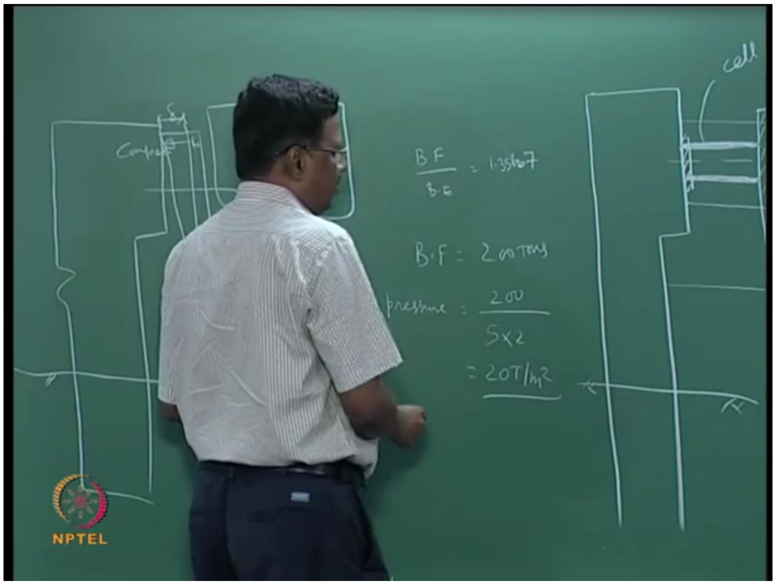

But for a cell fender, the berthing force to berthing energy will be somewhere around 1.3, 1.35 or 1.32, somewhere this 1.35. Once you calculate from this, we can get the berthing force. This is one of the important components of berthing.

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If you do not design the fender properly, there is a damage to the structure or damage to the vessel, it will be catastrophic. So this design is required. And we have a ladder here. This is also one of the component which we have to design and there is a bollard here. And you have a chain also here which is used to connect the frontal board, is having a large weight.

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This is called as a buckling fender. So these two arms will buckle.

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This is also buckling fender. This also will buckle. When it buckles, this height let us say it is 1.5 meter, this will get reduced to 0.75 meters. That much deflection will be there. Whatever is 1.5 meter, it will become 50 percent of that. Then when the vessel is not there, it will come back to 1.5 meter. So this goes in and goes out like this. That is why the life is only 10 years.

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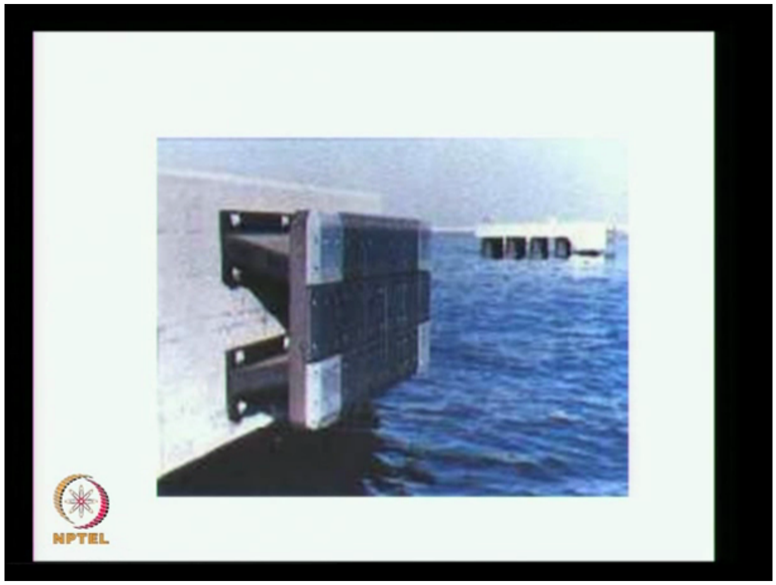

This is a frontal board elevation if you see from the other side how it is connected. This is horizontally fixed fender. This is used for low tidal ranges. So this height will be less. If you want to reduce the pressure on the vessel, you have to increase the this size, other dimension.

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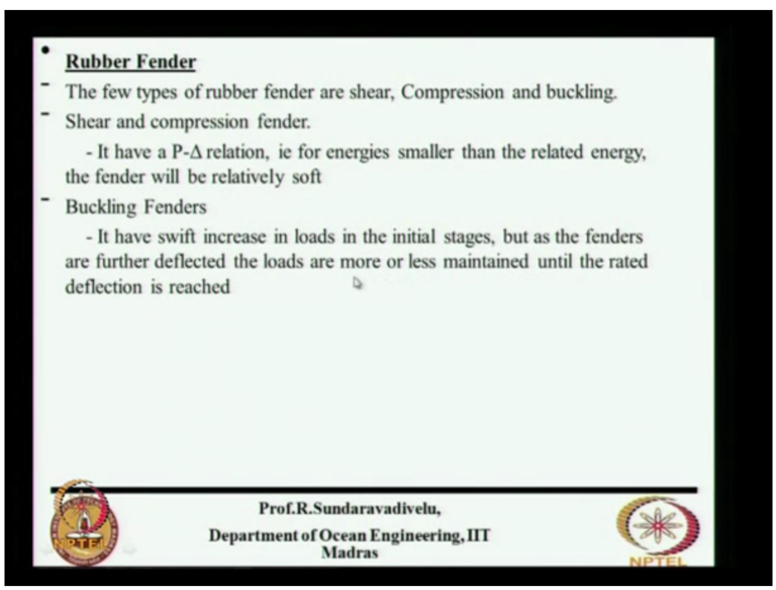

So we have rubber fenders called as a shear fender, compression fender and buckling fender. And this shear and compression fender are relatively soft. And buckling fenders, the deflection is, the load is, swift increase will be there initial stages and afterwards the load will be more or less maintained. I will draw the figure.

