Coastal Engineering
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Module - 5
Breakwaters
Lecture - 1
Breakwaters – I

So, having seen the littoral drift, littoral current, etcetera, the behavior of waves in the coastal environment, then now we move on to some aspects of structures. The most widely used structures are the breakwaters. As we have seen under the topic coastal protection measures, breakwaters can be used for mostly for formation of artificial harbors, so as to have a tranquility area within the harbor basin. Apart from that it can be used as coastal protection measure like off shore detached breakwaters. So, because of the diffraction of waves in between the breakwater gap you have the deposition of sand on the lee side of the break water, but you also have the alternate zones of erosion and deposition, but you need to carefully design the gaps as well as the distance between the shore line and the breakwater, etcetera.

Some of these aspects we have already seen earlier, but now so that is one one of the application of breakwaters. Then apart from the ports for the formation of harbors and also I would like to say that although we call it has breakwaters.

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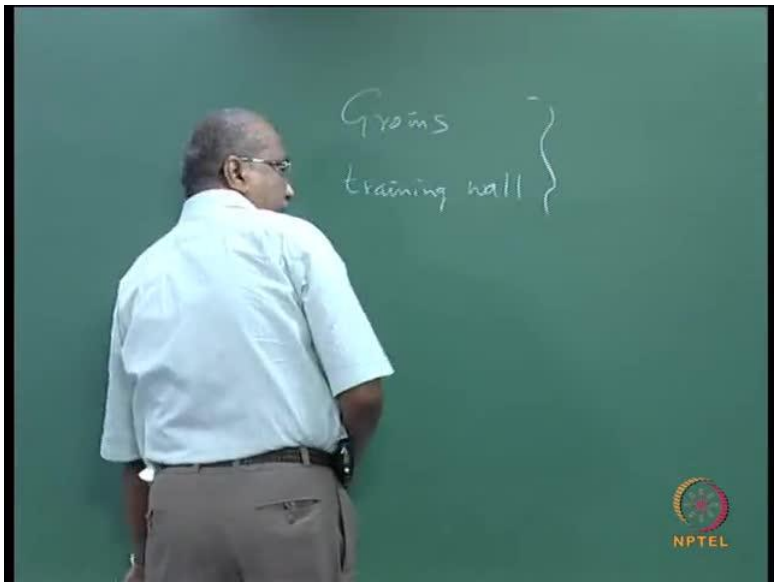

We also have the words the terminologies used as groins training walls etcetera. The design of these are almost similar to that of a breakwater, what I will do is I will just go into the details of the breakwater, the classification, etcetera. And then I will also, we will look into the advantages and disadvantages of each of the type of breakwater where and when you apply or adopt different kinds of breakwaters and then we will go on to the design aspects. And I will give you a design and example only if time permits, because we do not have enough time to look at the design, because we have seen other problem, but the design of breakwater is not, so difficult once you know the principles.

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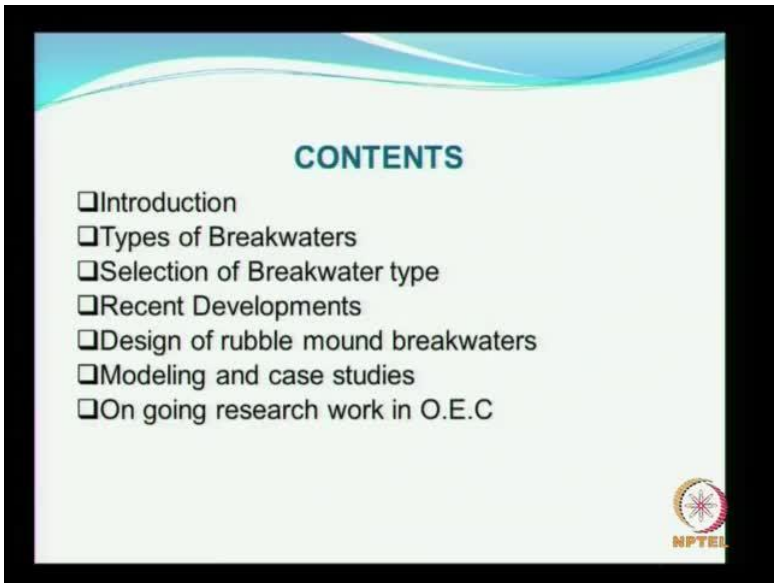

So, the contents of this lecture will be introduction types of breakwaters selection of breakwater type then some of the recent developments, the design of rubble mound breakwaters may be the design principles of time permitting, I might consider giving a sample design. Then we go in for modeling and some of the case studies, then we get into the some of the ongoing search that also if time permits. So, let us look at the definition. Breakwaters are wave energy barriers designed to protect the protect water area behind them from direct assault of waves.

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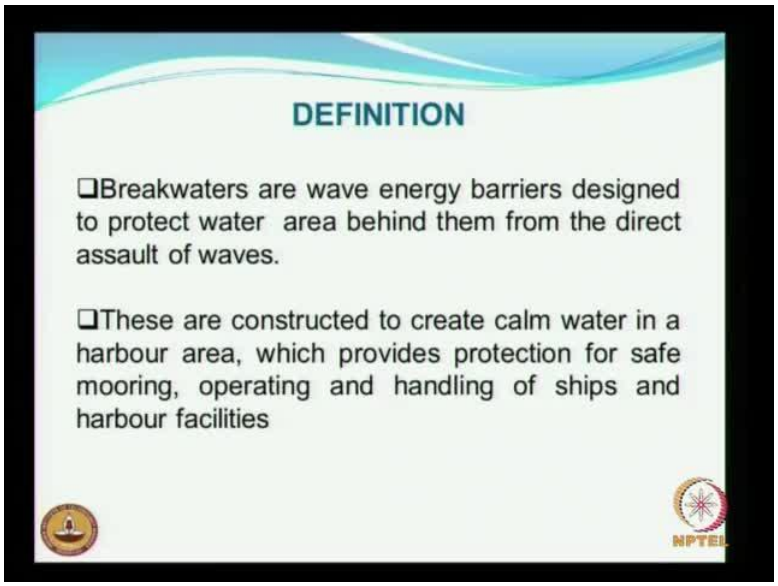

These are constructed to create calm water in a harbor area, which provides protection for safe mooring operation as well as handling of ships and harbor facilities.

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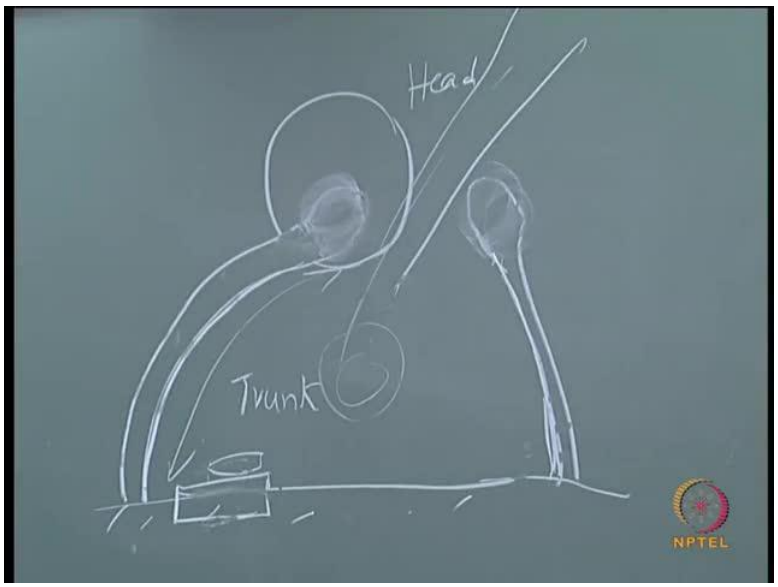

So, you people know already that this is the shoreline. You normally have a breakwater something like this, so this this is normally this is bulging out like this. This is called as the head of the breakwater and this is called as the trunk of the breakwater. This is, this portion is called as the trunk and this is the head of the breakwater. The, so in the cross section also I will show you how it looks like. So, the layer of a typical layout of a harbor

is as shown here where this would be to create a calm water a harbor basin where in the ships the vessels may be, be it may be fishing crafts or fishing vessels or may be, be commercial harbors.

