Port and Harbour Structures.
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Module-3.
Lecture-11.
Breakwater.

So we have so far discussed 5 lectures, all these 5 lectures are introductory lectures only. Our course starts only from this lecture 6 onwards. But we have given elaborate introduction because when you want to learn a subject, not for getting grades are marks, you should know what is the background, so the background I have given. The background I have given 5 lecture, all the important points that are to be considered for port and harbour structures. So from now onwards we will be giving in detail about various components.

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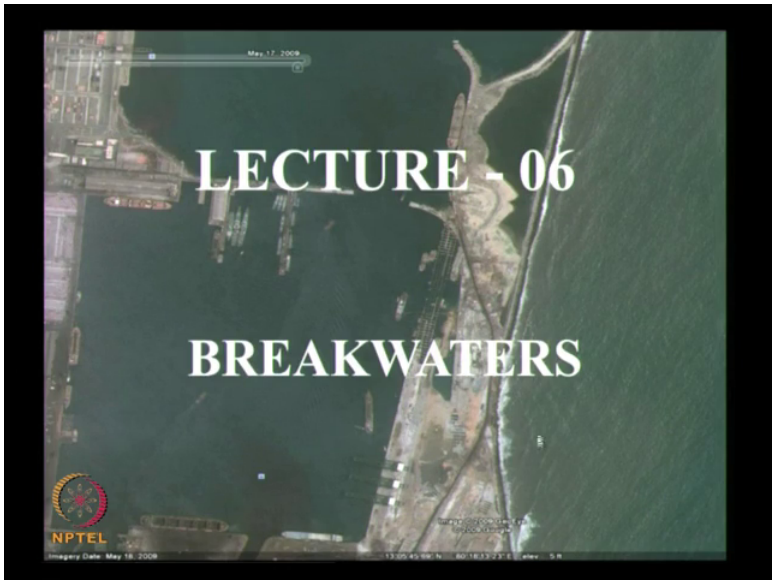

This figure shows the layout of Chennai port, here the construction is going on, as you see here from the satellite imagery, this is the 2nd terminal, this is the entrance to your their word, this is shown here and this is a breakwater which was extended over here like this. Original breakwater alignment you can see here like this, it goes here and goes here like this. This area is being filled up here, that work is on progress. So we are going to discuss about the design of this breakwater, how to design this.

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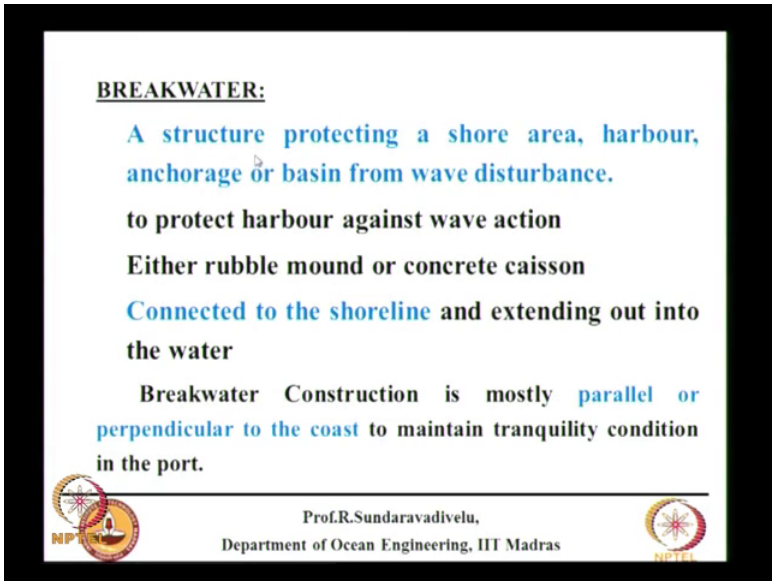

As you see here the waves are coming, they can come in this direction, they can come in any other direction also. So this breakwater should not get disturbed because of these waves, should not get damaged also. 1st definition, breakwater is the structure protecting the shore area harbour, Anchorage, or basin from wave disturbance. It is the general definition but the main purpose is, this is a structure to protect the basin from wave disturbance. It can be 2 types, one is rubble mound, another is concrete caisson. I will show the figures, combination of these 2, that is called as the composite type.

This breakwater can be connected to the shoreline and extending out into the water, but sometimes the construction is, I am sorry, breakwater construction is mostly parallel or perpendicular to the coast. So it is not that it is always parallel to the coast or always perpendicular to the coast. As you see in the previous slide, it can be either parallel or perpendicular to maintain tranquillity. You know what is meant by tranquillity? What is tranquillity? Tranquillity is calm. Tranquillity is a word, the physical meaning is calm, calm condition in the port. Tranquillity means the wave disturbance you said, wave disturbance should be reduced. That is the purpose of the breakwater.