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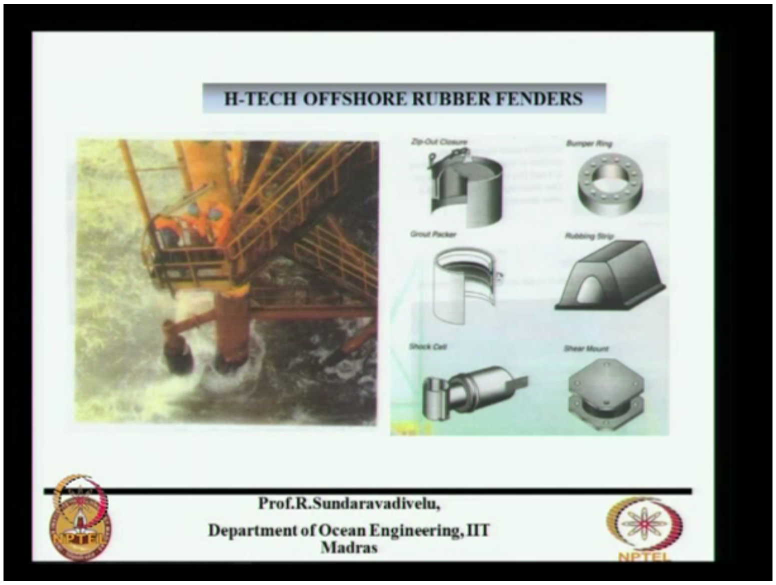

These are for offshore structures where we have this type of fenders which is attached to the main leg of the members.

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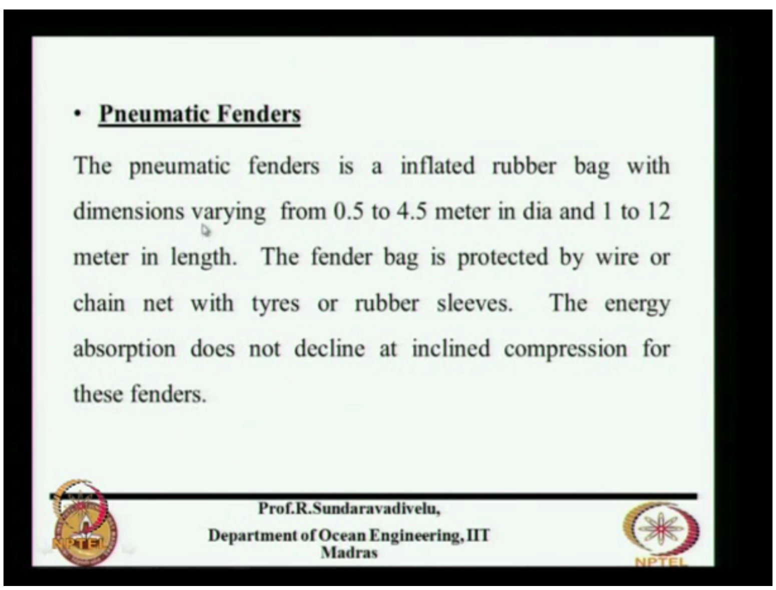

Pneumatic fender is a inflated rubber bag, dimensions varying from 0.5 to 4.5 meter in diameter and 1 to 12 meter in length. This fender bag is protected by wire or chain net with tires or rubber sleeves. The energy absorption does not decline at inclined compression for these fenders. I will explain about inclined compression subsequently.

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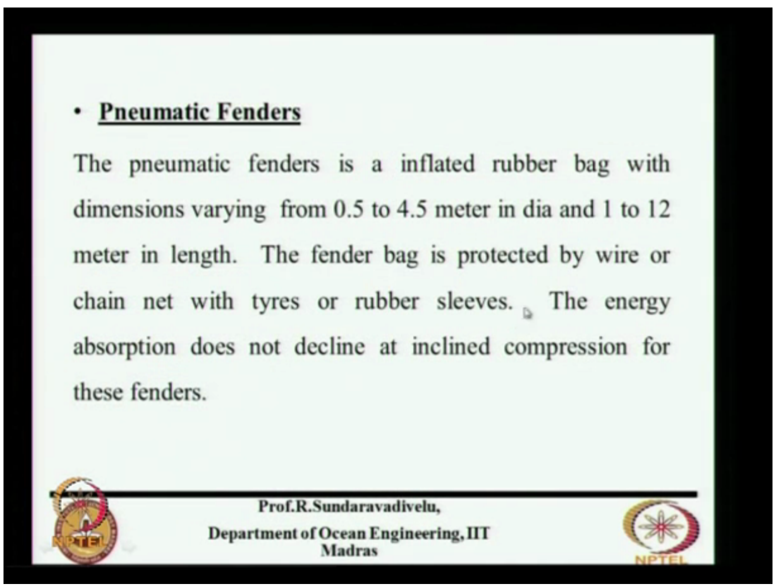

This is your pneumatic fender. We have discussed that these are protected by wire or chain net with tires or rubber sleeves. So these are the wires or chain nets with rubbers, with the tires which are protected. This diameter will vary from 0.5 to 4.5 meter. The length will be varying from 1 to 12 meters, that is a length. This is pressurized inside. I think this fender is of diameter 2.5 meter and length 5.5 meter.

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So this is a length 5.5 meter, this is 2.5 meter. For ship to ship transfer, the middle of the sea this type of fenders are used. When you have two ships coming in the middle of the sea, if you want to transfer, then we use this fender. The middle of the sea transfer is required normal time also and emergency also. Normal means when you want to transfer some cargo from a bigger vessel to smaller vessel, this will be used. Emergency mean one vessel is, the engine has failed and you have to transfer. Another is during war times also, you want to transfer some equipments for personnel, that also it will be used. Advantage of the floating fender is it goes up and down along with the tidal range.