So, they come and then once they come here then you normally have some kind of a a turning circle and then they turn and then may be berth go towards the berth and then you have the ships berthed here, and then the vessel the cargo from the vessel or may be the fish catch from the fishing crafts are offloaded and then it is sent for processing or delivery or whatever it is. So, the purpose is you need to handle again similarly, offloading as well as on loading, so you need calm water if there is no calmness within the harbor basin what happens when they are trying to load or unload? You see the the boat is going to be keep on will be in motion and that is going to create lot of problems and not only that if the motion is continuous, the mooring lines also can snap. So, you need to arrest the movement of the vessel.

So, in order to achieve a kind of a a desired degree of tranquility or the calmness in the basin, you have a pair of breakwaters. Usually a pair of breakwaters sometimes it can be more than a pair of breakwaters depending on the site. Sometimes it can be just a single breakwater also even with just a single breakwater you can have a a harbor basin. It all depends on the geomorphology of the site conditions, so the purpose of breakwater is to break the energy contained in the waves. So, we all know that the energy is there in the waves and when they are propagating, once you have a breakwater it breaks the energy in the waves and leaving certain degree of tranquility on its lee site.

What you would have is some amount of diffraction that the energy will try to penetrate. Here essential of the harbor is this should be if this end is ref, is is kind of a an impermeable medium, then you can have a kind of cross oscillation which is not desirable. So, hence we go in for rubble mound breakwater or a breakwater which has certain degree of porosity, so that it absorbs or dissipates the instant wave energy. So, I also have some photograph here a purpose.

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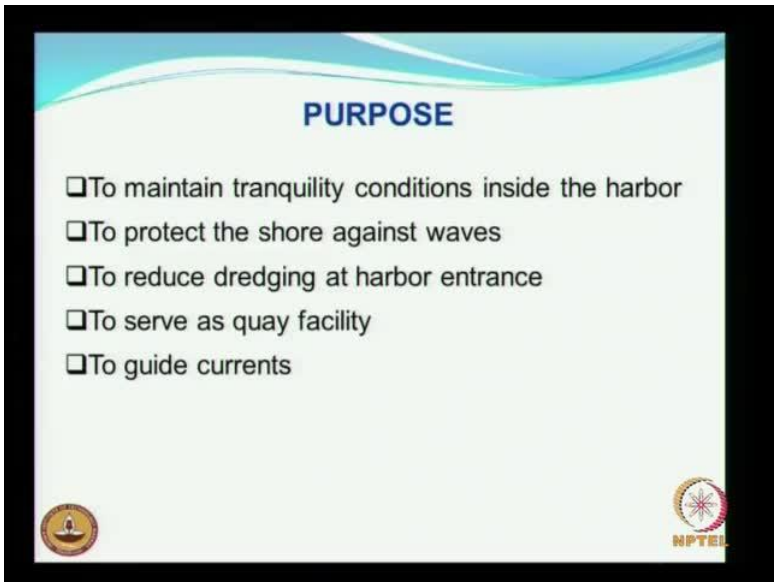

As I said earlier to maintain tranquility conditions inside the harbor to protect the shore against the waves, so it can be in terms of for example, submerged breakwater. We have seen submerged breakwater, what happens? It facilitates premature breaking allowing the deposition of the sand in between the shoreline and the breakwater or it can reduce dredging at the harbor entrance, depending on its orientation. It can serve as key facility you can berth ships if you have a breakwater with some kind of a vertical surface at certain locations then it can serve as a a key facility and when I say key facility when you look at the different types of breakwaters, the composite breakwater is one such type where in the break water face can be used for for berthing facility. And then the finally, it is also can be the (( )), one of the purpose is to guide the currents. We have a a variety of layout, you just go into the internet and then look at the just give harbor layouts then you will get a number of harbor layouts.

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So, this is the one such layout picked from the internet because I, this explains, this gives a very nice view about how layout, what are the essential components of harbor which is formed with a pair of breakwaters? So, and also it also considers to some extent the geomorphology. So, the geomorphology shows that there is an head land, this head land is going to serve as some kind of a natural barrier or a natural breakwater for the waves penetrating from this direction. So, this would be only this would need only to attenuate or reduce the energy in the waves coming from this direction.

So, you may have different options for example, you could have gone you can have a breakwater like this, getting into the ocean from this. This already would have been in a water depth of say 5 6 meters it is rough guess, you know. So, you can just have this breakwater somewhere like this or you can have a breakwater all the way going up to this a single breakwater all right? And then this itself can could be treated as a tip of a breakwater, so that the vessels can come from this direction. Weather the vessels will come the orientation of the layout the orientation of the approach channel, can be will depend on basically the wave characteristics, wave directions. So, this obviously shows that there are, this obviously shows that the predominant wave directions is from this.

So, the breakwater is oriented right angle to the predominant wave direction predominant or the most frequently occurring wave direction. So, when you do that, then there are, there could be some amount of disturbance in the harbor basin for the wave which are

approaching from this direction. Hence, you need to have yet another breakwater and that is why you see that there is another breakwater which comes running like this in this direction to take care of the waves which is coming from this direction. So, still there might be some degree of disturbance, you may not have 100 percent tranquility.

But I do not use the word seldom, but mostly if you are able to have a disturbance of about say even up to one foot or may be 30 centimeters it is it is tolerable, but only when you have a long period wave entering into harbor your problem will the problem will be very quite severe. So, now what are the other essential components of the harbor, although we, I am not supposed to cover this, I am just giving some of the only the just the overall view of picture. See you have some kind of a finger jetty so this is basically for a recreation harbor. Where in you have say for example, small finger jetties where you can have the pleasure boats coming and berthed here, they are berthed here and then the person after berthing here he walks over this finger jetty and then he climbs over the platform and then goes into his area, may be his his house or whatever it is on the land facilities you understand.

So, this is so you have some other kind of maybe you have a bigger vessel it can come and berth here or it can berth here or it can berth here. So, this is the berthing facility which is available here and this is going to take care of the waves. So, note note that you see the there is a kind of a bulging here and this is called as the head of the breakwater. Why there is a flatten, flatter surface, because this the cross section is obviously trapezoidal.

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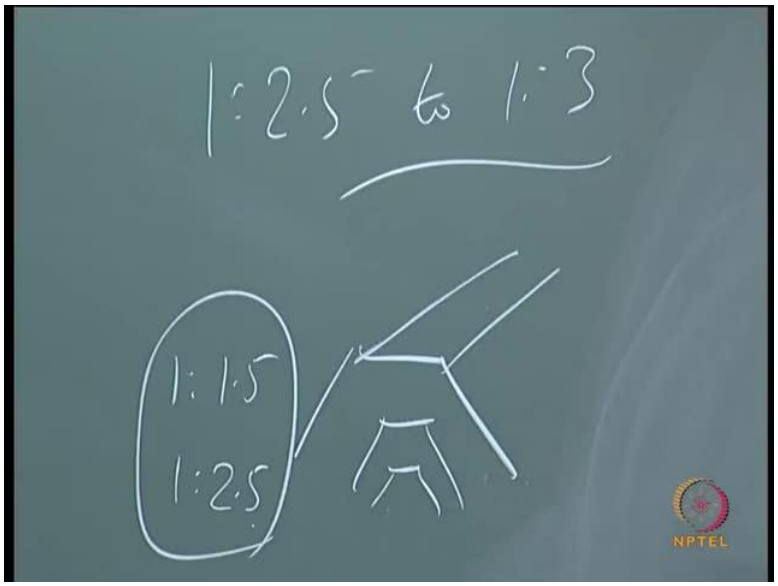

The cross section is trapezoidal, so it will have a number of layers which we will see later. So, this but this typically the side slopes, so the side slopes will be may be 1 is to 1.5 and 1 is to up to may be 1 is to 2.5, that is for the trunk portion. But the head portion the slope will be more flatter, may be 1 is to 3, so the head portion will occupy more material. The size of the stone which may be used for both trunk and the head will still be same, but we adopt a flatter slope for the head for the simple reason, at the head of the breakwater you will see that the the waves are coming from different directions.

The size of the stone, the weight of the stone for this section is designed or evaluated for the waves which are approaching the structure normal to it, based on that only we determine the size of the stone for the trunk. Since, the this portion the head is going to be exposed to waves from different directions, see one particular direction if you use a same slope for one particular direction which is just more more or less coinciding with this this this direction you may not have much of problem, but when you have a wave coming from the other direction, some other direction then there can be some amount of disturbance.