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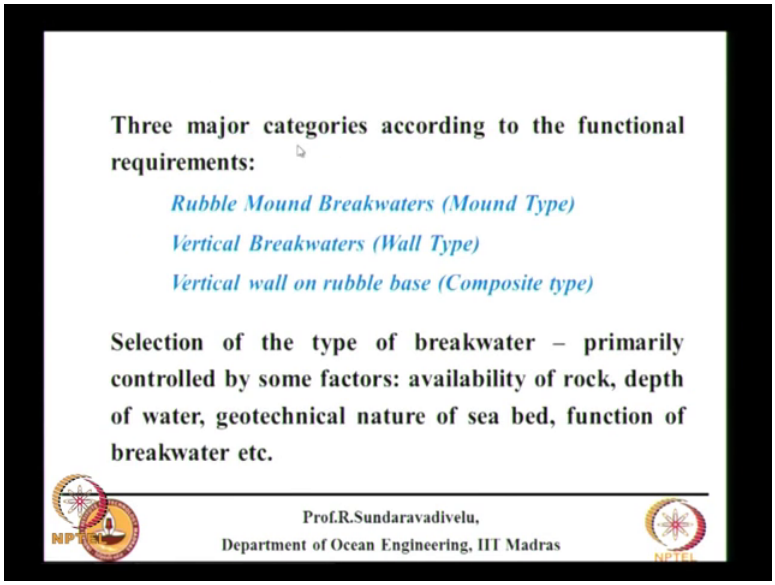

There are 3 major categories according to the functional requirements. One is called is rubble mound breakwaters, or simply called as mound type, the next one is vertical breakwaters, it is called as wall type, then we have vertical wall on rubble base, it is called as composite type. See whenever you study any subject, when we are giving 3 different types, we should find out where each type is used, the reason for that. If you are using vertical wall on rubble base, a composite type, there must be a reason where we have to use them. If you are using a rubble mound, you should know where they are using.

You will get to know more about it at the end of the lecture but in this continuation of this, we will see which type of breakwater is to be selected. These are controlled by some factors, one is availability of rock. The rubble mound breakwater, mostly will be using rock. The rock is available nearby, nearby means how near is near, it is about 30 kilometres, sometimes even 60 kilometres. But if it is more than 100 kilometres, it is not near. Another thing is there should be some, there are certain conditions for this rock, it is not all the rocks can be used for breakwater construction.

So the rock that can be used for construction, if it is available, let us say within 30 kilometres, then we can go in for rubble mound. 60 kilometre also if possible but more than 100 kilometre, we should think of some alternatives. Depth of water, so this depth of water is another important parameter. Suppose the depth of water is less than 15 metres, 15, then we can go for either rubble mound or vertical breakwaters. If the water depth is more than 15 metres, then we have to go for composite type. Greater the water depth, you have to go for composite type.

Geotechnical nature of seabed, so what are the types of soil I said, what are the different types of soil that can be encountered?

Sand and clay.

Sand and clay. There is one more in between that is silt and another soil that is rock. You can have either clay, silt, sand or rock. So out of all these things, if rock is available, that is this availability of rock is for getting the stones for the breakwater, whereas this rock what I am telling is the seabed rock, if seabed rock is available, then we can go in for vertical breakwater. Vertical breakwater is the concrete Caisson type, so the load intensity is very high. So is we have a good foundation, we can go for vertical breakwater.

In Sand if it is a very dense sand, then we can go for vertical breakwater. But if you have a very soft soil, clay or loose sand, then we have to go for rubble mound. It is not only the soil which is governing, we have the other 2 parameters also, you have to see it in combination. Even if the soil is rocky, still we may go for rubble mound breakwater because rock is available, depth is less than 15 metres. The function of breakwater, the function of breakwater is generally to protect the harbour against the waves.

Sometimes what they do is on the Leaside, Leaside means the backside, backside of the breakwater, if we want berthing to be carried out, then we go for wall type, is it clear. Rubble mound breakwater means it has slope on both the sides, seaside and the Harbourside, vertical wall type breakwater means it has vertical face. So one side of the breakwater we can go in for berthing of vessel, that is on the Harbourside, then we go in for vertical breakwaters. So this is the way in which you have to understand the subject, you should know what all the 3 different types, then you should know where it will be used, what condition you have to choose.

But in India we normally use rubble mound breakwater, most of the places. There is one reason for that, that is the technology, availability of construction equipment. Vertical breakwater means you have to build the Caisson elsewhere, either you have to lift it or you have to float it and sink it, that is more expensive. In Indian condition, transporting the rock from the quarry to the site and casing it will be cheaper, because a lot of man-hours required for that. Whereas vertical breakwater, man-hours are less but equipment cost is more.

In Japan and all, they go for vertical breakwater, whereas in India mostly we go for rubble mound breakwater. So if you want to design any structure, either you can use numerical

method or use experimental method. Experimental means physical model studies are to be carried out to see whether the structure what we have designed is appropriate. Mainly in ocean engineering and port and Harbor engineering, we use port and, we use physical model studies. But for breakwater, it is mandatory. You know what is meant by mandatory? What is the meaning?

Compulsory, you have to do a physical model test when you do a rubble mound breakwater. Mainly this is because the formula which is used is semiempirical. Semiempirical means it is not having 100 percent analytical or numerical basis. There are certain formulas which are derived based on experiments and based on certain concepts. So when you are designing that, then there is likelihood of certain inconsistency or certain deficiencies in the design. So to take care of that, you have to do is physical understudy.

Another thing at this level of higher semesters of B tech and post graduation, you should know that whatever structure you are designing, it is sometimes it becomes impossible to make it 100 percent foolproof. So you would have seen the recent cyclone, it is called as the Thani cyclone, what happened, most of the electrical distribution systems have failed, that is the towers have fallen down. You may wonder whether we can design it to resist this wind force. Wind is very high, we have not designed it for that wind force.

Why we are not designing it for that wind force what is the reason? You think that we do not know that this much wind will occur? Then why we are not designing? Or we do not know how to design? Why this failure has taken place? It will take one month to restore the power. Why are we not designing for that wind force?

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What is it?

Occurrence is less.

Occurrence is less, but still occurred.