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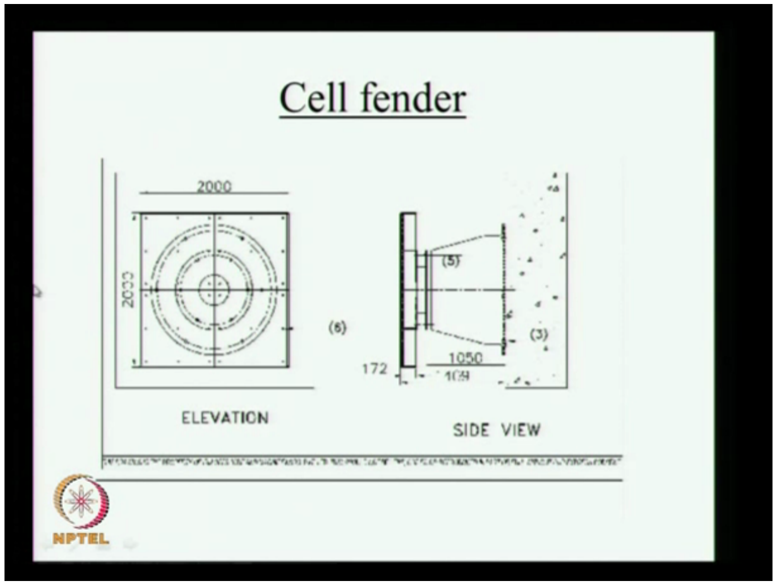

We have this cell fender which I shown here, the earlier slide. So how it is connected? This is on the concrete face, this is on the sea side. This is a frontal frame which is about 2 meter by 2 meter, it shows the cell.

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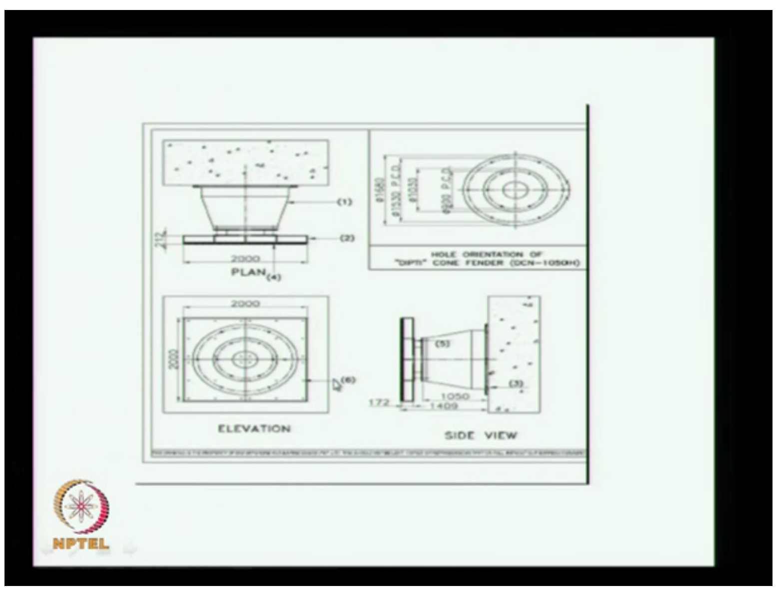

This is another view how it is fixed on that.

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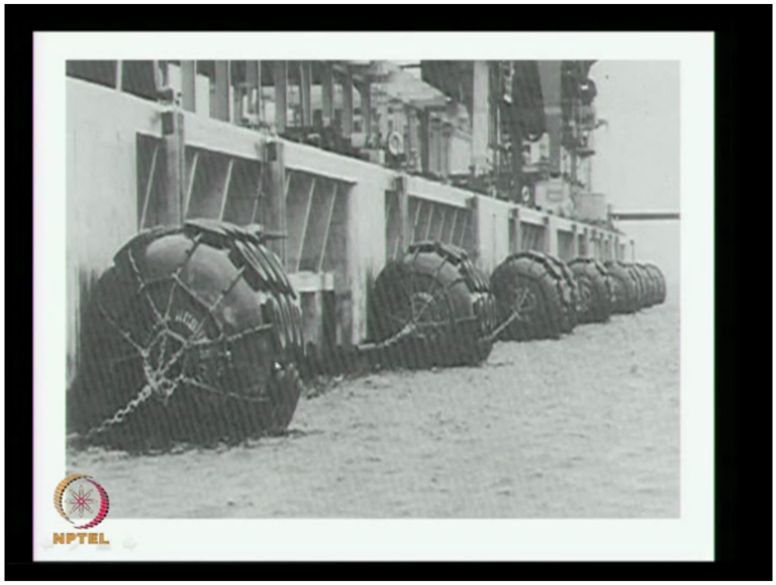

I was talking about inclined position. Whenever a vessel comes, it comes with an inclination. Whenever there is inclination, this type of rubber fenders, energy to the, reaction to energy ratio does not change, whether in cell fender, that ratio changes. It is a perpendicular if the ratio is 1.5. If it is inclined, it may be 1.7. That is here it does not change. This is how it will be fixed. You see the rubber bag, weight is very heavy, so the buoyancy will take care of the weight.

Then we have a chains which are connecting it to the structure. But we need a concrete face where the fender is connected. You cannot open face like this. So we need a concrete face. This concrete face should be from the lowest water level to the top of the berth. Unlike a cell fender where we need the this portion of the structure only from mean sea level to top level of the berth, if you want to fix a floating fender, you need from the mean sea level to the, I am sorry, top level to the lowest water level. Disadvantage, this is a diameter and this is a length of the fender.

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This is another type of fender which is a pneumatic fender only with a spherical in shape. This is used, this is a warship, so normally they use this type of fender with a better performance.