After all although you see huge boulders used, but the function wise you see once if one stone is removed it is something like removing a sand castle. So, you build a sand castle and it is stable and if you give a slight disturbance to bottom the whole whole sand castle collapses. So, such situation can happen even in the case of breakwaters. So, you need to be careful while designing the breakwater although the design is not so complicated. So,

when you, so this is the head of the breakwater, what I am trying to see is I am looking at the breakwater from this portion when I look not this breakwater.

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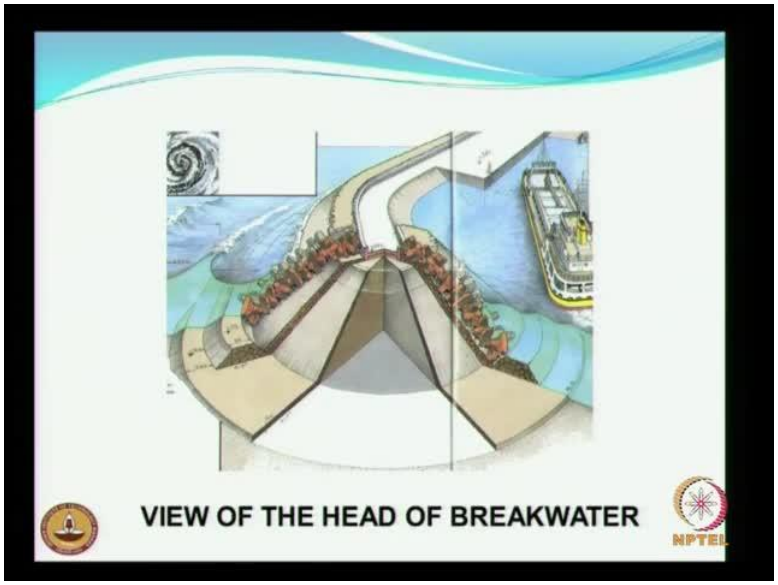

Generally, so when you look through the breakwater from the head, so then then you see that it may look like this. So, you see that there is a core layer and then there is a secondary layer and then over that you have the armour layer or what is called as primary layer. So, this will be the, this will be the kind of structure and you may have some kind of berthing structure and this can be supported on piles. Supported on piles means here this portion you know this portion can still be the same rubble mound so and then but then this portion alone will be supported on piles. What does that mean? What does that mean?

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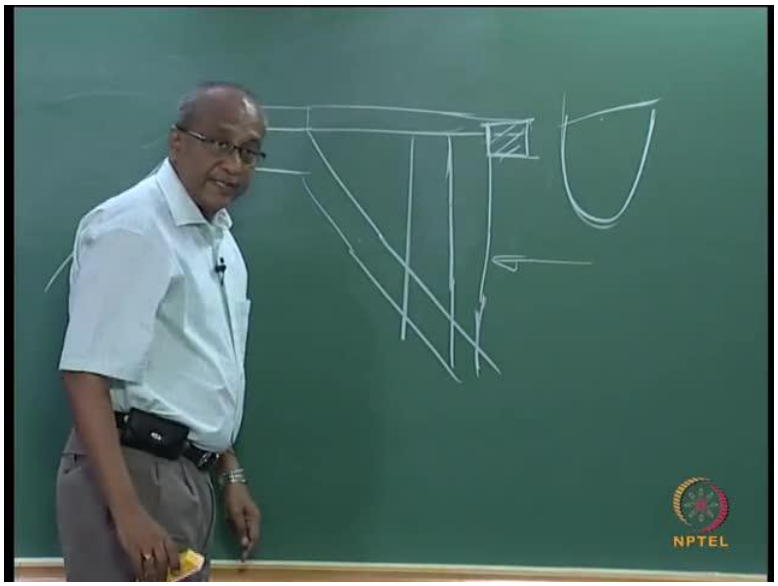

So, I have a breakwater then I have a berth, I have a berth take resting on piles all right? So, what will happen when the, this portion only, what I am trying to say is only this portion of the berth, your ship will be anchored here. So, what what is happening here because these are only piles at spacing's. So, you have a clear spacing through which the waves will still penetrate and it is going to be observed by this rubble mound, so you do not have the problem of reflection from the medium. You understood? That is what, that is a purpose of having a berth supported on piles. The other way is you have the berth here itself, but then you are going to have a reflecting reflecting medium. So, I will, we will just look into the classification as well as the advantages and disadvantages of the different types of breakwaters.

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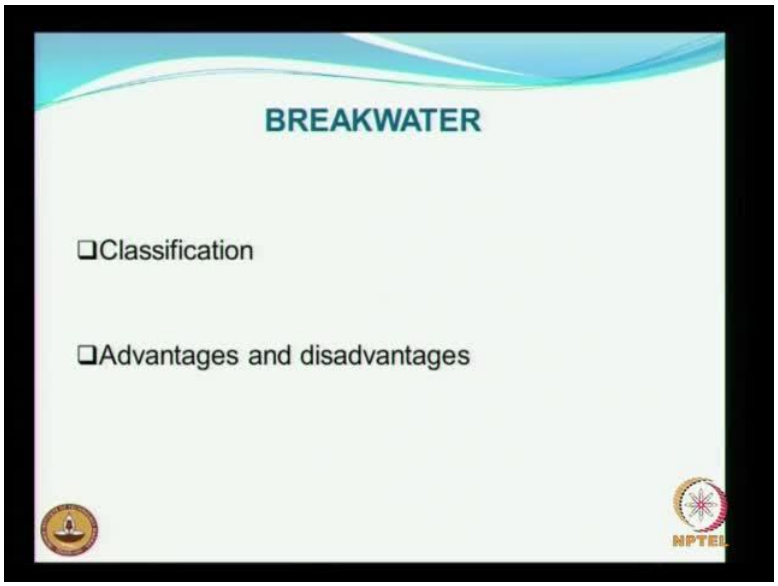

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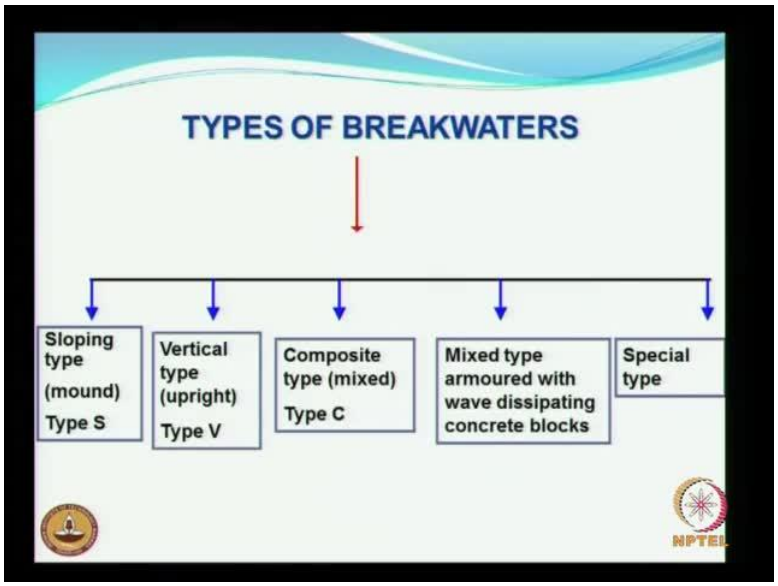

Types of breakwaters. We have the S type breakwater that is the slopping type breakwater. S type is sloping.