It is designed for a probability like a hundred-year probability.

For a hundred-year probability, this may come, we may not have used it. Yours is a very good answer but still if it is coming in a hundred-year probability, we may not design, why? See hundred-year is a return period, once in a hundred-year, whatever is the wind that is coming,

you will use it for the design purpose. See it is only the cost factor, if you are designing for the wind, your structure becomes very heavy. Sometimes you may not have the cost, you may not have the finance, you build for that. So these are the 2 reasons, one is what is the return period which you are considering. Mostly what they do is there is certain structures we have seen which are designed for one in a hundred-year return period, they fail, then we go for one in 1000 year return period.

Gulf of Mexico, where we have mostly offshore platforms, certain conditions, we will be designing it for one in 1000 years. Certain conditions means not the design of the structure, we know what is the air Gap is required, air Gap means water level + half the wave height than 1 metre air gap. For that case wave height, we take one in 1000 years, only for the air gap. Because if the wave is hitting the bottom of the deck, the wave force will be enormous, we want to avoid that. You understood no?

The return period that is used for design condition is not the same for all, one needs to find out the forces in the members and another is to design the foundation, the 3rd one is to fix the top level of the structure, for all these things we can use different design wave conditions. Similarly designed wind also you can consider, one is for operation, another is for extreme condition which will be used for which this will not be falling down. I what they have done, whether they have used one in hundred-year wind or otherwise.

Even if they have used one in hundred-year wind, there is what is known as gust. Anybody knows what is gust? For example, you are measuring the wind over a period of let us say 12 hours, can take an average, that is one minute speed. If we measure over a period of 1 minute, over a 12 hour record, you select 1 minute, where the wind is very high, that will be another wind speed. Average is not the same, I think today because of Sarang, the class is very less. You take the average of this class, you take the height and take the average, you will get one height, one average height.

Suppose all the students earlier, you can take an average, another average become, like that depending on which direction you are taking the average, it will be different. Best is for a smaller period, when you take the average. We may not design it for that, even if you take only in hundred-year, you may not take the average of a shorter wind period. So normally in design purpose wind we do it for gust also. So in this case when you do your rubble mound breakwater, what they assume is, they assume about 5 percent damage.

5 percent damage criteria means whenever the wind for wave for which it is designed, it occurs, certain components of the breakwater may get damaged but the damage should be limited to 5 percent. After the damage is over of the, after the cyclonic storm has receded 5 percent damage has occurred, you have to go and repair the structure. It should not be complete collapse but we permit 5 percent damage. That is how the formulas are developed.

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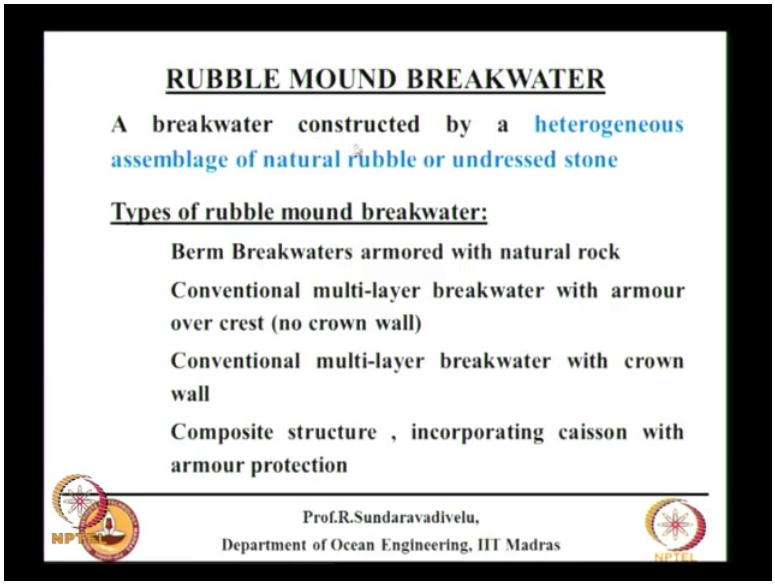

So now we will see rubble mound breakwater constructed by a heterogenous assemblage of natural rubble or undressed stone. Rubble means store only, undressed stone, undressed means you do not make it perfect. You go to temples and all, they make the size perfect, but perfect size is not good for rubble mound breakwater, you should not dust the stone, it should be random in shape. What is heterogenous, what is the literal meaning of heterogenous?

Mixture of different kinds.

Here it is mixture of different size. So we have different types of rubble mound breakwater, we have berm breakwater, armoured with natural rock, then we have conventional multilayer breakwater with armour over Crest, no crown wall. Conventional multilayer breakwater with Crown wall, then we have a composite structure incorporating caisson with armour protection, these are the various types. We will be discussing these 2 types conventional multilayer breakwater with Crown and without Crown.