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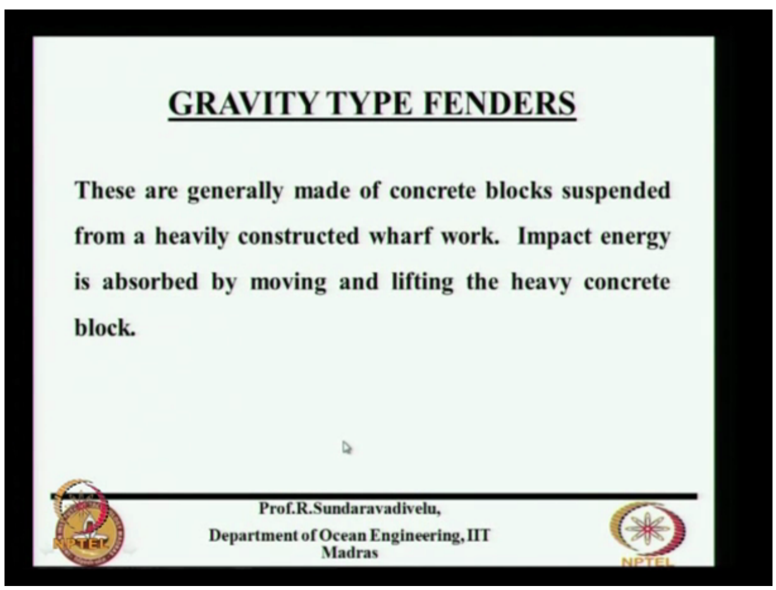

Gravity type fender, I will not discuss. Nowadays it is not being used.

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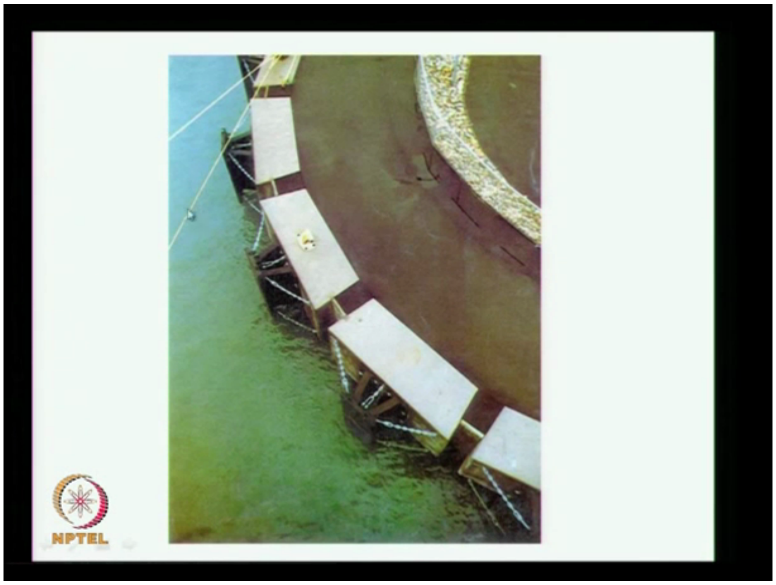

This is another type of fenders, cell fender only with a frontal board. There is a curvature structure, we will be using these isolated fenders along the curve.

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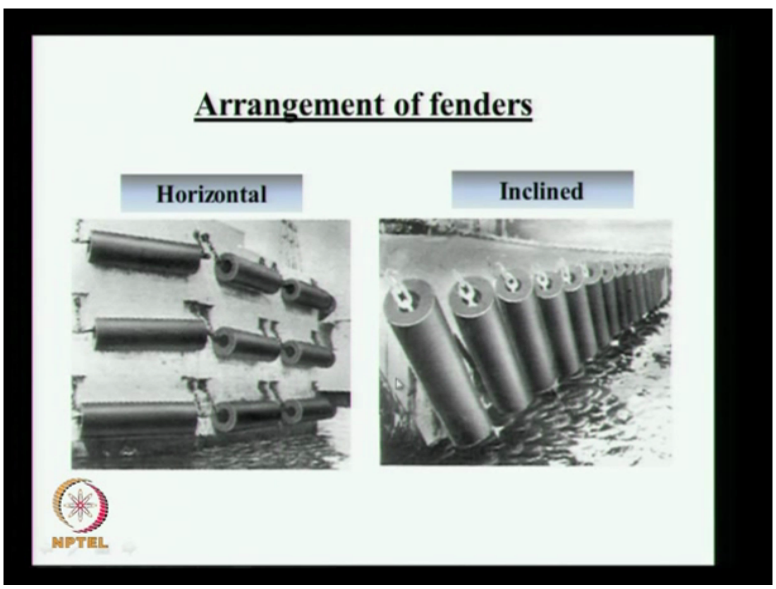

These are for small type of vessels. This is called as the direct compression fender. So whenever there is a vessel coming and hitting like this, then it will get directly compressed. So it can be kept at different levels to take care of different water levels. This is for small vessels, a naval vessel, coast guard vessels and done, this will be used. And three levels we have fixed or you can put it like this also. Diameter is very small, maybe 300 or 500 mm diameter.

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This is called as air block fender with protector panel. This is also similar to the pneumatic fender.

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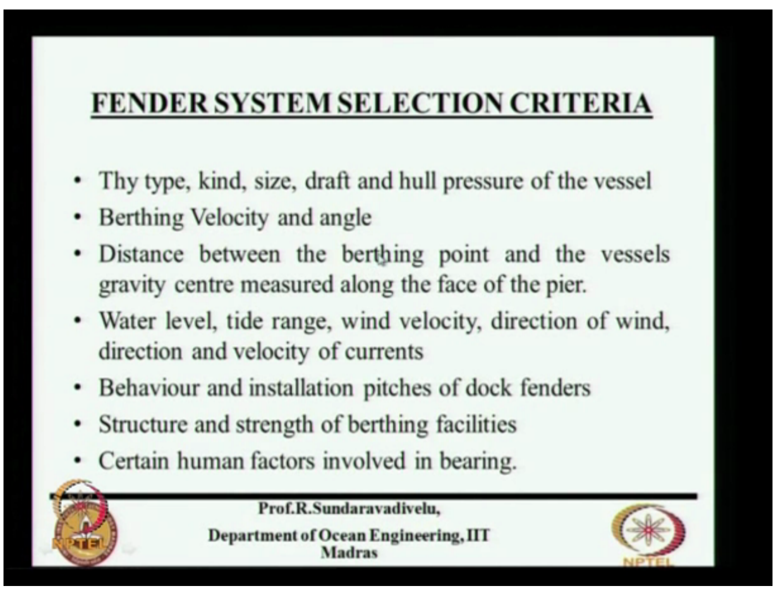

So next we will see how to select the fender. Before that, I will draw this force-displacement relationship.