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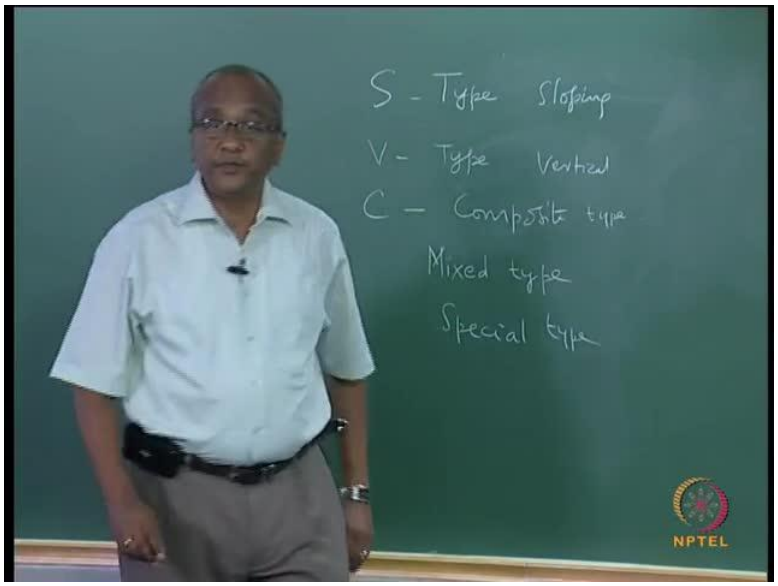

Then we have the V type, which are the vertical breakwaters. Then we have C type which is the composite breakwaters, then we have mixed type combinations and then finally, we have what are called as the special types of breakwaters. All the lecture material, what I am presenting will be made available to you, so you have the pdf files so that you can just have a look and then try to listen to the lecture also, if you are interested. So, what is sloping or the S type breakwater?

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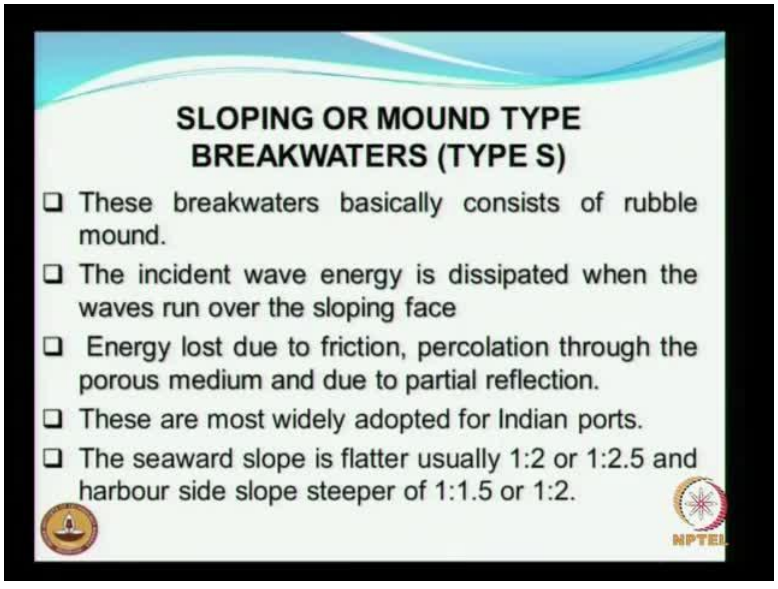

These breakwaters basically consists of rubble mound, that is how it originated. It started with rubble mound, the incident wave energy is dissipated when the waves run over the slopping surfaces. You have a slopping surface and you have certain amount of permeability, and also the surfaces going to have some of degree of roughness when the waves are going to move over this roughened surface, and the energy will be lost by the due to the friction offered and as well as the energy will be lost due to the permeability.

When the waves are trying to the penetrate through the permeable medium, energy is lost due to friction percolation through the porous medium and also due to partial reflection. The partial reflection may be more if your slope is going to be steeper. If it is flatter the the reflection is going to be less, as we have seen earlier. So, the sea side slope is flatter usually of 1 is to 2 to 1 is to 2.5 and the harbor side is steeper to an extent of 1.5 to 2. This, what does that mean?

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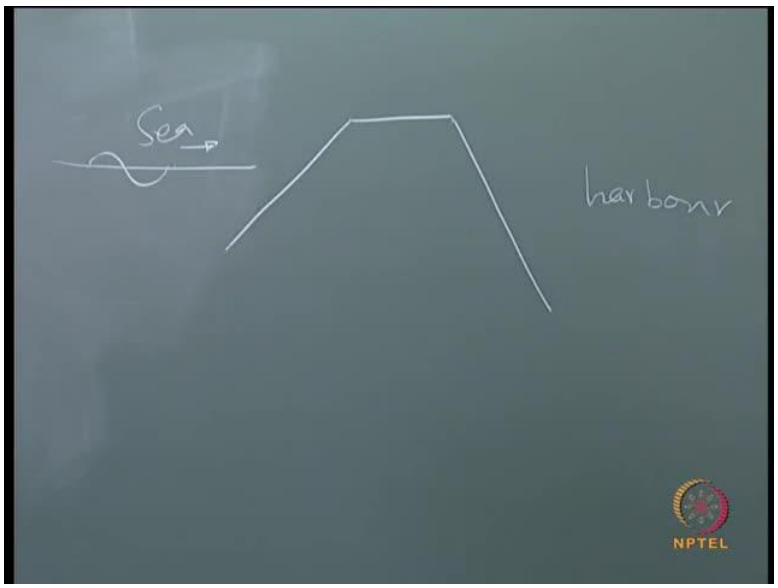

So, if I I can have something like this, approximately. So, what does it say? Flatter on the sea side, so this is going to be your sea side. Why this side is flatter? What will happen if it is steeper? Reflection will be more, forces exerted on the structure will be more, is that clear? So, if the forces are exerted more then you will have more disturbance, but here when you have the waves coming here, this is the sea side and this is the harbor side. Since, the energy has to be absorbed and since the structure is directly exposed to the action of waves you need to have a flatter surface, so that there is certain degree of

dissipation taking place, when the waves are running over the flatter surface and reflection also is going to be less.

But once the energy is observed on the lee side the energy is going to be less, when the energy is less why should you have flatter flatter surface? There is no harm you can still have the same surface, same slope. Is there any any problem with the stability of the structure? No problem only thing is you are adding on unnecessary material to the structure because it is quite good enough only you have a a steeper slope here because there is not going to be much of disturbance here. When you have two breakwaters what is the kind of I mean force which is going to be acting on the rubble mound. It is only the due to the diffracted waves which is going to be much less. So, you have a a steeper slope here then comes the slope of the head of the breakwater is still flatter, that is the reasons I have already told you 1 is to 3 to 1 is to 1 is to 5.

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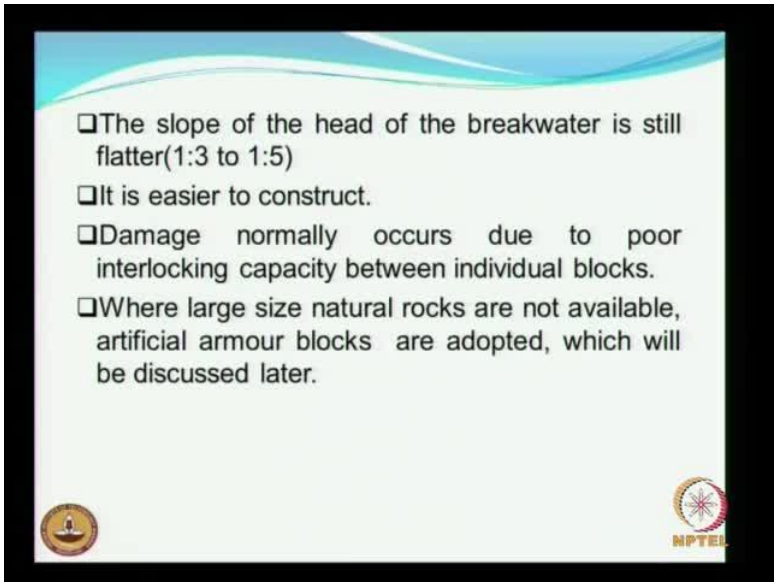

So, rubble mound breakwaters are easier to construct. And the kind of machinery you need, is not very sophisticated kind of machinery which you need to construct a rubble mound breakwaters. It is easier to construct and it is also termed as kind of a flexible structure for the simple reason, the type of damage that occurs is only removal of stones, not very often the entire material is removed. The more often what would happened is some individual stones may be rocking, the problem comes only when a single unit is totally displaced from its original location to a new location.

And if this new location is more than one times diameter, one times the average diameter of the stone then it is really very highly questionable. I mean the stability of the armour layer. So, the stability of the armour layer is verified usually through experimental facilities. I mean through physical modeling which we will see later. So, now so whenever only very important in the case of double rubble mound breakwater is, once there when once you notice some kind of a degree of failure, immediately you have to replenish. So, there is need for continuous monitoring, particularly during a storm.

