Port and Harbour Structures
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Module 4, Lecture 21
Design of Offshore Berthing, Structures-1

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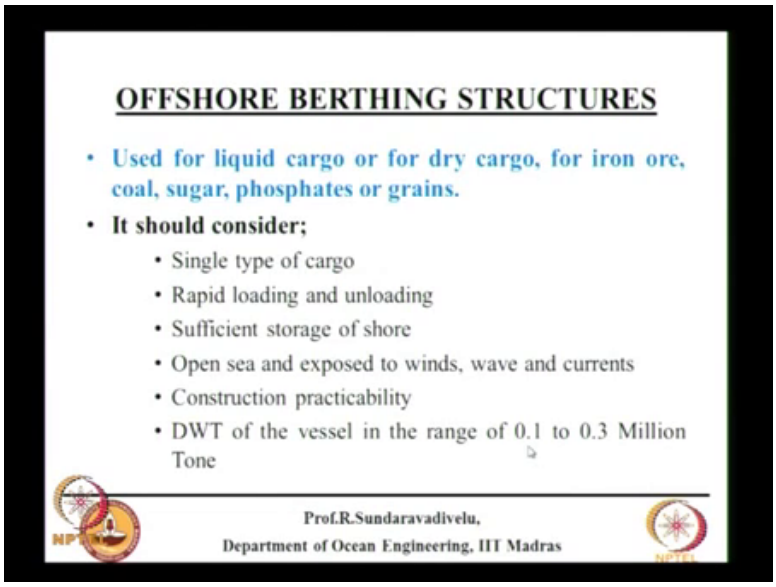

Last class we are discussing about Berthing structures inside the Harbour either a artificial harbour or a natural harbour. But we have what is known as off shore berthing structures that means the environmental not be protected but you may build it in out shore exposed to sea condition. This may not be all weather; all weather means this may not all the 365 days may be for 270 days or so. And mainly this is used for larger vessels. Larger vessel means 0.1 to 0.3 million tons typically about 0.3 million ton dwt vessel that is about 20 to 23 meter draft.

In India we have this type of facilities using a Single buoy mooring in (())(01:01) in the Gulf of kuch to handle PLCCs that was the first structure which was built like that we have many Single buoy mooring systems. Then we have a approach tussle for a long distance may be 7 or 8 kilo meters then berthing and mooring dolphin is being built in Dahej gulf of Combay for liquid Cargo. Mainly it is used for liquid cargo but it also can be used for die cargo mainly for iron ore, coal, sugar, phosphates or grinds.

In Australia Indonesia and other places we have these off shore berthing structures, but mainly these structures are built for a single type of cargo that is only one type of cargo it is for liquid it is for only for crude oil. If it is dry cargo if it is designed for iron ore it is only for

iron ore. Rapid loading and unloading rates, unloading loading rates is generally about 1000 500 tons per hour but here it may go even upto 4000 tons per hour and if it needs sufficient storage offshore and main problem is it is open sea and it is exposed to winds wave and currents. So current is also predominant in Gulf of Combay.

And another is construction practicability other we can build the structure. Another problems associated with the offshore berthing structure is I told you the top level of the structure is high tide level plus there is a gap from the water surface to the bottom of the deck, whereas in the open sea out shore berthing structure the top level can be plus 20 meters, plus 20 means it is 6 story height above the lowest water level. In the high general the top level is plus 20.

In Nagapatnam we have a out shore berthing structure for Chennai petroleum chemical limited CPCL the top level is plus 11. Say adjacent Nagapatnam the top level is only plus 4 whereas here it is 7 meter more. This is to take care of the waves which are breaking on the structure during this type of cyclones storms and things like that. So this goes to about 25 meter of the water depth for larger vessels. Nagapatnam it is only upto 12 meter water depth. Even then 8 meters rays will come, so when 8 meter wave comes above the high tide level you have to provide sufficient clearance that is why it is there.

So we will discuss about the off shore berthing structure separately with a figures for a Single buoy mooring system as well as approach tussle with berthing dolphins. But these structures can be built only if the cargo to be handled is very huge may be more than 10 million tons of cargo at a berth.

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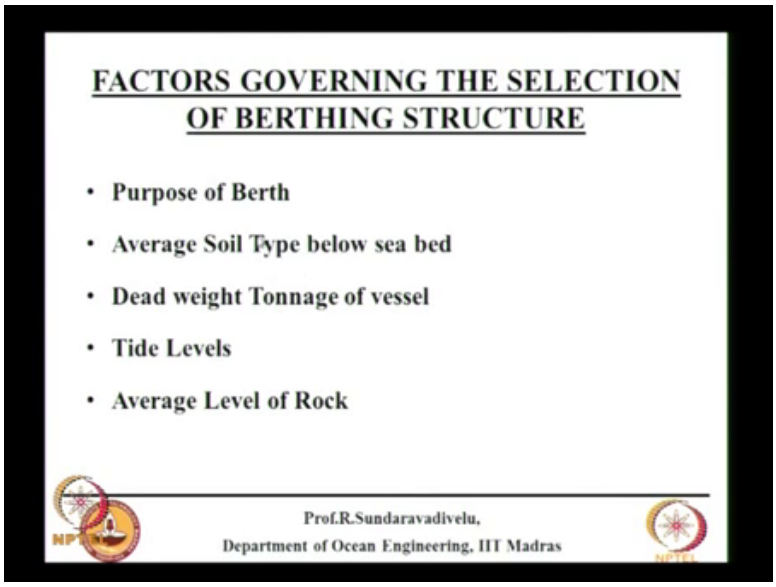

Now we have to see what are all the factors governing the selection of berthing structure, this is very important what type of structure you can choose depends on the purpose of the berth where it is loading unloading, type of cargo, average soil type below the sea bed, Dead weight tonnage of the vessel, tidal levels the average level of rock where the piles can be found at. So these are the factors which will come at, So we will discuss these when we choose any typical situation in a berthing structure.