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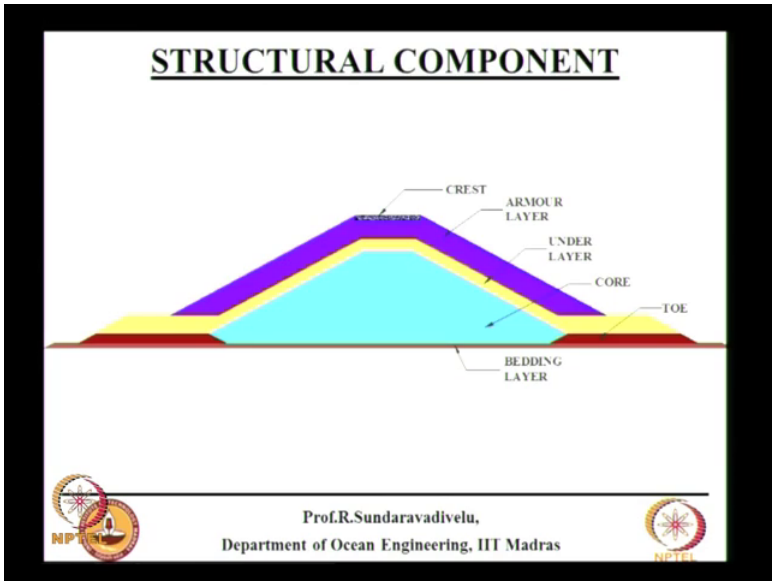

This shows the rubble mound breakwater. I will be asking you to draw this figure, so you please try to draw it to the scale which it is drawn. Do not draw it to some other scale. And I also would like you to have the proportion of the thickness what is shown here in the various layers. The previous slide we have shown, it is a heterogenous mixture of stones, size of stones. So we have, starting from the bottom, we have what is known as the bedding layer, you remember that we are working in the sea and we are dumping the stone from the barge or by endow method from the already constructed breakwater.

The control is difficult to achieve, but still we are able to achieve certain control. So initially we have what is known as the bedding layer. The bedding layer thickness is uniform for below the core, whereas we need this toe, the toe, the bedding layer is slightly higher thickness and this you provide, I am sorry, over the bedding layer we provide the toe and I should not have shown the same colour, the toe is slightly different colour, then we have under layer, this under layer also goes like this.

Sometimes we may use the bedding layer itself as a come up to this portion, then use this under layer as a toe layer, otherwise we will do it separately also, either way it is possible. So one thing is to have the same bedding layer continued for increased thickness, then have the under layer or have the bedding layer like this itself, then provide a uniform to layer which will be different from the under layer. Then we have the core layer, more than 50 percent of the stones, of the stones, used here for a rubble mound will be in the core layer.

Then we have a armour layer, then we have the Crest, top of the Crest we can have a wall, that is called as the Crown wall. So we will have the waves coming from one side, this side if it is waves coming, this is the seaside, this side is the Harbourside. Typically the top width is about 8 metres, but if it is for fishing harbour, it can be about 4 metres. We cannot have anything less than 4 metres because we need certain vehicles to pass through this. So when a vehicle has to go, there should be minimum width available, so this is like this.

And that is a slope here, this slope is typically one vertical to 2 horizontal, 1 is to 2 slope, similarly here, here it can be steeper, 1 vertical to 1.5 horizontal. So we have the road which is formed separately by Crest, then we have the armour layer, under layer, core layer, bedding layer and these toe layers are important. Because whenever you see any failure of any type of structure, 90 percent of the failure can be associated to one component, any type of structures, any failure, the reason can be mostly it will be the same, 90 percent of failure.

This toe failure is one of the main reason for most of the failures of rubble mound breakwater. So the toe has to be done properly. A complete collapse may take place if there is a true failure. Any structure, there are certain components which fails, which triggers the collapse, you should know that.

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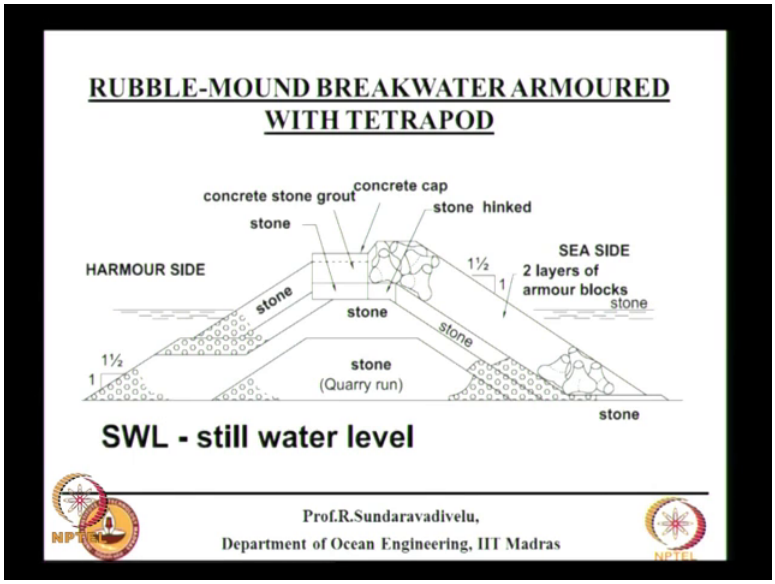

This also shows the typical cross-section, in this cross-section we have the, whether mistaken, this side is the Harbourside, this side is the seaside, then we have this artificial armour units, this is called as armour layer with armour stones and we has the stone which is called core layers, this is quarry run, this is a concrete cap, there is a slope 1 vertical to 1.5 horizontal.

Here the toe is not shown here, sometimes toe is not required if the water depth is less. And we have the armour layer, under layer 1, under layer 2, then we have the core layer.

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This is the shape of the armour layer, I have this, this is another type of armour layer, this is called as core lock, it is a patented technology. This core clock has certain advantages because interlocking is better. When you dump the stone, interlocking is not good, whereas here the interlocking is good. Another thing is, this can be with single layers. So if we see this figure, what is written on the figure is 2 layers of armour blocks. We have to put 2 layers, suppose we used this type of Tetrapod, we should use only 2 layers.