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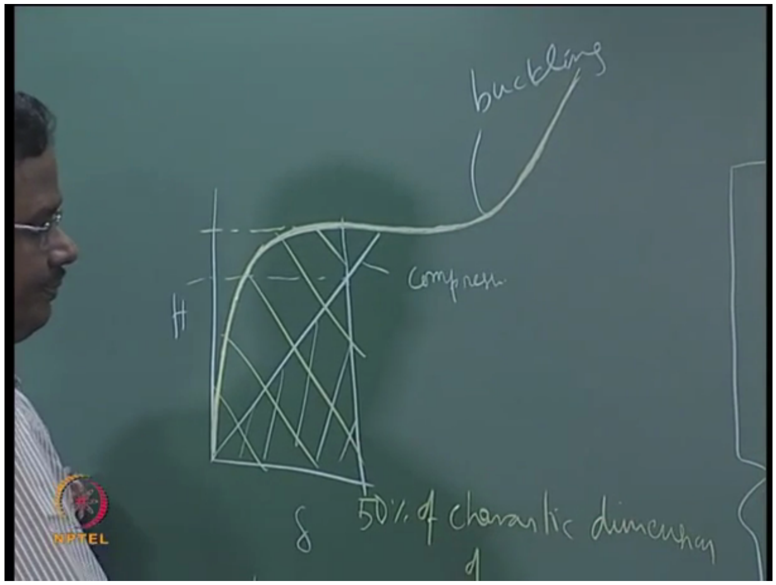

So this is what is used for direct compression fenders. This is a relationship for buckling fender. I may be asking question in this throughout the load-deflection relationship for direct compression and buckling fender. So if the same deflection is there for a buckling fender, the energy absorption is increased by this much amount. See here, energy absorption is almost twice, that of the direct compression fender. So your reaction will be the slightly higher.

For this, this is the reaction but with slight increase in reaction for a same deflection, we will get more energy. The yellow curve is for the buckling fender. So it buckles here, then it increases beyond certain deflection level. So your energy should not go beyond this, then the reaction will be higher. This is equal to, generally is called as 50 percent of characteristic dimension of the fender.

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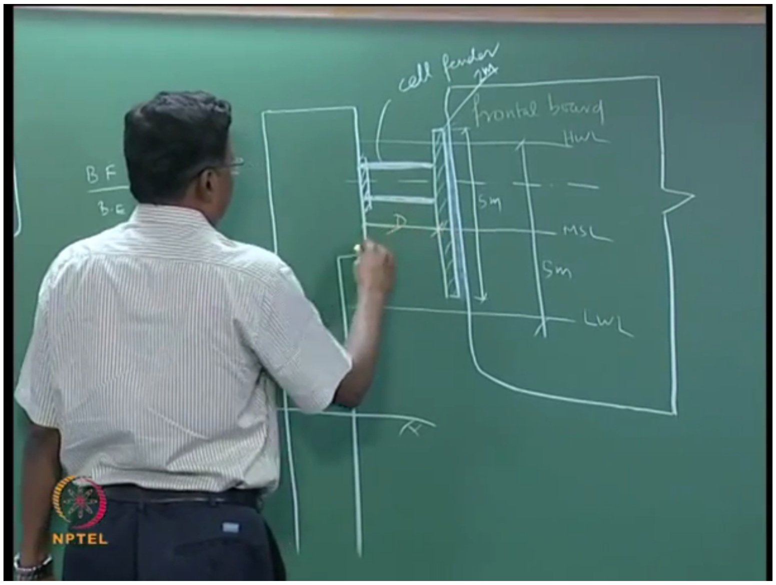

For this case, the characteristic dimension is nothing but this size. This is called characteristic dimension. So 50 percent of the dimension, you get.

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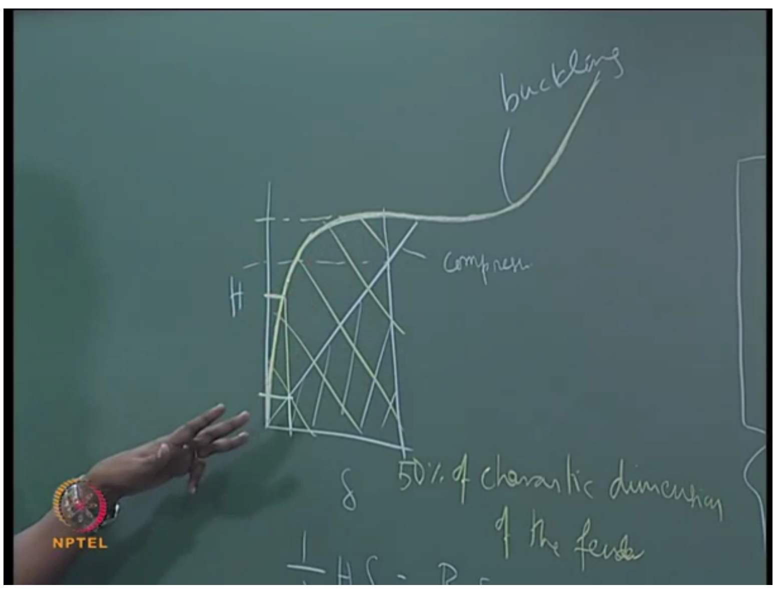

One more thing we were telling is even if the energy is small, suppose you want to take only this much deflection, the reaction is this much. Whereas in this case, for the other fender the reaction is less. This point is clear. This is what we are discussing in point. Even for very small deflection, very small energy to be absorbed, the reaction level will be very high because this curve is steeper compared to this curve. Whereas this fender we prefer for smaller vessels because the reaction will be less. Smaller vessel, reaction will be less. Bigger vessel, reaction will be higher.