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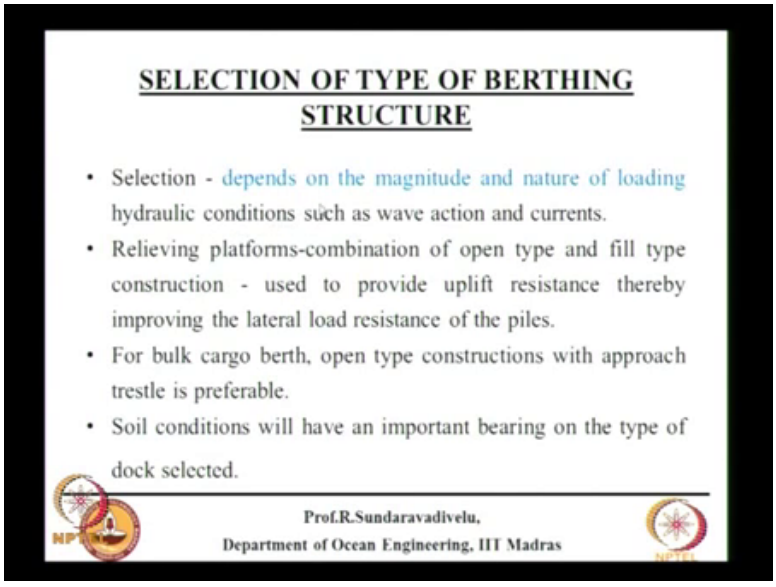

The selection depends on the magnitude and nature of loading this we will see in the next lecture, hydraulic conditions such as wave action and currents and the relieving platforms, it

is a combination of open type and fill type construction, this is to provide uplift resistance thereby improving the lateral load resistance of the piles. This I will discuss with the example, for bulk cargo berth open type constructions with approach trestle is preferable. Mainly the soil conditions will have an important bearing on the type of doc selected. So it depends mainly on the soil condition or type of structure that is to be preferred.

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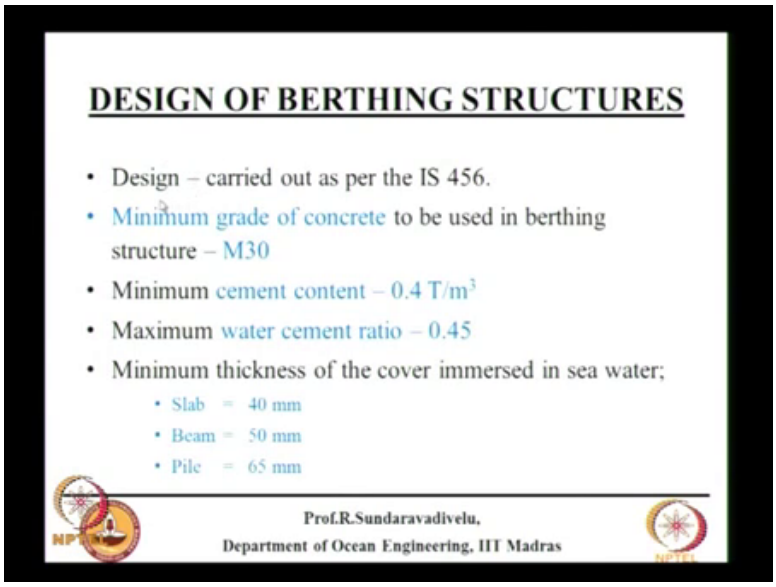

And there are certain provisions that you have to follow mainly the design has to be carried out as per IS 456 discuss in the next slide about the type of design which will carry out. The minimum grade of concrete is M 30, 30 means 30 mega Pascal is the compressive strength of concrete cube, minimum cement content should be 400 kg per cubic meter 50 kg is 1 bag of cement minimum 8 bag of cement it can be more than this, it should not be less than this least you ensure the durability.

Then the maximum water cement ratio should be 0.45 that is if we reduce the water cement ratio your grade of concrete will improve but to take care of workability we need higher quantity of water but if the water is increasing durability will be a problem. I will discuss separately M 30, 30 defines the strength durability I will discuss separately.

To ensure durability you should have lesser water cement ratio and to increase the durability we have to increase the cover thickness for slab you have to provide 40 millimetres, beam 50 millimetres, pile 65 millimetres is a general guideline but if we go to IS 456 they give for different exposure condition what is required to be provided. So all these things you have to specify while doing the construction.

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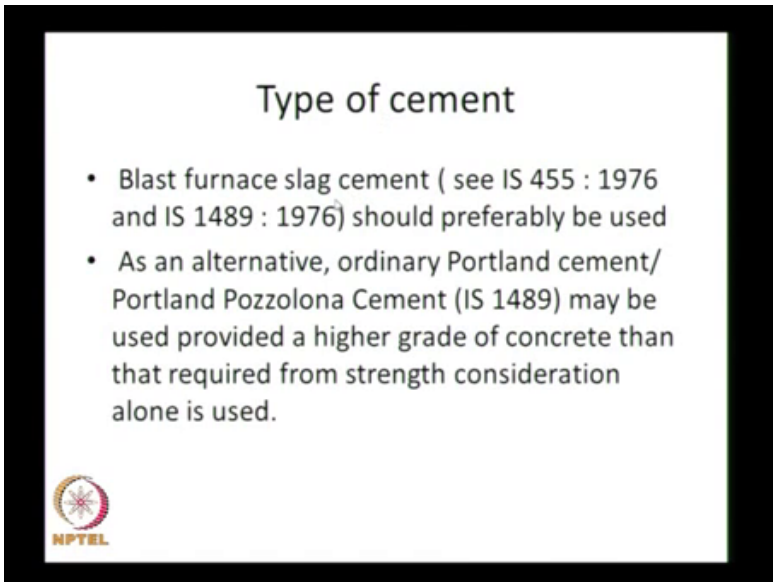

And there are different types of cement what is normally used is ordinary Portland cement while it is preferable to use a blast furnace slag cement it is again to ensure the durability but if we use a ordinary Portland cement you have to provide a higher grade than required from the strength consideration alone that is what is specified in IS 4561 that means M 30 grade is specified for the strength calculations if we use blast furnace slag cement you can use M 30, but if you use ordinary Portland cement you have to use M 35 that is what is specified many people do not follow that.

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Then the cover also depends on 3 zones I am sorry 4 zones, one is atmospheric zone that is above the splash zone and where direct wave or spray impingement it is in frequent that is slightly above the high tide level that is atmospheric zone. Splash zone is where there is a water level variation where there is a wave splashing where the cover should be higher, when there is a continuous sea water immersion, we can put 75 mm from 0.5 meter below lowest astronomical tide to the sea bed level.

Below the sea bed level we can put 50 millimetre, the provision is we are having a pile the cover need not have to be uniform. But generally we provide uniform cover of 75 millimetres but what they say is above the splash zone and below the sea bed we can reduce the cover to 50 millimetres. What is the implication of cover and the design?

Is there any implication? Corrosion, corrosion design I am asking to, to improve movement carrying capacity, yeah if you have a lesser cover the movement carrying capacity will be increased, to take care of that you can reduce the cover. This way we can see you can say why we can provide 75 mm throughout, you can provide till restrict the corrosion but if you provide a lesser cover for the same diameter of the pile the movement carrying capacity will be higher that is why you provide a lesser cover.