After a storm you you need to ins inspect the rubble mound breakwater to check for any kind of disturbance and if there are some disturbance, if you need to replenish this you need to replenish it. And that is where most most of the breakwaters people who are in charge of breakwaters sometimes they mess it. They postpone it for want of funds, due to positive of funds once you postpone the rehabilitation, what happens the next storm comes the cumulative damage will be more severe. There are instances where the whole breakwater has breached, but this breakwater gives you enough time for you to take a decision on its rehabilitation, but if you do not do that rehabilitation then the whole thing can even collapse.

So, that is the advantage of having a flexible structure like your rubble mound breakwaters. When large sized natural are not available artificial armour blocks are adopted, which we will discuss later because when you calculate, later you see that the weight of the stone is directly proportional to h cubed. Have you heard of Hudson's formula, all of you? So, when this wave height this is very important when you fix the wave height. If you make any small mistake when fixing the wave height, since it is cube, the weight you may you may estimate with a lesser wave height can lead to a substantial under design, which can result in failure. So, you need to carefully do that.

The most fundamental breakwater of this type is the one randomly place stones, so this randomly placed stones even now people are used to this. For example, if there is some kind of a flooding somewhere, what do you? Do you either dump sand bags or stones. Although it does not having any engineering engineering background, but certainly it has a degree of relief. As a temporary measure it it could always serve its purpose, so this is how the whole thing started.

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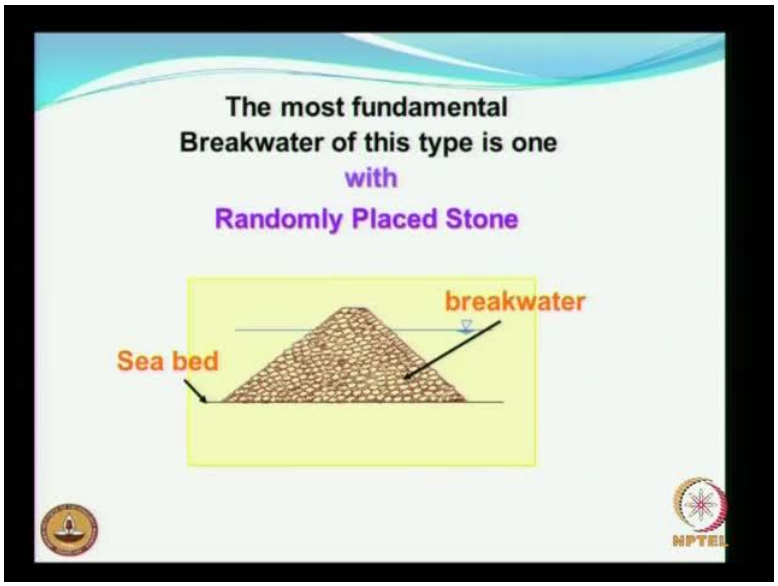

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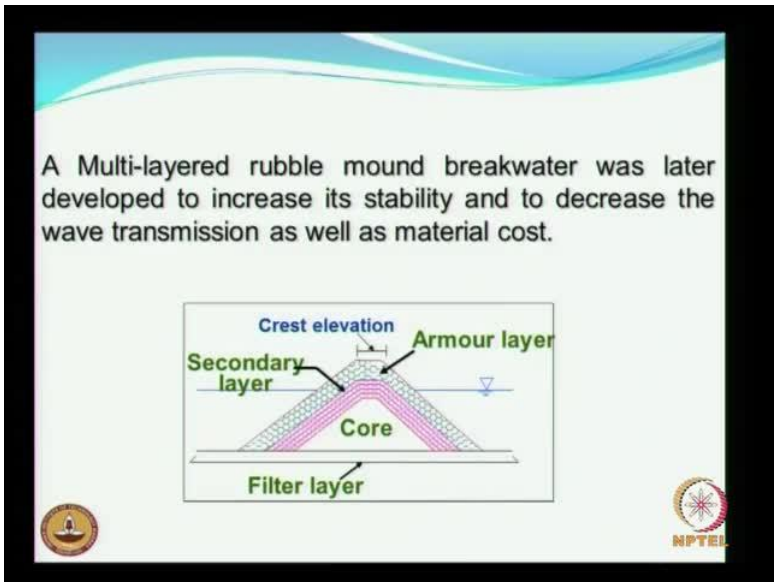

Now, then slowly developments in the breakwaters took place. A multilayered rubble mound break water was later developed to increase its stability and also to decrease the wave transmission, as well as material cost. So, when you design a breakwater you you are, you you need to have a number of things in mind the run up should be less, the dissipation should be more, the cost should be less, the cross section has to be stable, you also have to take care of some points concerning the environmental conditions and also the kind of labor you have, machinery type of machinery you have because in certain locations where you cannot get good machinery then there is no point in having some big

breakwaters, which can which has to come up. So, all these things have to be done in planning stage itself, man material etcetera which I will we will look into it when we are going to talk about the different kinds of breakwaters.

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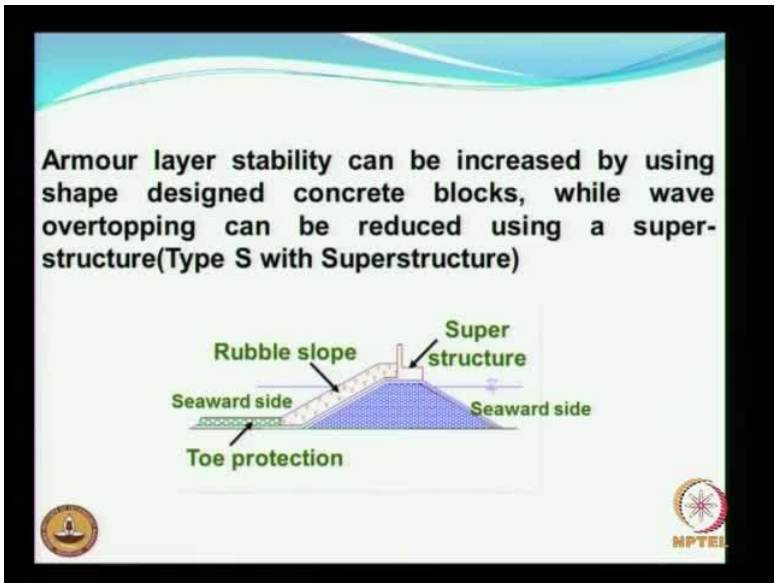

So, armour stability can be increased by using shaped design concrete blocks while over topping can be reduced by having a super structure. So, this is type S. Although this is type S what will happen under type S you can either have over topping structure or a non over topping structure. When you have a over topping structure you have to be very careful with this rear slope. If this kind of a structure you allow the over topping to take place, what will happen? This whole thing will yield and in fact the failure will progress from this end, which can ultimately result in the breach. So, you you what exactly you want to do?

If you do not want to have any over topping, then you have to increase the crust level. Where do you want it compensate? Whether you want to increase the crust level and design it as a non over topping structure or you have strengthened harbor site and have a reduced top level crust level, so that occasional over topping is permitted. The options is left to you, when I say options are left to you you need to consider the wave climate in that particular area based on which only you can design and take a decision. We know that, we have issues like sea level rise or tsunami all these things, one one need to be very careful

when he wants to propose a non over topping structure at locations where you have this kind of a phenomena that can occur or that might occur.

So, you go in for what is called as a crown wall. So, here you have the crown wall, see the design of all these things may not be much of it is it is not so complicated, but here design of this needs a lot of attention. Stability of crown wall is also very important. Now, stability of crown wall the forces coming on this may be very less because this is going to be acting as a attenuating medium, thus reducing the energy. But in the event of an extreme event, what would happen if the water level here goes much higher than this, then this portion is directly exposed to the waves.

And you know that when you have a vertical wall and here when you have a vertical wall and waves are coming and hitting the structure the reflection is 100 percent more or less 100 percent because you have still a permeable medium here, so it cannot be 100 percent, but still it will be on the higher side. So, you can have enormous forces acting on the wall and also the base structure. The base structure there will be uplift pressures acting, so this needs careful design, carefully it has to be designed. Under the same thing you can have reef breakwaters or the submerged breakwaters, this I have, we have already covered under the coastal protection so I do not want to repeat this anyway, this will serve as for the coastal protection measure.