Whereas if you put this fender, smaller vessel also reaction will be high, it will not be very much less. Higher vessel also, it will be very much high. And it should not go beyond this point. If it goes beyond this point, then this increase is very high, so we should not do that.

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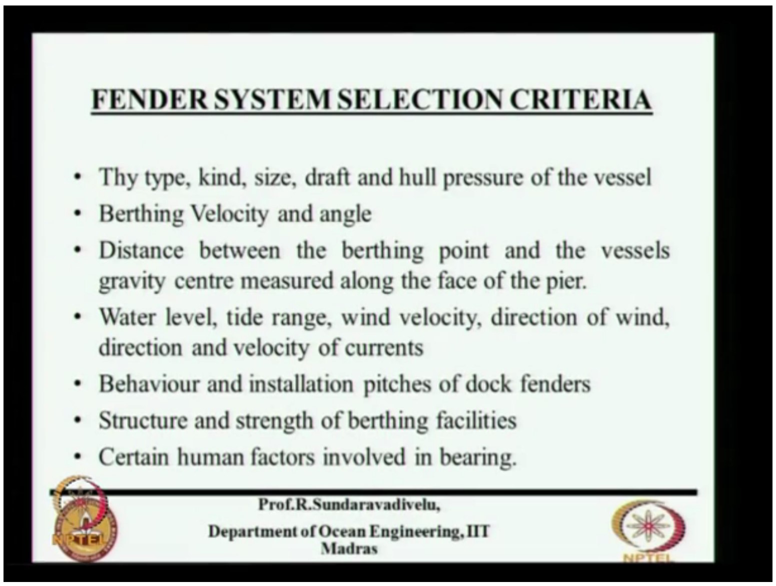

So this fender system selection criteria also I may ask. So this type, kind, size, draft and hull pressure of the vessel. Size you know, all of you know what is a size dwt, that governs the berthing energy. Draft is what will be the fully loaded draft. Hull pressure is between 20 tons to 40 tons per meter square. The type and kind generally it classifies whether it is, what type of cargo it handles and things like that. Whether it is a bulk carrier, it is POL vessel, container vessel and things like that.

The most important thing is this berthing velocity and angle of approach. Angle of approach is generally 0 degree for small vessels. For bigger vessels it goes up to 10 degrees, I am sorry, for smaller vessels it may go up to 20 degrees, for bigger vessels 0 to 10 degree.

“Professor-student conversation starts.”

Professor: Berthing velocity, you should remember the range. What is the range of berthing velocity? What is a velocity which ship can come and hit? What is smallest value to highest value?

Student: 0.3 meter.

Professor: Uhh….?

Student: 0.3.

Professor: Range you have to tell. Two values you have to tell, lowest value to highest value. Lowest is about 0.1 meter per second. Highest will be 0.75 meter per second. The highest value is for smaller values, smaller vessels. 0.1 meter per second to 0.75 meter per second.

"Professor-student conversation ends."

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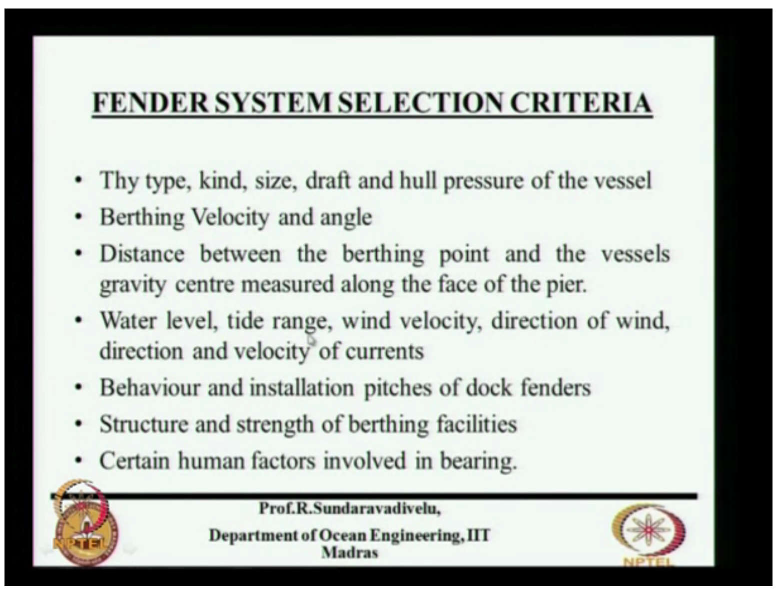

This water level, already we have explained what is a thing. Tide range also we have explained. This wind velocity is when the vessel in position, this will be important. Direction of wind and velocity of currents. Behavior and installation pitches of dock fenders, that is at what interval we have to put the fender. This interval is typically 0.1 times length of the vessel.