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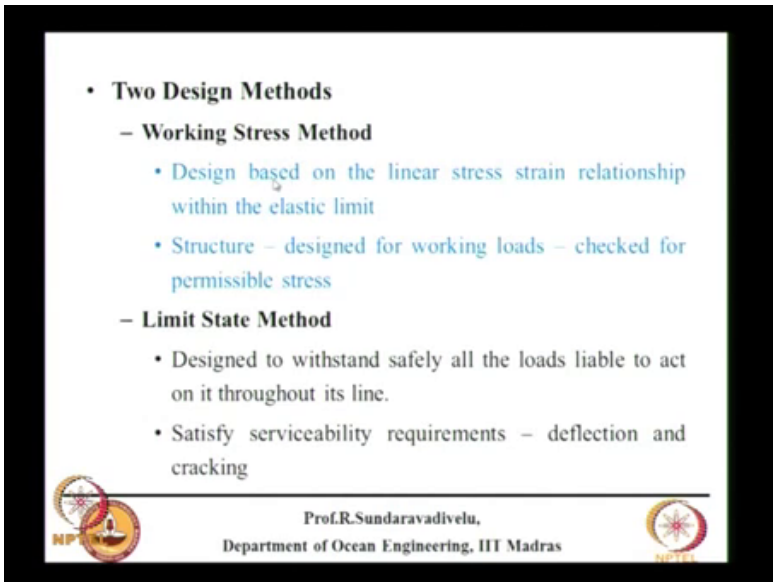

There are two methods which are used for the design one is called as a working stress design another is called as a limit state design. Earlier people are using working stress method, now days they are using limit state method. This design is based on linear stress strain relationship

within the elastic limit. The structure is designed for working loads checked for permissible stresses. So I request all of you to go through this slide.

I told if some question is asked you have to answer the answer is like this. Working stress you design it for the working loads. There is a dead load you design it only for the dead load we do not increase the load. And we take this stress strain relationship to be linear. The stress strain is not linear is non linear but you take it upto the elastic limit, and you check it along the permissible stresses. Permissible stresses is there is a M 30 grade of concrete and it is a permissible axial compressible stress M 30 means it piles at 30 mega Pascal.

What is a permissible axial stress? One fourth of sigma permissible bending compression one third permissible bending compressions is one third and permissible direct compression is less than that may be 75 percent or 80 percent of that. So M 30 mega Pascal means the strength of the material is 30 it fails only at 30 mega Pascal, but we take the permissible direct permissible bending compression as one third of that, that is 10 mega Pascal. That means in that range it will be linear.

And the elastic limit we are considering as one third of crushing strength, ok. But limit state we want to design it withstand all the loads liable to act on it throughout its life, it is a mistake here throughout its life. That means we assume the load as probably stick we assume the return period of the load and trying to find out how much is the load.

Suppose we assume that the load acting on the structure is x for a return period of 60 years the load may be around 1.2 times x if it is 100 years it may be 1.5 times x. So depending upon the return period we can increase the load. And it also has to satisfy serviceability requirements that is both deflection and cracking is what we do. But one thing is we check for permissible stress. The permissible stress what we are assuming is the yield stress divided by 1.5 that if it is 30 mega Pascal we assume that it can go upto 30 by 1.5 that is 20 Mega Pascal.

If it is steel 415 mega Pascal divided by 1.15 is it clear? Here it is only one third whereas here what we are assuming is 0.67, two third we are assuming for for concrete, for steel it is 1 by 1.15 that is 0.87. So the limit state method the factor what is given is different for steel, different for concrete, the load factor what is assumed depends on the type of load which is active act pressure or differential water pressure load fact is 1.2 which is dead load, live load,

crane load the load factor is 1.5 which is a wave load depends on the return period of the load.

So I have given three different methods to estimate the load factor one is depending on the type of the load, active act pressure or differential water pressure. This will not increase enormously that is 1.2 is the maximum load factor if it is a live load it can be 1.5, if it is a wave force it depends on the return period (())(13:12). Serviceability requirement is without any load factor you do the analysis try to get the deflection and cracking. Here there is no load factor for serviceability requirement there is no load factor given for the given to the load in limit state method.

Just like working stress method only we do not give any load factor you calculate the deflection and crack width and check whether the deflection and crack width are within the limits, deflection is span by 350 crack width is between 0.1 to 0.3 millimetres. We check these two cases. So this is what we have to do in limit state method. This is for concrete structures for still structures it is different.

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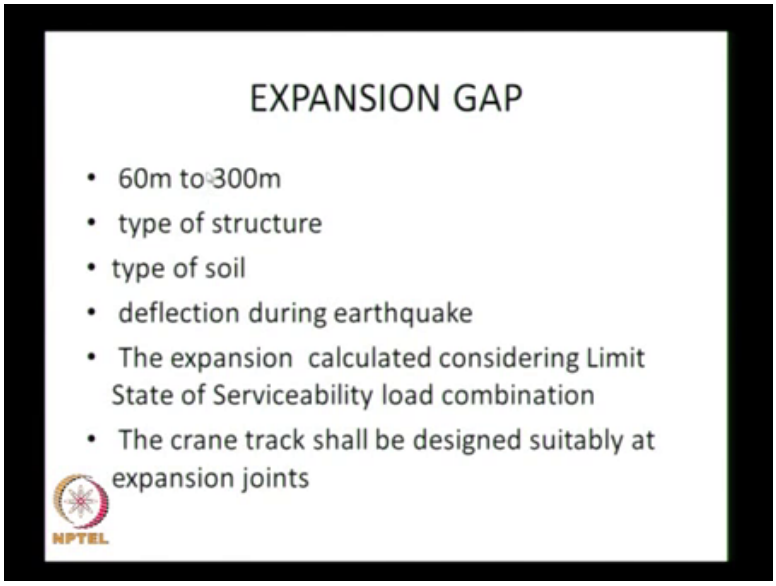

Another important parameter is expansion gap. This expansion gap varies suppose you have a 300 meter long structure, some places like Tuticorin we have built without any expansion gap at other locations at every 60 meter intervals you have to provide the expansion gaps and depends on the type of structure there is a open type structure or a solid type structure again it depends on the type of soil for a length of 300 meters if you make 5 bore holes each 4 holes give a different type of soil.

Then you provide for each bore hole location one block the type of soil is, type of soil is different it happens in Port Blair every 50 meters the rock level varies sometimes even every 30 meters. At first bore hole the rock is at minus 15 the second bore hole the rock may be at minus 30 third bore hole it is minus 12, so we cannot penetrate the pile very deep into rock. So in that case you have to give the expansion gap then deflection during earth quake there is no permissible deflection for earth quake. But when earth quake happens when there is a deflection you should provide sufficient expansion gap.