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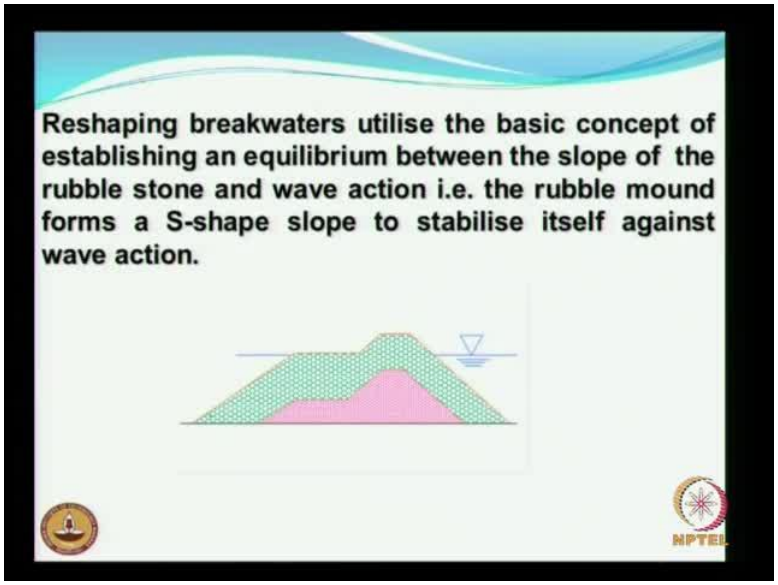

Then you have the reshaping breakwaters, all these things are coming under the S type or the rubber mound breakwaters. So, reshaping breakwater utilize the basic concept of establish an establishing an equilibrium between the slope of the rubber mound and the wave action. That is the rubber mound forms S shape slope to stabilize itself against the wave action, that is when the waves are coming and hitting the structure ,what is the kind see now you have a a rubber mound.

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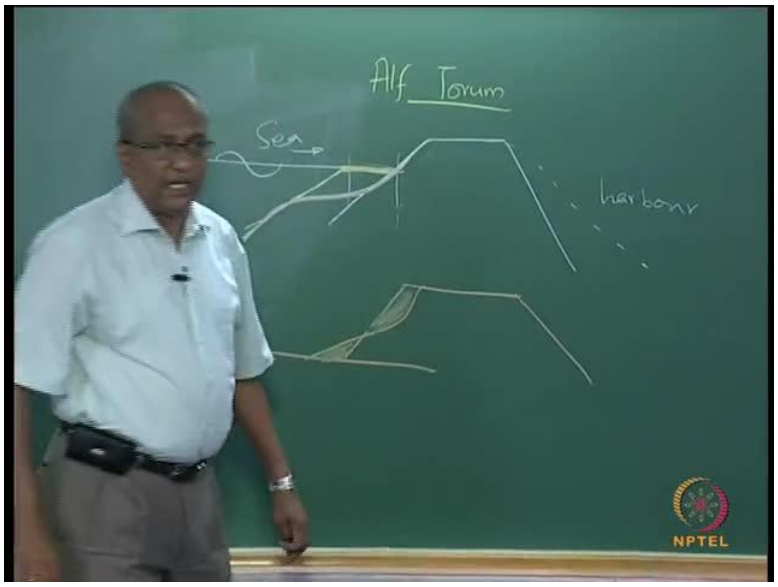

One aspect is this is going to serve as a a burm, this is going to serve as a burm and when there is a failure this is how it takes care, that is when suppose, Sorry. So this is how a a structure would fail. You look at the type of failure the waves when come and when they come and hit the structure, it will remove the material at this location because this is where you have maximum force exerted. These stones will be removed and where it will be deposited it will be deposited here. So, what is the type of failure? This is a S type failure, so in order to take care of that you have provide a burm here.

And this is going to this is why what is called as a reshaping breakwater. A lot of work has been done in this area the Alf Torum in fact he has done a lot of work on the S shaped breakwaters. So, I suggest if you are interested you can look at this some of his papers, he has published number of papers. And this has gained importance particularly in Europe, but there is still an argument whether the material is going to be more than the conventional breakwaters because when you have burm breakwaters you see that material

is slightly more than what is needed for the conversional type. Advantages of rubber mound breakwaters, use of natural material is a very big advantage especially when large quantity of rubber stones are available near the site. So, this results in a reduction of the material cost. Particularly when you have, when you can get rock mat rocks very close, use of smaller construction equipments this is what I have been telling you.

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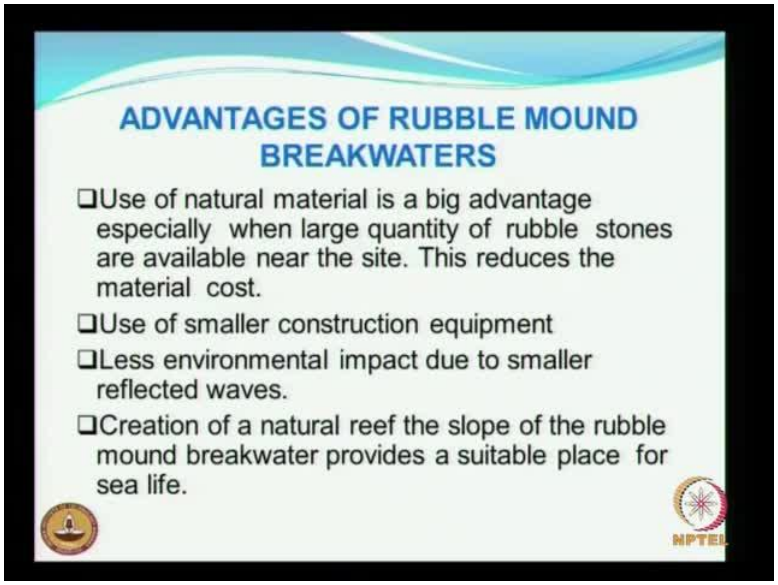

And then less environmental impact due to smaller reflected waves because most of the energy is absorbed, reflection is less. Creation of a natural reef the slopes of the rubber mound breakwater provides a suitable life a suitable location for the marine life. This again being debated because certain locations where there are cert, certain species. They do not like the rock material, they do not like rocks. So, a number of projects have been have been set no has been told for a number of projects with this kind of I mean rubber mound breakwaters etcetera. That is how, that is one of the reason why geosynthetics have come into play.

Now, we move on to vertical types. Are there any questions? Are there any questions?

(( ))

It is only stones basically stones only they use for the core, but now recently what they have started talking is you fill in geo bags with sand and that can replace the core, that can serve as a core, but still its only on experimental stage it is not well accepted practice. This

I will touch when we discuss about geosynthetics that time we will discover about that. So, vertical type breakwaters are the type V type.

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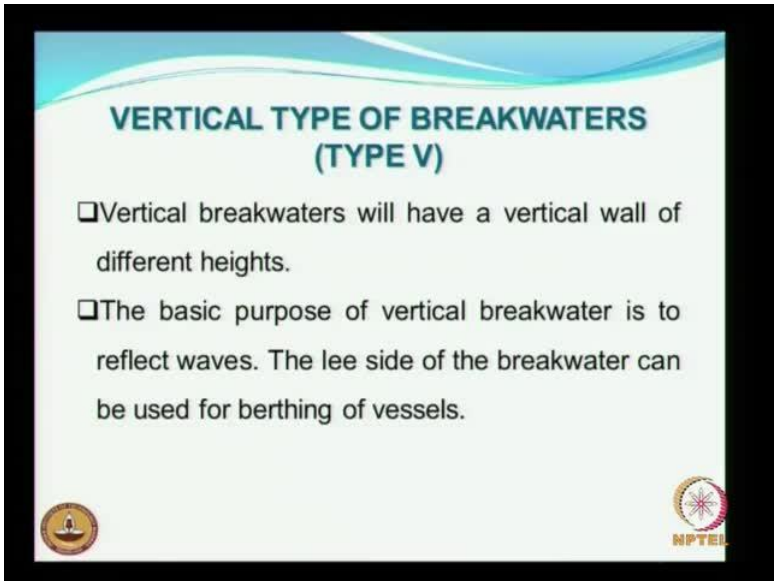

Vertical breakwaters will have a naturally vertical wall with different height. The basic purpose of a vertical breakwater is to reflect energy. So, you will not have any energy on the armour side on the lee side of the breakwater unlike rubber mound. Rubber mound permits certain amount of transmission because the absorbing will be may be about 50 percent say and some amount of energy may be about 10 percent is lost in friction. 10 percent is lo lost when it is running over, so may be 30 percent to 20 percent is being transmitted or may be even 50 percent is being transmitted. But in the case of a vertical breakwater the entire energy is reflected back, so on the lee side of the breakwater there is no energy.