If it is stone also, you have to put 2 layers. Right, with this core clock we can put single layer alone. But this is a patented technology, you have to pay some royalty for this. In Ennore port, they have used this, armour layers. The other type of breakwater is called as vertical wall caisson breakwater.

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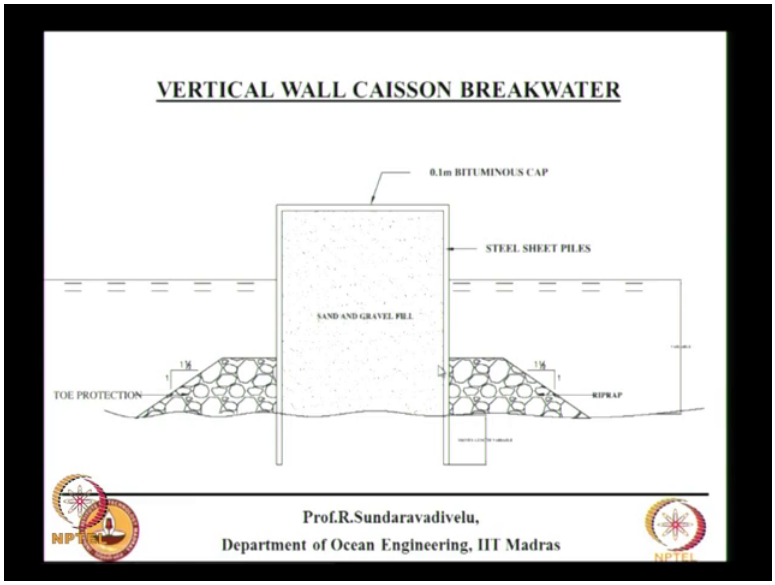

So as you see here there is a vertical face. This can be made of concrete or steel, here they use steel sheet pile wall on either side, then in between their filled with sand, here they have put a cap on top of it. They have provided some rip rap on either side as a toe protection for this steel sheet pile wall. And since it has a vertical face, suppose this is the seaside, the Harbourside you can bring in smaller vessel and berth. That is the, what is called as function of breakwater, it is only for breaking the waves or for using the Leaside as berthing.

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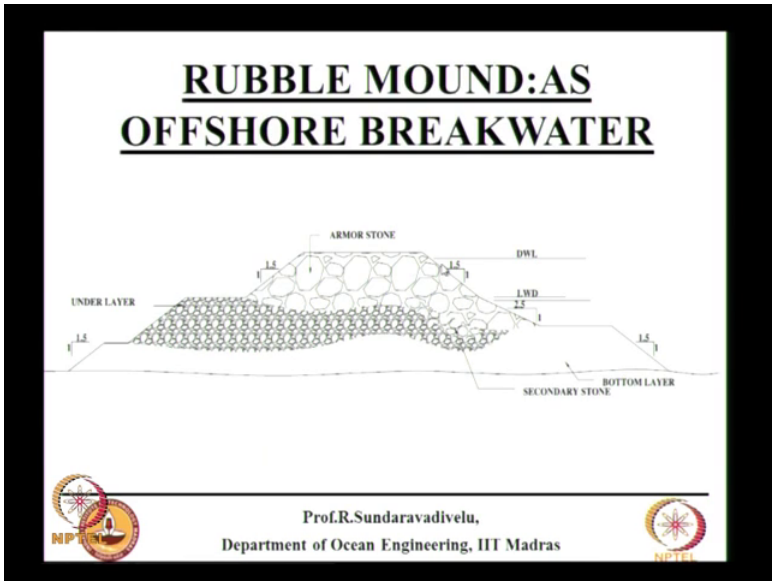

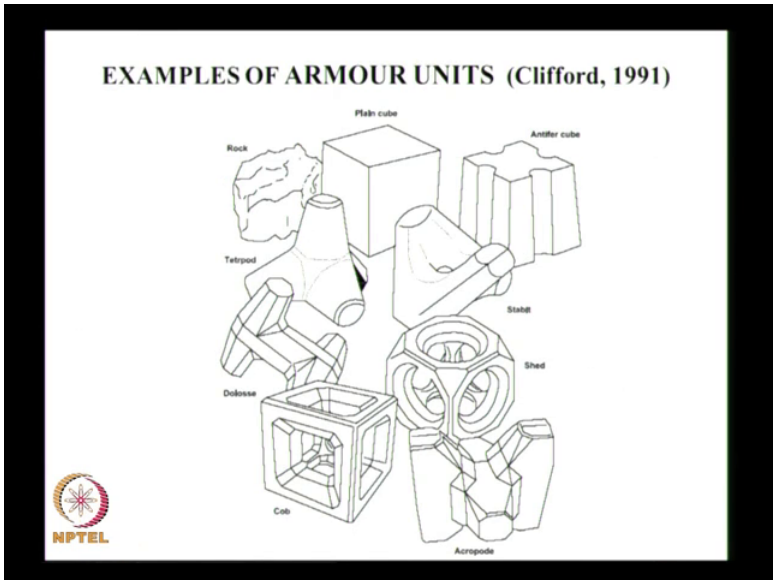

This is offshore breakwater, offshore breakwater means the top level is very close to the design water level. These are the various armour units, this is called as tetrapod, plain cube, this is natural rock, this is called as acropode, acropode is same as this only, but slightly different in shape. So these are the different samples.