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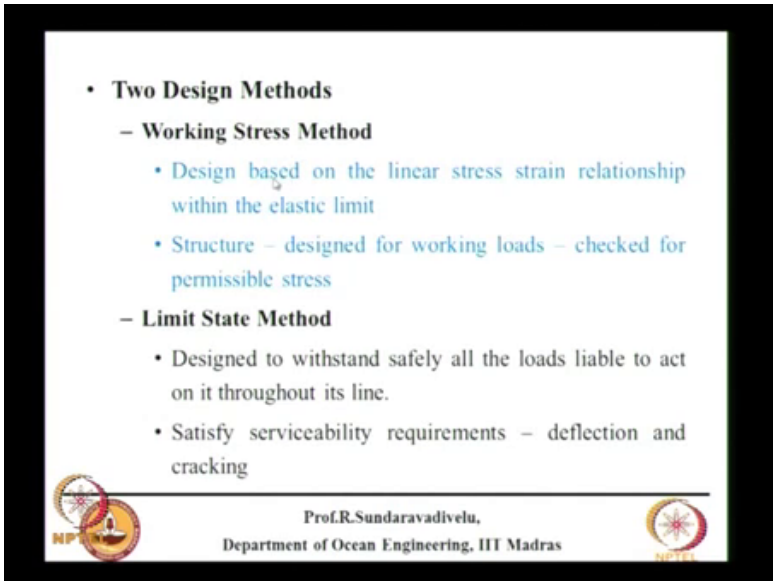

So previous slide I told about deflection, deflection is not checked for all the load combinations if you want to check for expansion I am sorry if you want to check the deflection for earth quake span by 350 or if you want to check the deflection for berthing force it may not be possible because the forces are very heavy this occurs once in a while. If you want to restrict the deflection the cost will be very high, deflection is checked only for permanent loads: dead load, live load, earth pressure, and differential water pressure. Not for occasional loads like berthing force, mooring force are done.

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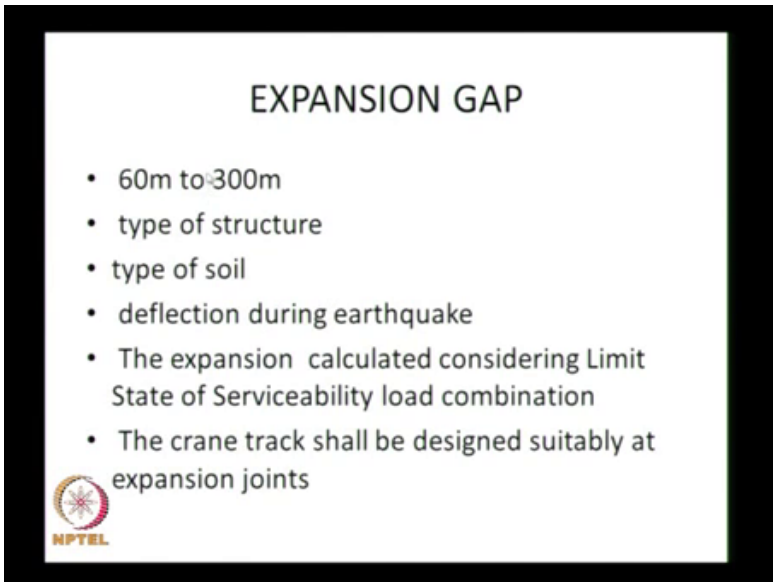

But expansion gap you have to check for earth quake, otherwise one block will collide with another block. The expansion is also calculated considering the limit state of serviceability load combination. The crane track shall be designed suitably at expansion joint, this is another important thing. Suppose you provide more gap at the expansion joint when the rail is moving, when the rail is placed and the crane is moving at the expansion gap there should not be any problem. So you have to design it suitably, so this design is very important it is expansion gap.

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This is a typical passenger berth, you can see the top level is higher people can go down like this also or there can be a ladder also here like this.

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Then we have a cargo berth here we have the cranes here you are seeing there is a crane rail on the sea side there is another crane rail on the land side, and this crane there are two cranes this is one crane this is a second crane, this crane is operating on this hatch the other crane is operating on the other hatch.

So that simultaneously remove from the forward as well as after otherwise it will tilt. So we need two cranes, each crane is having two rails sea side rail and land side rail, each rail we have two legs. So totally we have four legs, human beings two legs, cranes are having 4 legs. Each leg typically has 6 wheels sometimes they may have 4 wheels spacing between the wheels is about 1 metre centre to centre. And this is pollution free they polarize it and suck the cargo there won't be pollution at this, some of the ports if you see they will openly remove the cargo that is not desirable.

This is called as a hatch cover, the hatch cover has to be removed then they will take the cargo out like this. Can be used for both loading as well as unloading. You have to take care of the loads due to this you should provide sufficient space also for the crane to move. Typically the rail spacing is about 12 meters can go upto 30 meters for container cranes.

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This another example is bulk cargo or over berth which I have taken here this is the ship and you have the hatch cover the crane is in the ship itself called as the self geared vessel. So you take the cargo from the ship and then put it on a chute here through which it can go to a tipper and it can directly move. So this is a bucket which is used to grab the cargo and put it here. This is the berth the crane is not on the berth, the crane is on the ship itself .

It is not that all bulk cargo or over berth will have the self geared vessels it can be of this type,

or this type,

this is generally used for smaller vessels 30000 dwt vessels,

this is used for bigger vessels.

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This is a typical container berth this photograph is taken from Jawaharlal Nehru port this is berthing face there are approaches here there is a high mass tower here. The vessels will be having containers may be three stacks or 4 stacks or 6 stacks in the vertical direction. This is a ohm so we can lift the container take it here and drop it to the waiting truck. The waiting truck will move away what you are seeing here is a construction which is going on for the extension.

And here you can see the colour difference here so the water level can go upto this which is fully loaded and it is partially loaded the vessel will go up and up and it is going up and up this top should not hit the top of the crane. So this height will be typically about 30 meters because to take care of the free board of the vessel plus number of the containers which is there.

This width is in this particular port is about 20 meters or 22 meters or so that means this will be more than 30 meter this may be around 40 meter or so. And the containers will be on top of the deck, deck will be covered with hatch cover the hatch cover is removed and placed here. So some hatch cover from the ship we have removed the cargo then we have removed the hatch cover kept it here and they take the cargo below the deck top also.

And then put it on the truck and then they move away. And this shows the fender so the water level taken at this time is low tide level. So the fender board is not touching the bottom of the

water level. But when the water level rises it may come upto this. So we have to take care of the under design adequately these are the mooring lines which are connected to weather.

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This is a liquid cargo berth there will be marine unloading arms at the centre is called as a mooring dolphin berthing dolphin so they will take the cargo from the middle and take it out. This is called as a catwalk which is connecting between the ballads the ship may be connected to this mooring dolphin as well as this dolphin also. The ballad is at the middle of the mooring dolphin. So these are the different types of berth that you have to design.

This isolated dolphins is a continuous berth and this berth is located far away from the coarse line because we want to reduce the dredging this berth is very close to the break water this passenger this cargo berth also can be parallel to the break water or the navigation water way.

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Here you have the access to the city very close by and this portion is the pith of the structure which is designed for heavy loads is the backup area. So we will be discussing about design of this portion which is called as the Apron.