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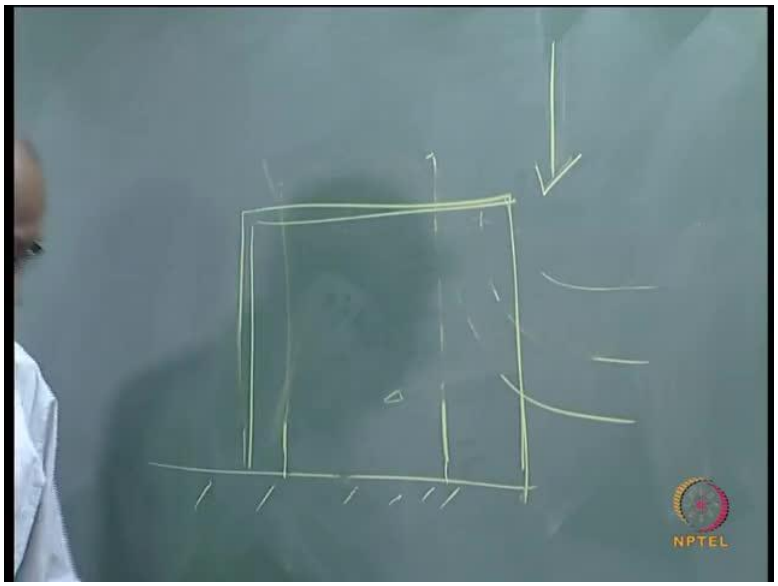

So, when you have a st, the shore line if I construct a break water like this, do you see any anything here? Any disturbance? Absolutely no, it be something like a swimming pool. If you remove one, then the disturbance is going to be, there should, there will be some amount of disturbance because there will be waves coming in this direction. Suppose, if you construct a wall like this and another wall like this, this is left and when the waves are moving in this direction, what do you see? You will see the diffraction taking place, so there will be very little energy that will be penetrating, but still there will be some amount of disturbance here.

Suppose, if you close this then it will be some something like a swimming pool, but if you close all the three sides with a rubber mound medium you will not have something like a swimming pool because there will still be certain amount of disturbance, it depends on the permeability that is being offered by the kind of, if you have a really a lot of permeability then you can have still a disturbance taking this is very simple. So, the lee side of the breakwater can be used as berthing facility, absolutely no disturbance, so the ship can be anchored. So, this is how vertical break water looks so this will be very calm.

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Now, we also have composite break waters. What is meant by composite break water? Composite break water you have both vertical composite break waters as well as horizontal break waters.

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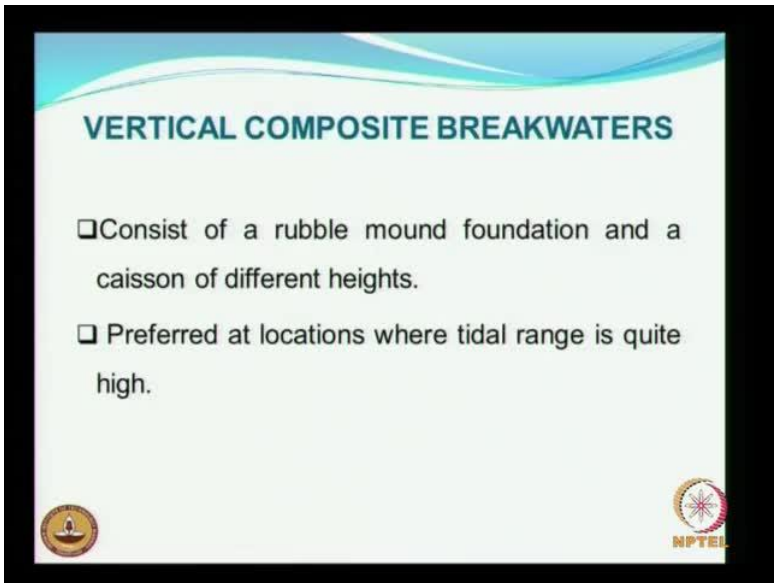

Under the vertical composite break waters this consists of a rubber mound, found rubber mound foundation and Caisson's of different heights, preferred at locations where tidal range is quite high.

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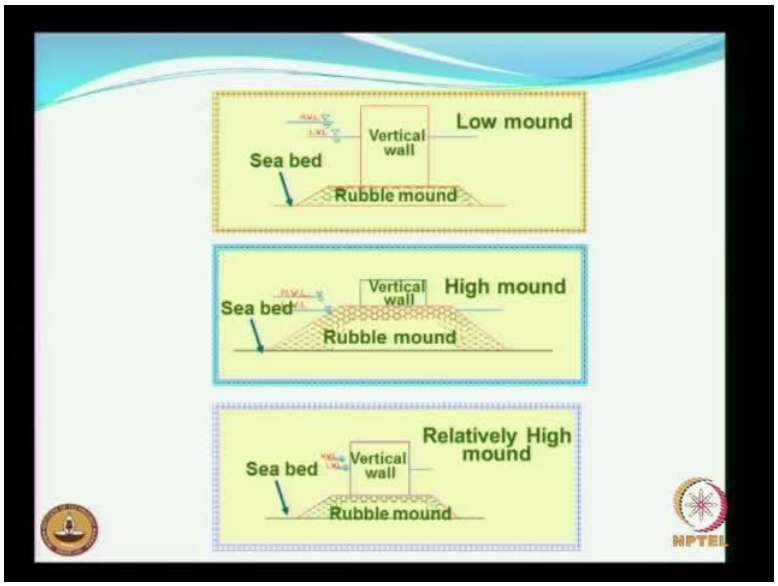

So, you can have a relatively low mound, where in you have this is going to take care of this stability of this mound, of this wall. This is low mound, where as this is a high mound and this is relatively high mound. Composite type break waters are preferred at locations where the tidal range is large. Why so because during a low tide rubber mound break water will work sorry composite break water will work or function as a rubber mound break water, during low tide.

During high tide the composite break water will work water or perform the role of a Caisson break water. And this also offers scour protection, when you have the sun there is not much of scour taking place near the tip, near the toe of the breakwater. So, what you need to do you need to find out the stability of this structure, you need to know the stability of the structure by evaluating the pressures acting on this. So, pressures exerted on composite break waters through which you can find out the stability of the Caisson is very well discussed in book of Goda.

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Refer to book, I think it is random waves random waves on structures or something like that it is an excellent book where Goda has given formulas for evaluating the pressures on the vertical composite break waters, evaluating the pressures on a vertical wall. We will see later and we will also cover something, some aspect on evaluation of the pressures on vertical break waters using the coastal the method of costal engineering manual.

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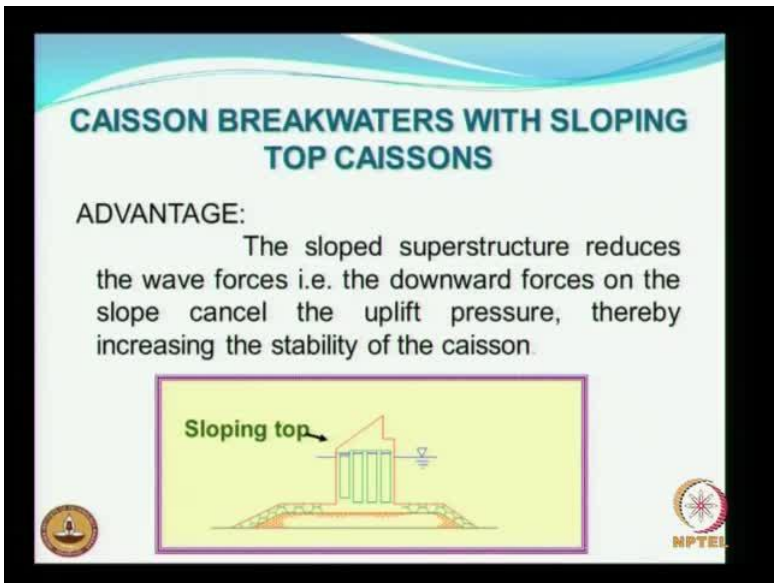

Caisson breakwaters with Caisson's with sloping tops the sloped super structure reduces the force, that is the downward force on the slope cancel the uplift force. So, thereby

increasing the stability of the Caisson, so there is a principle why you have a sloping surface particularly near the free surface. So, and that is why you are going to have a maximum force acting on a Caisson.