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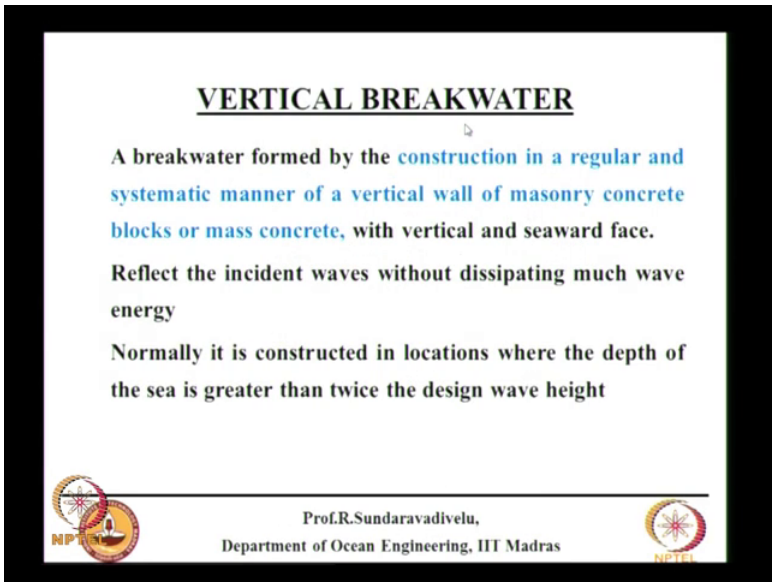

Now we will see what is vertical breakwater, vertical breakwater is formed by Construction in a regular and systematic manner of a vertical wall of masonry concrete blocks or mass concrete, with vertical and seaward face. See when we discuss about the breakwater, whenever there is energy from the wave, the wave is formed by the wind. See whenever there is a wind which is blowing in the sea over an area, which is called as pitch and for a

considerable duration, then the wind is transforming the energy into the sea which creates the waves.

When the waves are created, when the water surface goes up, due to gravity waves come down. That is why this is called as gravity waves. So these waves when they are formed, the energy has to be either absorbed or reflected when it comes to the breakwater. When you see the rubble mound breakwater, the waves will come and hit the rubble mound slope and there is a voids in that, so through the voids the energy will get dissipated and the waves also will run up, run-up means it will climb over the top. So that is called as energy dissipation, that is the concept of rubble mound breakwater.

Whereas in vertical face breakwater, the incident waves are reflected without this impending much wave energy. Then will be some dissipation devices in a vertical face but that will be very less, maybe 70 to 80 percent will be reflected, we are not absorbing the energy. Normally we construct this vertical break whatever the depth of the sea is greater than twice the design wave height. So this is another consideration which I have not told earlier. So whenever the designed wave height is, when the water depth is twice the designed wave height, then we go in for rubble mound breakwater.

When the depth is less than twice the design wave height, let us say the design wave height is 5 metre, twice the design wave height is 10 metre, that is of water is 15 metre, then we go for this. Depth of water is 10 metre, we go for rubble mound breakwater.

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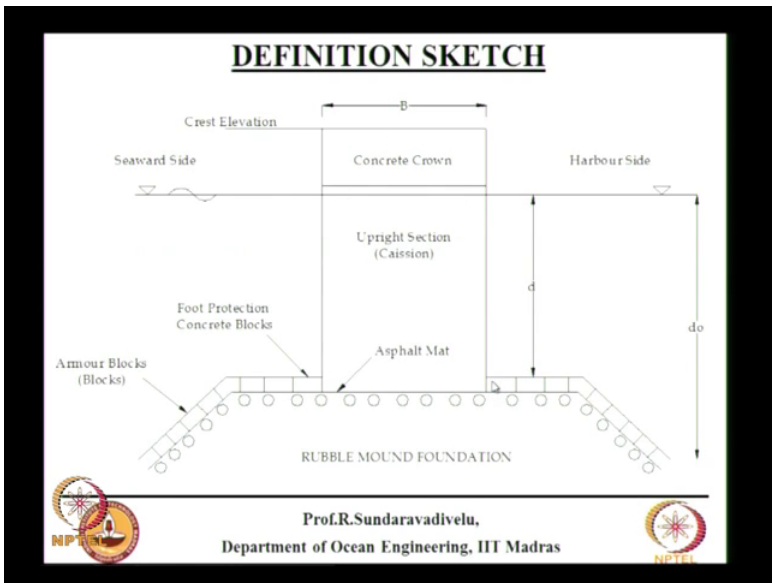

This shows the vertical face breakwater where we have a rubble mound foundation. Composite breakwater is also like this but normally even when you use vertical face, we provide some base foundation, so this is the water depth, in front of the caisson this is the water depth with respect to the seabed. This side is seaside, decided Harbourside, we have shown the waves here, we have not shown the waves here, it means the waves get dissipated here. There is a crest elevation, the top level, so whenever the waves come here, not only gets reflected, the waves also runs up on top of this. So there should not be, normally this is non-overtopping, that means the waves should not be allowed to go on top and go to the other side.

This is called as caisson, the width B is the main parameter that you have to design in this case. Due the width of the caisson, there is a weight here, due to wave there is horizontal force, so the base friction into the weight, mu into V, should be greater than the horizontal force due to the waves, that is the concept for the design. The B is important because whenever there is a horizontal force coming, it creates an overturning movement, it may create some tension and compression. Due to the weight there will be uniform compression and the width is sufficient, everywhere there will be compression, one side the compression will be more, other side the compression will be less.