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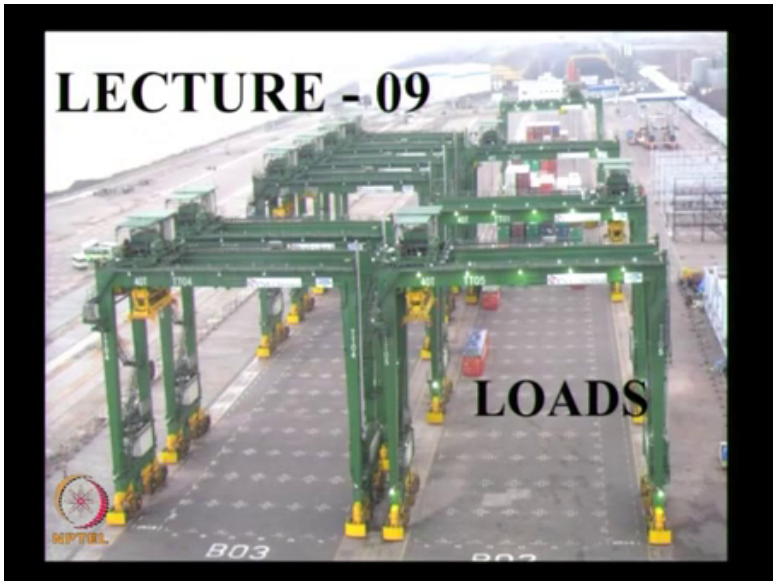

We will go to the next part of the lecture, this is one of the very important lectures which you have to study which is on the loads, what you are seeing in the figure is the containers packing yard where we have the tier mounted cranes which are used to stack the containers at different locations this is far away from the berth this is a stacking yard what you have to design.

Here what you are seeing is some storage tanks which are used for liquid cargo vessels liquid cargo storage. So these are the different storage that are required storage tank for liquid cargo, a container stacking yard, tire mounted pick cranes which are used for picking up the containers.

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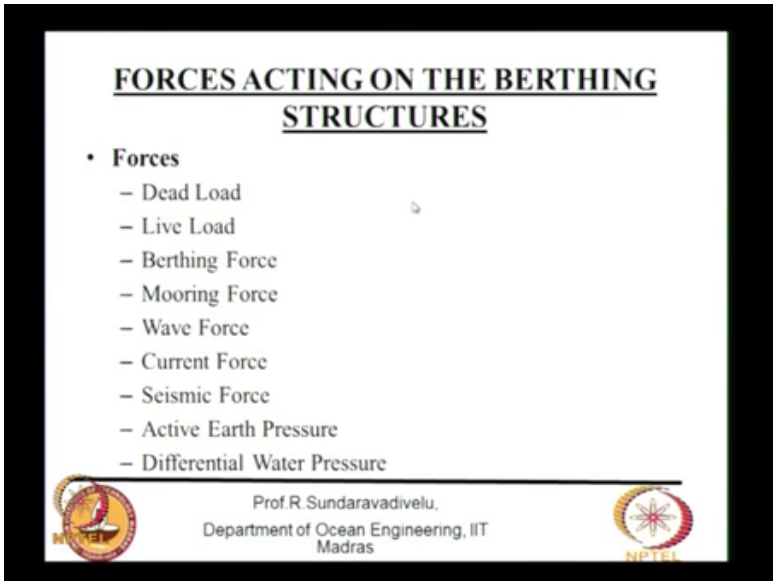

What are the forces that are acting on a berthing structure all of you know dead load that is width if the structure, Live load can be uniform and distributed load, or a Crane load berthing force, Mooring force, Wave force, Current force out of which the berthing and mooring force is due to the ship. The berthing force is due to the acceleration of the ship, mooring force is due to the waves, currents and wind acting on the vessel.

Wave force can be on the structure itself, current force can be on the structure itself. That means the wave and current force can act on the ship wave current and wind, wind is missing wave, current and wind may act on the ship and then they can create mooring force. There is a wind force that can come under live load it can act on a crane from that it can give a horizontal load the current force can act on the structure itself, way force can also act on the structure that means the piles or caissons.

Then we have a Seismic force then active earth pressure and differential water pressure. These are the various forces that are listed which are to be estimated for each individual structure and given as an input for an analysis and design. So this we will discuss how to estimate all these forces. I will give you overview in this class and in subsequent classes I will tell how to calculate each force separately.

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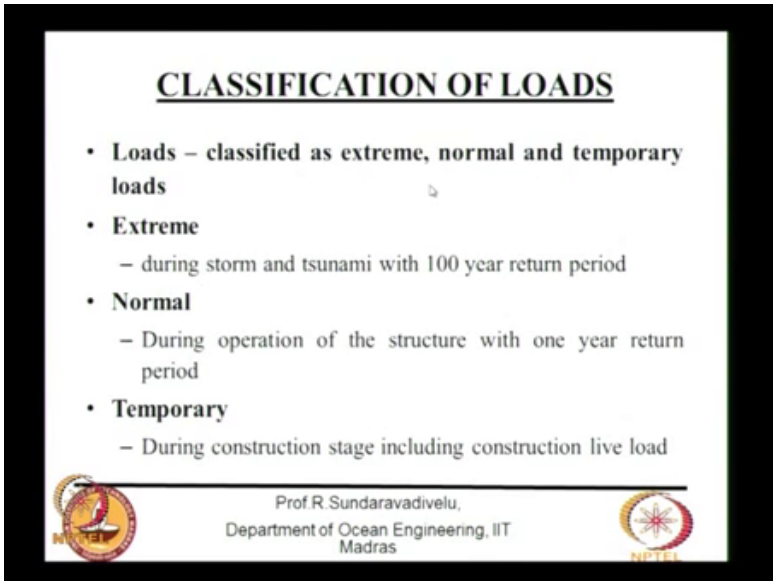

We can classify the load as extreme, normal or temporary. Extreme means it is during storm or cyclone or Tsunami typically with a hundred year return period. Tsunami return period is not 100 years Indian context Tsunami return period is about 500 years, once in 500 years only you get a Tsunami may not be at the same coast, different coast. So storm and cyclone we have to consider 100 years. 100 year means once in 500 years you can have a storm or cyclone.

But once in a 100 years the intensity will be very high so that you have to take care. Normal means during operational structure during one year return period. This is a normal load one year return period means suppose you take the wave height occurred for one year takes the data for typical Chennai coast the one year return period wave height may be about 3 meters. For 100 year return period it may be about 9 meters. If you take 1000 year return period it may be around 10 meters, is it clear?

The load factor is different for extreme case and normal case and into a limit state of design for a extreme case the load factor is different from normal case. That is why you want to classify then temporary that is during construction stage including construction live door. This is for the temporary. Many failures that takes place during construction this is very difficult to understand but most of the failures if at all it has to take place, it takes place during construction itself.

I showed one example where one structure has collapsed, it has not collapsed during construction but during dredging it has collapsed even if it is done before putty use either

during dredging or during construction the collapse will take place, but 90 percent only 10 percent during operation also will take place. So most of our course does not give weightage to temporary load structure nobody does the design also, but for harbor structure construction period is very crucial. So we are introducing this temporary loading as important loading.