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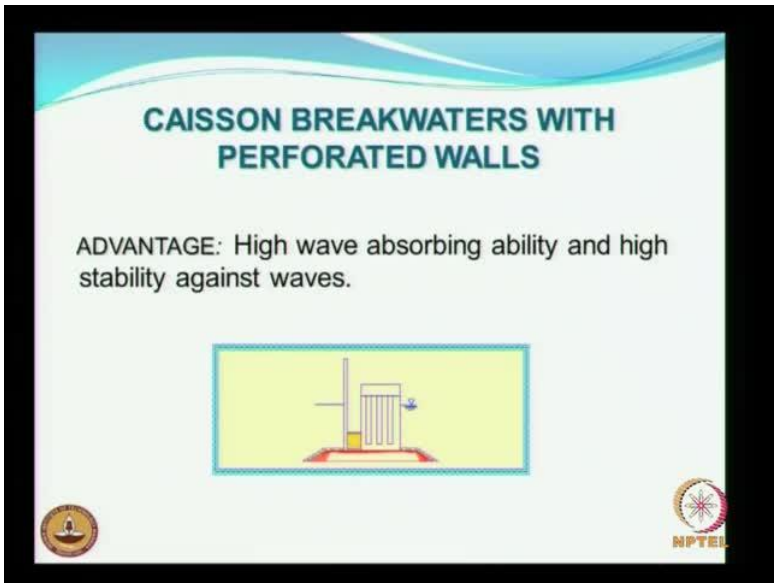

Caisson break waters with perforated walls. This can perforated walls, because you have a caisson already and suppose in case the caisson is in distress. Caisson is in distress means it might have been constructed many years back and probably it is serving more than its designed life, and it is playing an important role in a particular environment say. Then and you want to protect and you do not you cannot afford to lose the structure.

So, the apart from so many other ways of rehabilitation of the existing caisson type break water, you can also have a perforated wall in front of it on the sea side. So, when the waves come and feel the perforations on the sea side of the existing Caisson break water, the energy gets dissipated, because it is flowing through the pores medium and also the oscillations here can mostly the dissipation is taking place through the perforations. So, this perforated sheets or perforated walls, this is one area where lot of work has been done and is also being done even now.

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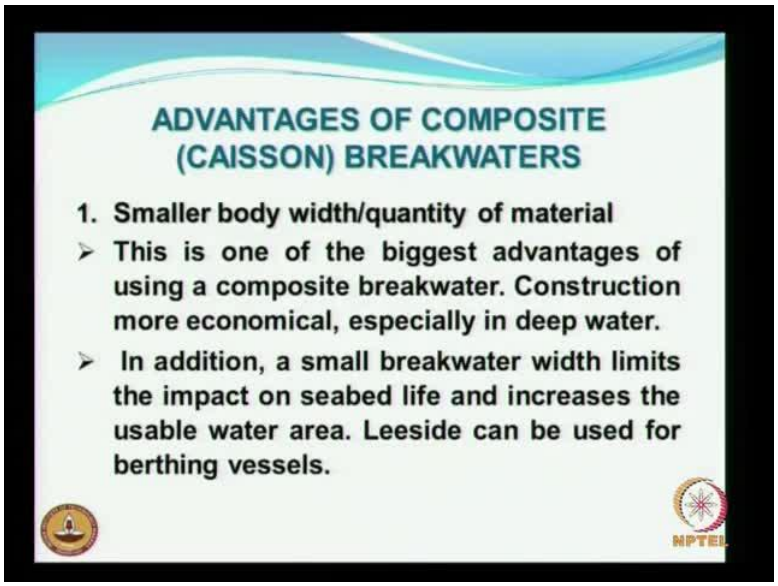

Advantages of composite break waters, small body width because the imprint on the in the ocean is less.

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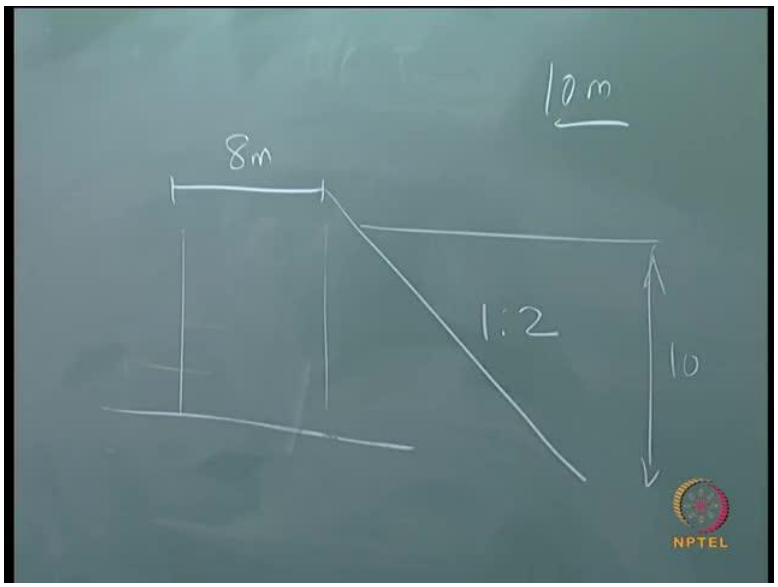

The base width of a rubble mound break water is huge, when you have a rubble mound break water the top width is usually about 8 meters, 8 to 10 meters. Then think of a structure think of a rubble mound meters, rubble mound breakwaters in a water depth of 10 meters. So, when you adopt 1 is to 2, so maybe this is 10 meters, now you calculate what is the base width? You understood? This is 10 8 meters plus you need to add up this

this kind of base width on both sides, so the total base width is going to be quite huge compare to a composite break water. So, that is a big advantage.

Construction is more economical particularly in deeper waters. If you go in for deeper waters the construction is quite easy, mostly it is a Caisson which is cast on land and then it is stored and then it is erected. In addition a small break water width limits the impact of seabed life because it does not really hinder the seabed life and increases the usable water area. Leeside can be used for berthing of vessels which we have already seen.

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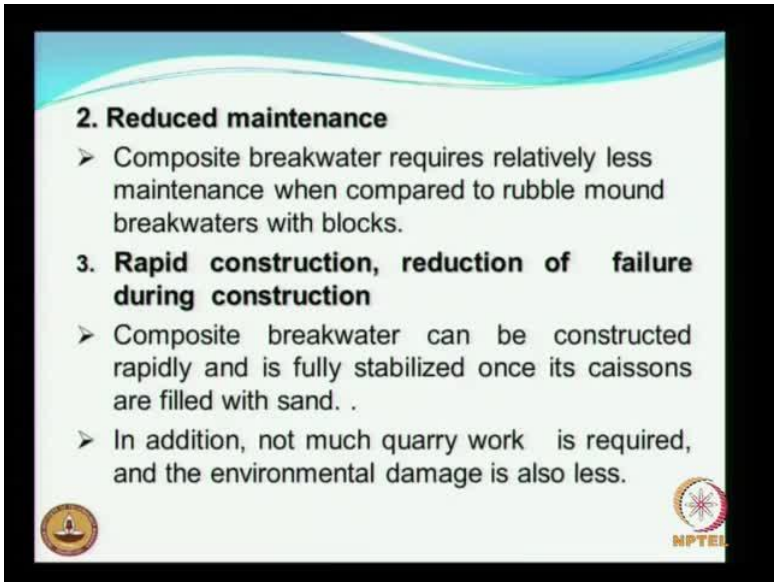

Reduced maintenance, composite break waters requires less maintenance relatively compare to rubble mound break waters with blocks I, it is almost free from maintenance, but still there is some amount of some degree of and the the construction is quiet rapid reduction of failure during construction, composite break waters can be constructed rapidly and is fully stabilized once the Caissons are made like a gravity structure, but by putting sand inside.

So, in addition not much of query work is required the environmental damage you do is far less compare to your rubble mound break water. But for fisheries harbor can you go for vertical break waters? No for fisheries harbor you go only up to about 6 meter, so you do not need to go for vertical type break water. So, with this I will stop here and we will continue in next class.