If the width is small, one side there will be tension, another side there will be compression. So that is another concept. So 2 things I have told, the 1st one is, the horizontal force should be less than mu times vertical force, the 2nd one is due to the horizontal force and about turning movement and due to the vertical force there will be a distribution of pressure at the seabed. The distribution of pressure should be always compression, a combination of these 2, that condition also should be seen.

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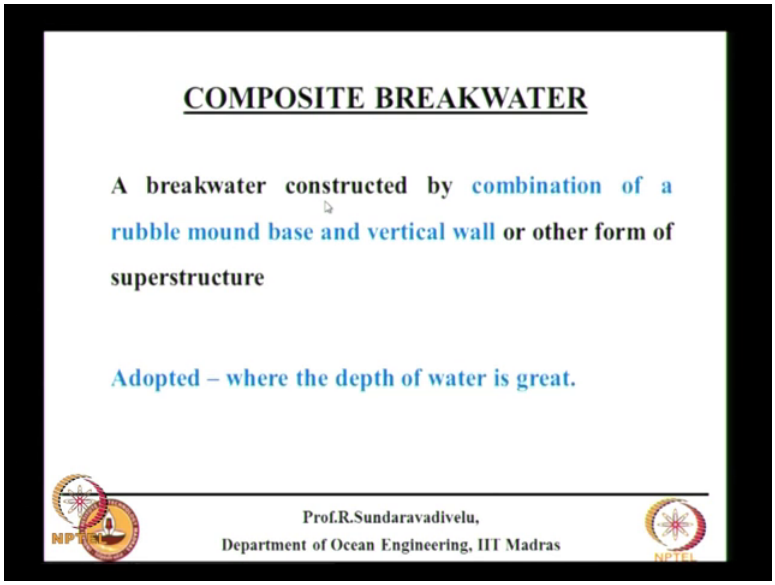

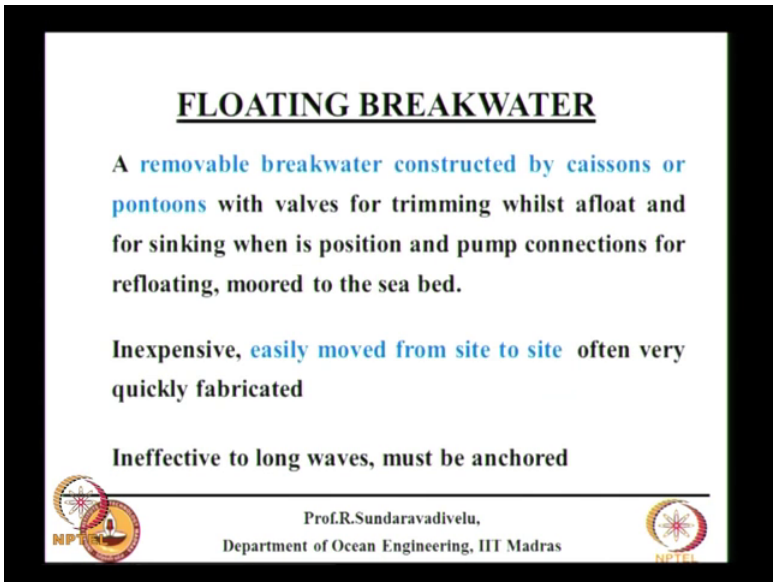

A composite breakwater is a combination of rubble mound base and vertical walls, besides vertical wall it can be others form of superstructure. This is adapted where the depth of water this more, more than 15 metres. Then we have other types of floating breakwaters, 2nd type of breakwater. The 3 types of breakwater rubble mound, caisson, composite, we can say 95 percent of the breakwater in the world, they are of that type. Whereas the other types, maybe 5 percent will be used.

The advantage is removable breakwater, this can be constructed by caissons or pontoons with valves for trimming whilst afloat and fall sinking when is in position and some connections for refloating moored to the seabed. You can float it in place, use the valves and you can sink in position and you can refloat also. They are inexpensive, easily moved from site to site, this

can be often very quickly fabricated, this can be used for defence purposes also. But we do not use this because this is ineffective for long waves and this also should be anchored.

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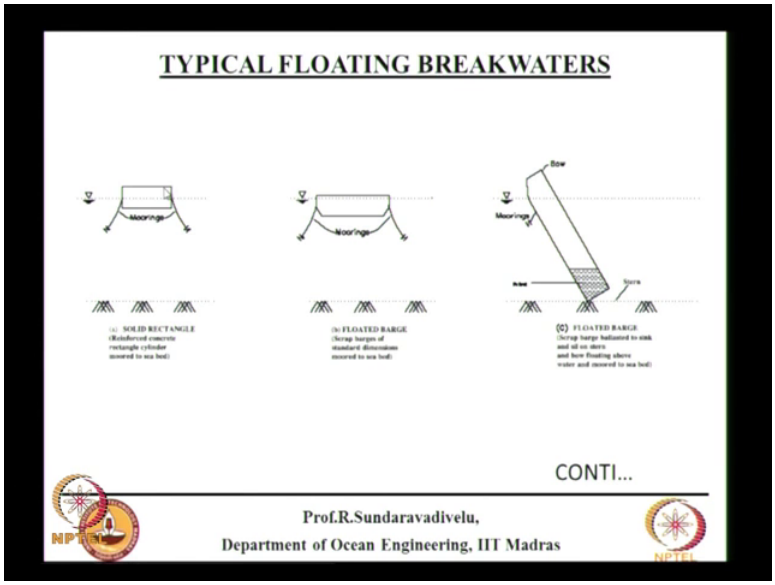

This is typically a breakwater, floating breakwater with mooring. This can be used when the current is very high, it is environmental friendly, the cost does not depend on the water depth, whereas other type of breakwaters, the cost is proportional to the cube of the water depths. So it is insensitive to the water depth in the sense the mooring line cost only has to be added. Mooring line cost is not more than 10 percent of the total cost. These are 3 different types of floating breakwaters. But one problem with this floating breakwater is this cannot be used for long period wave.