I will explain what is temporary loading during construction there will be lot of loads that are to be considered. So you have to use that as an odd stick for the design, is it clear classification? I will be giving two or three types of classification one depend on the return period of the structure, return period is 100 year return period for extreme, only a return period for normal, temporary there is no return period it is during the construction period may be for a during the construction suppose Gant tree is moving for driving the piles.

The construction period may be 15 days then you have to take that load during that time.

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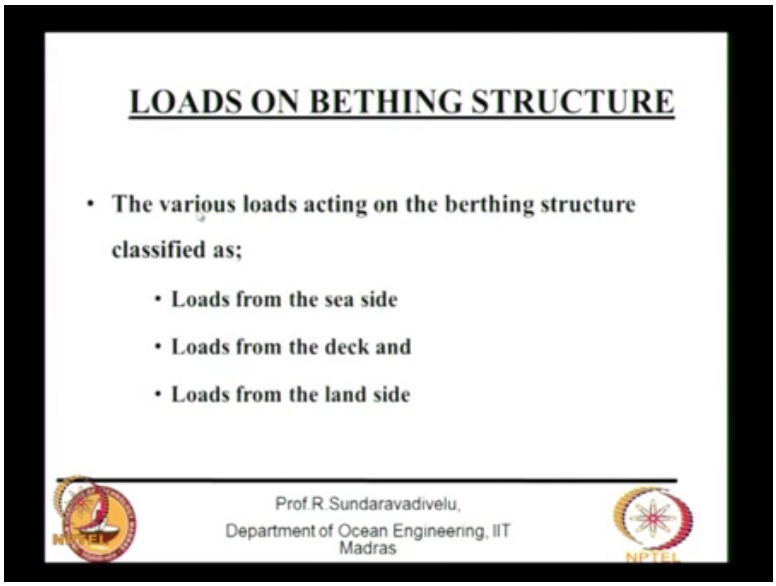

Another type of classification is where the load is coming from whether the load is coming from the sea side or it is coming from the top of the deck or it is coming from the land side. The berthing force or mooring forces are from the sea side active act pressure and differential water pressures are from the land side, crane load is from the deck. Seismic force can be in any direction it can come from the sea, it can come from the land, it can come from the top left to right, diagonal any direction.

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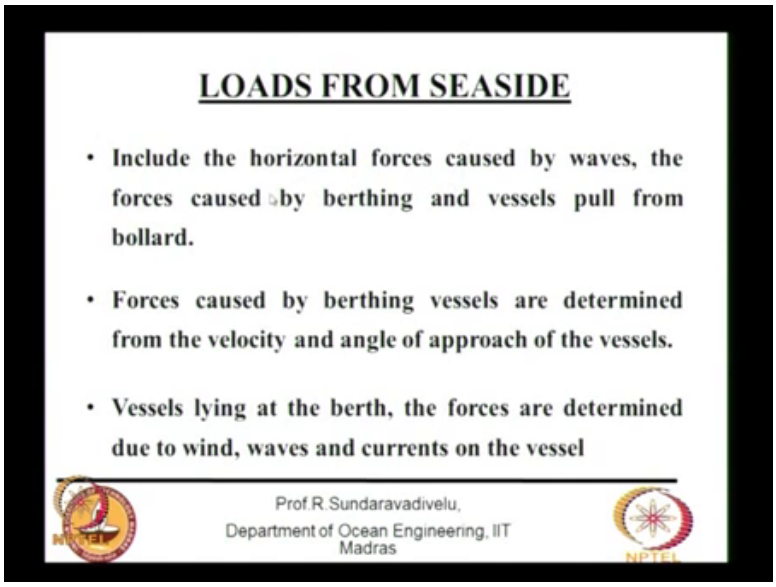

What are the loads from the sea side? It include the horizontal forces we have to talk the loads in two categories one is the horizontal loads another is vertical force. Horizontal forces are caused by the waves, forces caused by the berthing and vessels pull from the Bollard. These are the from the sea side. The forces caused by the berthing vessels are caused by the berthing vessels are determined by the velocity and angle of approach of the vessels basically it depends on the square of the velocity and for that we have to take care of the mass of the vessel also.

The vessels lying at the berth the forces are determined due to wind, waves and current on the vessel. This for the mooring forces we have to find about the wind wave and current. Wind also we can have normal wind and extreme wind. In case of extreme wind we remove the vessel from the berth we do not keep the vessel at the berth. We do not design for all the cases. We specify a wind velocity we say about 20 meter per second is the permissible velocity when the wind speed becomes more than 20 meter per second. We give the instruction to the vessel to move it away from the berth.

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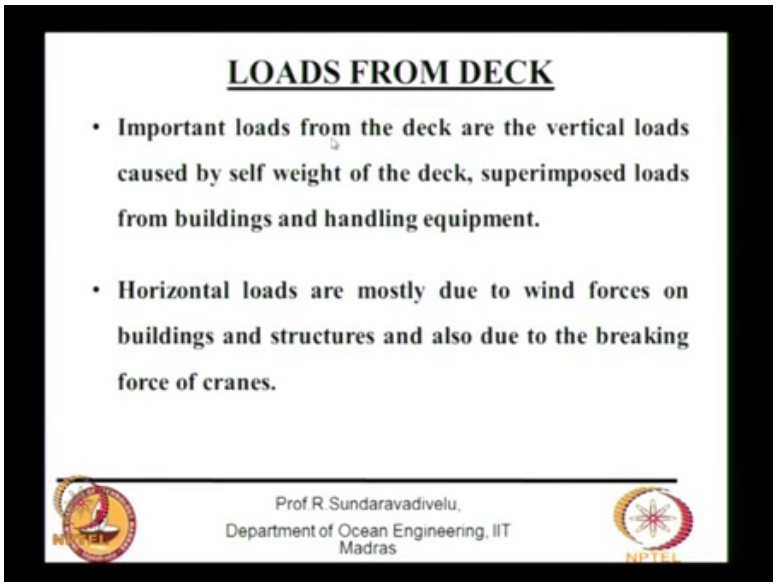

Load from the deck important loads are the vertical loads. These are caused by the sulphide of the deck super imposed loads from the buildings and handling equipment and this also consists of horizontal loads they are mostly due to wind and building and structures and also due to breaking forces of cranes.

So we have both vertical load as well as horizontal load. Vertical loads are right over deck super imposed loads from buildings and handling equipment and horizontal load is due to wind acting on the crane or on the building, it can be lateral and longitudinal and it also can be a breaking force and the crane is moving suddenly apply a brake due to that there is a longitudinal traction that also will give you the breaking force.