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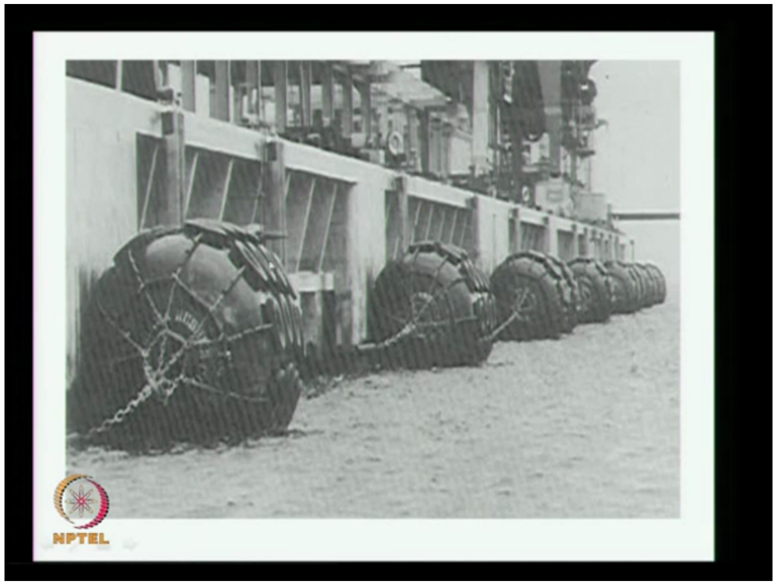

Suppose you have a fender like this placed. Installation pitch means the center to center of the two fenders, this distance is typically about 10 percent of the length of the vessel. Suppose the length of the vessel is 250 meter, then this distance is about 25 meters.

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These vessels are small length in nature. These vessels may vary from 40 meter to 70 meters. So in that case the center to center is 4 meters. That is why it is at very small spacing.

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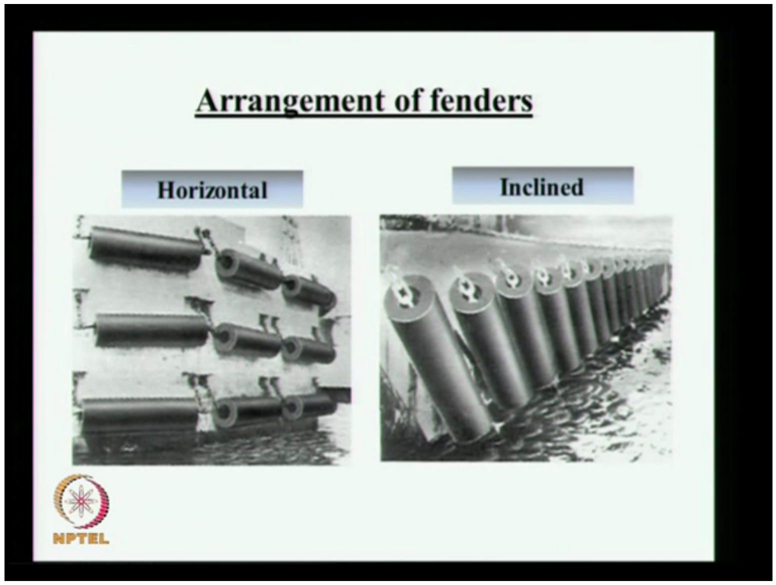

This is also for smaller size fenders. So almost it is continuous.

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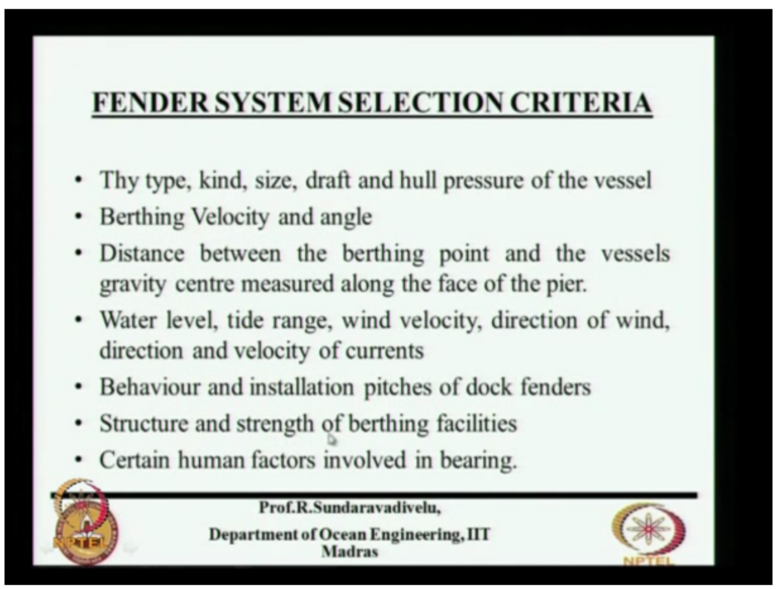

Structure and strength of berthing facilities, then certain human factors involved in berthing. This is a typing mistake here. Human factors means when you are, it is very difficult to control the vessel because very big vessel, the vessel with the engine on, it is very easy to control. That is why I asked you whether you have gone in for slow cycle race under. So slow cycle race if you go, you will find it is very difficult to control the cycle.

We go with speed, it is possible to control easily not a slow cycle. Same way the vessel also normally it operates at 15 knots, 15 to 20 knots. That is about 10 meter per second. We are operating at one hundredth of that in berthing while moving out only one-fourth of that, 2 to 3 knots only we will have. Very difficult to control the propeller handle and you have tug assistance. So unless the pilot is understanding the configuration of the berth and the characteristics of the vessel, very difficult to either berthing or deberthing.

We have seen many failure that are taking place when they are taking the vessel out. So once when they want to take the vessel out from the berth, it went out but instead of going out it was coming back to keep the berth, it has taken only 2 minutes to come and hit. Within 2 minutes he is not able to control the vessel and take it back. But see, suppose this is a berthing structure, let us say that there is a berth here and he has come out here like this and he was going like this, so going like this he has come and hitting here. It is coming and hitting one more berth here. So he has seen that it is going to hit but he has given all the control but it just touches and it has left.

Because the distance is very short about 30-40 meters, somehow he will, instead of rotating the control the right side, he has started rotating on the left hand. By the time he realized now, he thought the ship is going forward and ship was going backward. So very difficult for him to control it.