In one of the class I told you what is the period of the wave, range of periods of the waves, what is it? 5 to 20 seconds. Sometimes it can be smaller also, 3 seconds also is there but floating breakwater is used between 3 seconds and 7 seconds, nowhere used for more than 7 seconds, very difficult, for 5 seconds, it is good.

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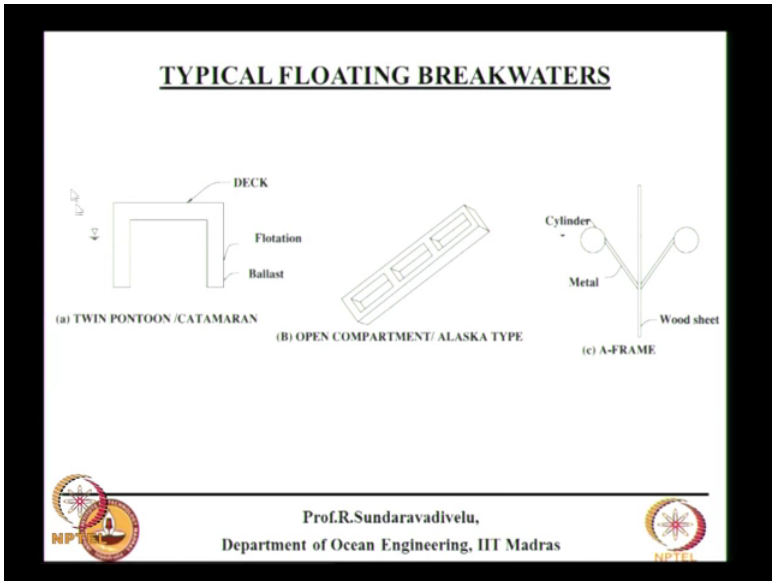

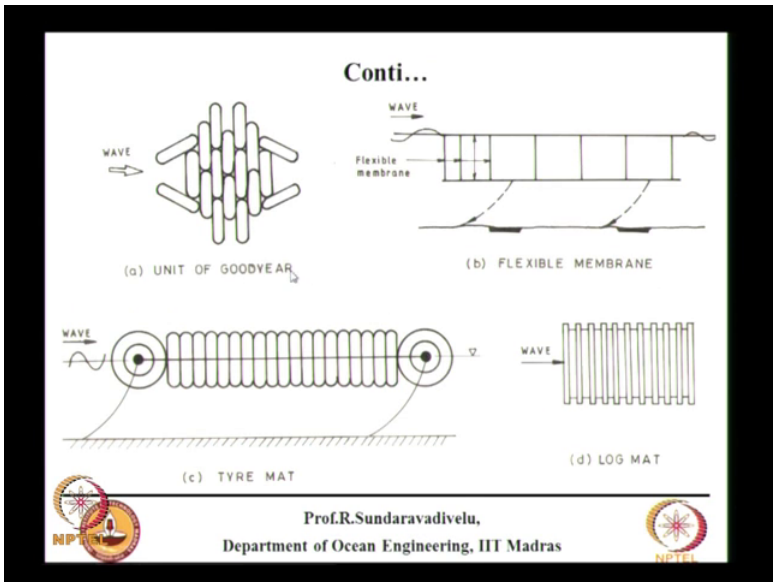

These are other forms of floating breakwater, this is called as twin pontoon, is open compartment, then this is A frame. This is tyre breakwaters, flexible membrane, this is a tyre mat, this is a long mat. These are some of the photograph showing the various breakwaters, built at various locations. This is called as rubble mound breakwater. This is called as tripod which is used, here we use what is known as the X block. So we will see the design in another class, but I was telling you about the model studies.

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NPTEL


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This is carried out in our wave basin, what you are seeing here is the Tetrapods, the waves are coming and hitting the structure. As you see when the waves are running over it, it loses its energy, I think sounds back. This, here the armour units are stones, here you can see different colors, bottom one is toe mound, this is under layer, then this is armour layers. When the waves are coming, it comes and runs up over the slope, that is called as the run-up.

When the water is running up, it can go on top of it and then overflow, that is called as overtopping. Here what is happening is, it is splashing only, the run-up is going only up to this level and the waves that are generated is a random wave, random wave means waves of different wave heights and wave periods. Here you have wave probe which is used to measure the waves. And on the Leaside also imagine the waves. This is the wave probe, this is the frame, this is the probe which is seen here.

What kind of damage that will be there? 5 percent damage I was telling, damages i some of these armour units may roll down, may fall down, that is called the damage. Once the damages happened, after the software subsided, you can go and replace the armour units, no complete collapse. So what is the design issue here, design issue for this type of breakwater is, you have to find out the weight of the armour units. For rubble mound breakwater, you have to find out the weight of the breakwater.

There is a formula what is called as Hudson's formula, I will be discussing only that formula, Hudson's formula. There is another formula called VanderMeer, I will not be discussing that, I will be discussing only about the Hudson's formula. This breakwater weight, that is the armour weight what you have calculated, that will be used to find out the weight of the

underlayer, core layer and other things. So only one single parameter you have to calculate. So we will see that in the next class.