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Loads from the land side are caused by the active act pressure and the differential water pressure the vertical loads are caused by the weight of the filling super imposed load on the filling. So from the land side you can have both horizontal loads as well as vertical loads. Horizontal loads are due to earth pressure and differential water pressure. The vertical loads to the surcharge load that is coming on the filling and super imposed load on the filling.

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So now we will talk one by one the loads, dead load, this loads coming on the structure due to sulfide of its various structural components. Live load is due to surcharge due to stored and stacked materials, there are general cargo, bulk cargo, containers loads from vehicular traffic.

It can include trucks, trailers, Railway, cranes, container handling equipment. First slide I have shown the container handling equipment and construction plan they constitute the vertical, vertical live loads.

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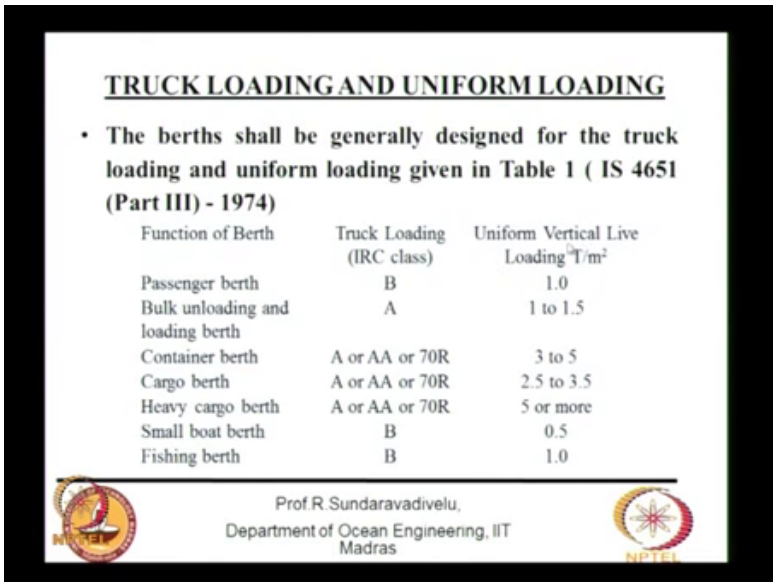

The truck loading this is given in IS 4651 there are two types of loads one is called the IRC plus, what is IRC? Indian Road congress then you have uniformly vertical live load. So depending on the classification of berth you can classify the berth as passenger berth, bulk berth container berth, cargo berth, heavy cargo berth, small boat berth, fishing berth.

So the truck loading is classified as class B, class A, class A, AA or 70R, B and B. It depends on the size of the truck bigger the truck it goes to 70R load, smaller the size of the vessel size of the truck it goes to class B loading. It is given in IRC code and in standard text books number of axles the tyre dimensions and the load coming on each wheel it is given.

But this will govern the design with your passenger berth, you have to take one ton per meter square. But to have some understanding of this load the heaviest load for building is library. Library is the loading is 400 to 500 kg per meter square whereas for a berth it is 1000 kg per meter square. It is twice the load is it clear compared to your building suppose we are sitting here and discussing, this building might have been designed for class room 400 kg per meter square whereas a passenger berth will be designed for 1000 kg per meter square.

Bulk loading or unloading berth 1 to 1.5 tons per meter square, container berth 3 to 5 tons per meter square you see tons per meter square is much more than 500 kg per meter square it is

10 times higher load we are designing and then cargo berth is about 2.5 to 3.5 then heavy cargo means the finishes steel products they are all heavy cargo berths. It can go upto 5, sometimes you design upto 10 tons per meter square that is a amount of cargo for which you have to design. That means your berthing structure is much much heavier than normal buildings.

Then we have the crane loads, so it comes from crane wheels an another mechanical handling equipment. You have to consider impact of 25 percent. What is impact? what do you understand by impact? When it will happen? Railway, in the rail there is sudden impact load, the accident take place impact take place(())(35:33) we are dropping a suppose a crane is lifting a cargo container itself and is dropping from a height then also impact comes. And the impact may come from the wheel also.

So we assume 20 percent as a impact for the wheel loads when it is suddenly stopping and the wheel is moving suddenly apply a brake then also impact will come. And two cranes are moving side by side you have seen 15 percent it is because the crane operator if it is another crane nearby he will not operate with high speed, is it clear? In a berth only one crane is here he will operate at its own speed. But two cranes are nearby they will not operate it high speed that is why they give 15 percent at as a impact factor.

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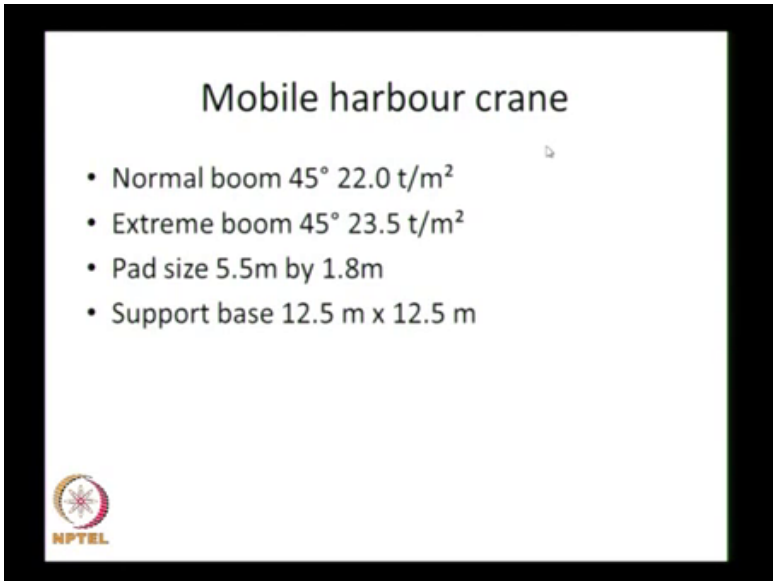

The Mobile Harbour cranes: There load intensity is 22 tons per meter square, this you have to compare with what we have discussed earlier. What is that we have discussed? Normally container berths will have upto cargo berths upto 5 tons per meter square. But if we have a

mobile harbor crane I will show the figure separately instead of wheel it has pad it will have 4 pads two pads on the sea side and two pads on the land side. Each pad is 5.5 meter by 1.8 meter spacing of the base is 12 and half by 12 and half meters.

The load is 22 tons per meter square normal boom, in the extreme position it is 23.5 tons per meter square. So this load also we have to consider which is using a Mobile harbor crane. Now a days many people are using a Mobile harbor cranes.