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These are some of the fixtures that will be adopted. You are seeing the fixtures also.

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This particular slide, you can see the lowest water level is here, how they have fixed the highest water level, these two levels. Bottom of the fender and top of the fender, how the chain is connected. When the vessel is there touching the water, there is so much of free board. So it is not required that your bottom of the fender is going to the right up to the low water level. But you can see the shape of the vessel. So only in the middle portion of the vessel, the berthing will be taking place.

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These are the fenders which are attached intervals.

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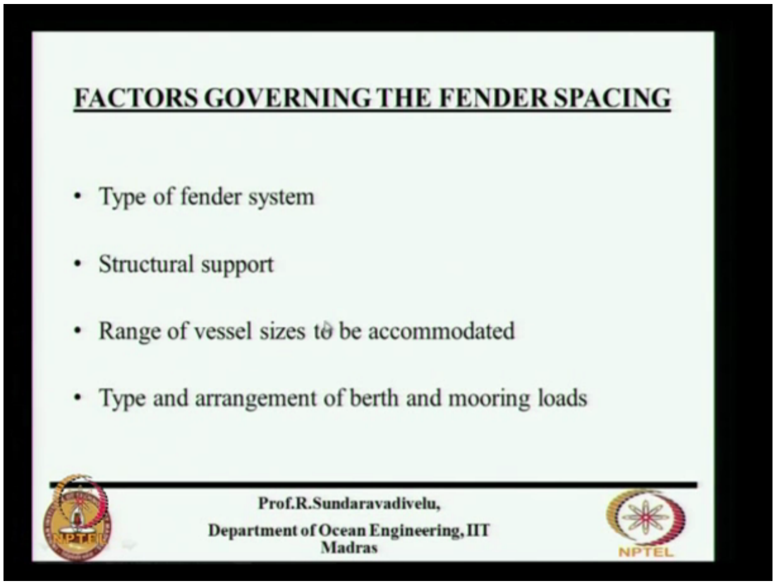

So what is the factor that govern the fender spacing? Type of fender system, structural support, range of vessel sizes to be accommodated, type and arrangement of berth and mooring loads, this only govern how to design the fenders. I told about 0.1 times the length of the vessel, that is one consideration.

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I am inspecting one fender here, this is at Goa port. Because of wear and tear, you can see how it has failed here. So you see the height of the fender is almost equal to my height. If certain failure takes place, there is no repair, you just remove it and replace it. Normally when you procure a fender, suppose 12 fenders are required for a berth, they are 20 percent extra. Out of 16 fenders, 4 they keep it with them. Whenever it fails, they remove the fender and replace it. This type of fenders are very prone to failure, that is why nowadays we do not recommend this type of fender. This is also a buckling type fender only.

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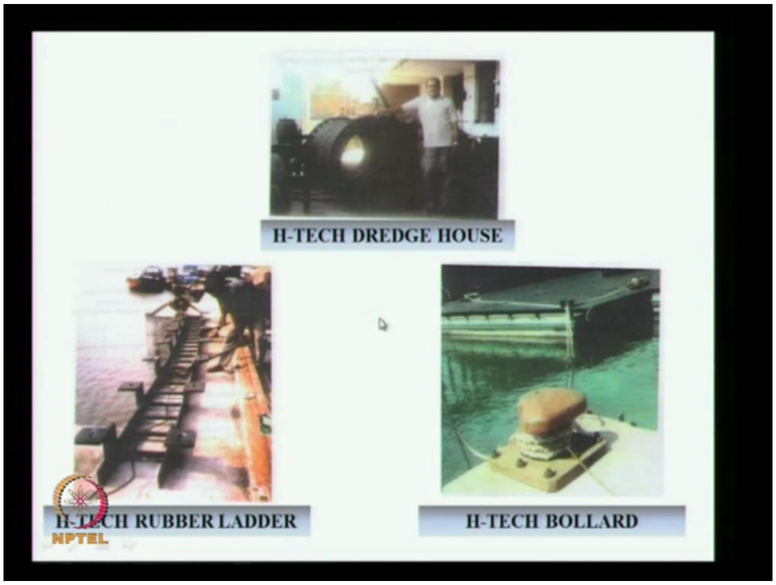

This is a ladder what they will be fixing. This is a bollard, the company is called as Hi-Tech. This, they make some, dredge house also they make.

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These are the mooring aids which are fixed.

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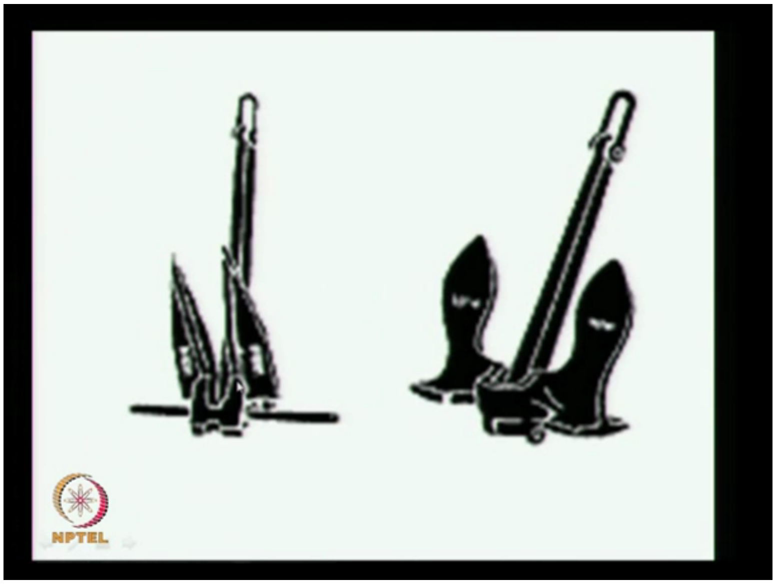

These are the anchors which are used for a ship. So this I will conclude my lecture.