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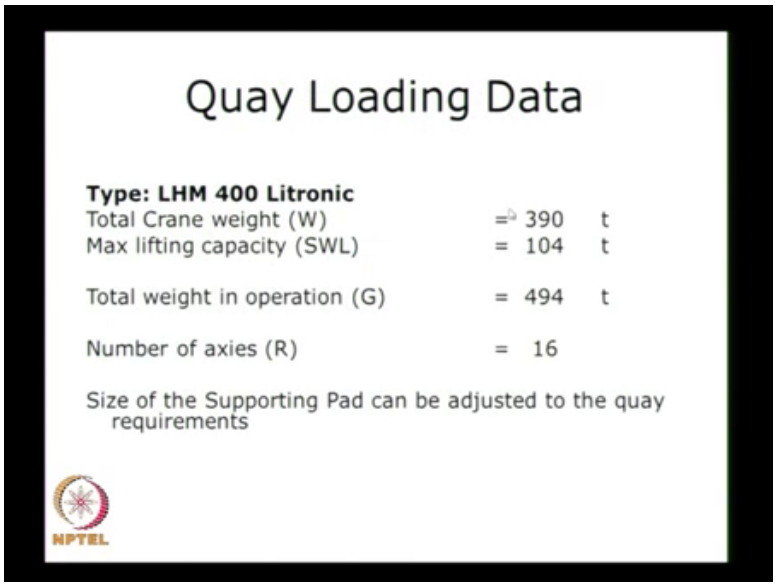

So this is called as one typical crane LHM 400, the weight of the crane is 390 tons about 400 tons it is to lift a cargo of 100 tons. If you want to lift about 100 tons the weight of the crane required is 400 tons. So the total weight is 494, so it moves on a axle that is about 16 axles then it when it is operating the four pads are lowered, all the tyres are lifted up. That time only you have the maximum loading.

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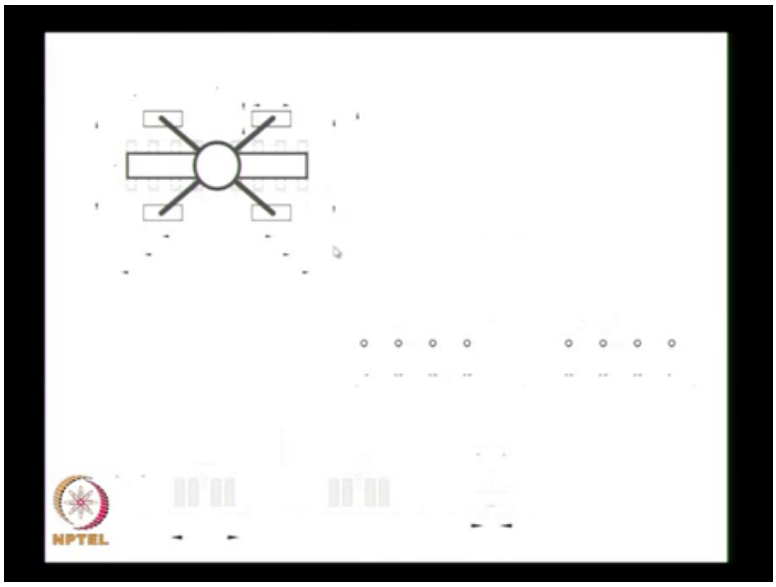

So this shows the photograph of the Mobile Harbour crane, this is a crane with axles here and tyres here and it moves on this tyres. It goes to a particular location then it drops the pads, these are the four pads each pad size is 5.58 meter by 1.8 meter. The centre to centre distance between the pad is about 12.5 meters, this distance also is 12.5 meters. It is what is given here in this figure. Pad size is 5.5 by 1.8 support base is 12.5 by 12.5.

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So it moves on a truck that is what is shown here and tyres. This shows the close-up view of the container crane moving on the rails is not a Mobile harbor crane it is called as a key

crane. This is one leg of the crane, so we have two wheels here like that we have assembly of 4 such units. So totally we have 8 wheels.

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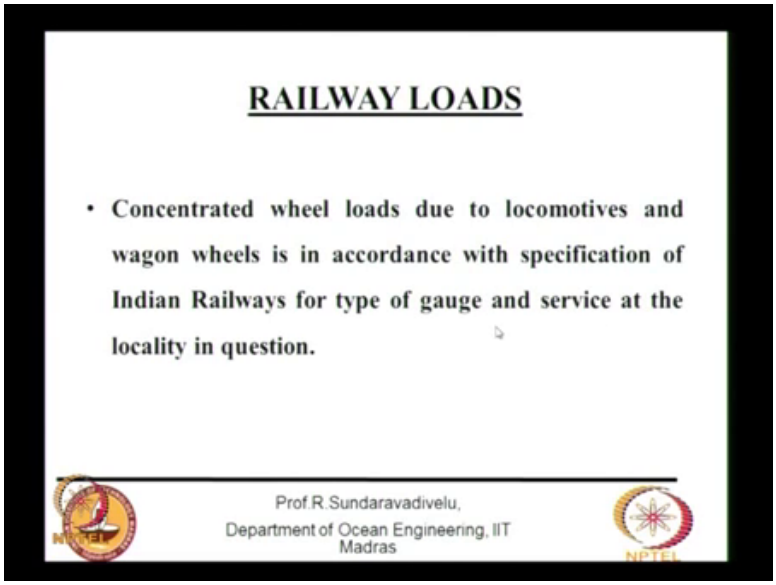

Then we have the railway loads,

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Then we have special loads like pipelines conveyers etc.

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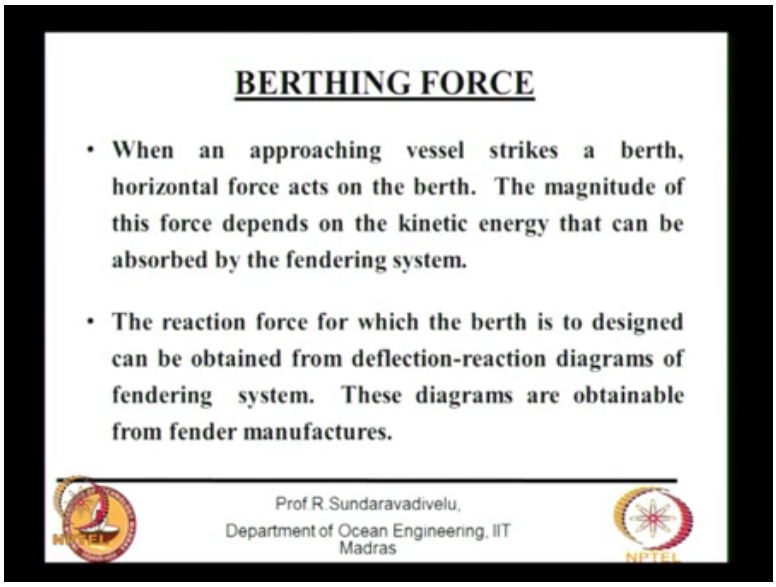

Then we will discuss about this forces in separate class that is about the berthing force, Mooring force, Wave force different type of wave force, current force, Seismic force. I have given some classification here, but next week onwards I will be discussing about this I already discussed how to calculate. So we will discuss about the various forces also in the next class differential water pressure.

With this our load will be completed.