Port and Harbour Structures.
Professor R. Sundaradivelu.
Department of Ocean Engineering.
Indian Institute of Technology, Madras.
Module-3.
Lecture-13.
Design of Breakwater-Part 2.

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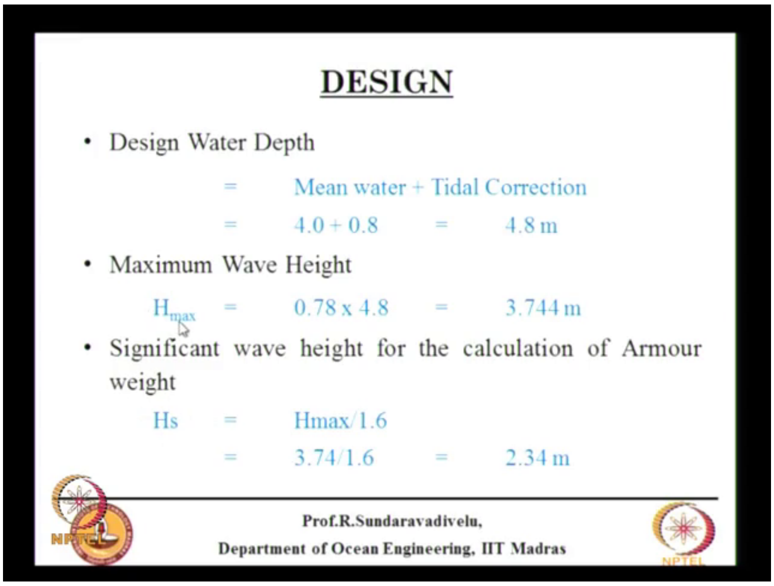

In last class we had seen the design of breakwater, we continue the design. We were designing for 4 metre water depth with surge and other high tide levels giving 0.8, 4.8 metres, maximum favourite we had calculated, 0.78 times the water depth and we have to design for significant wave height, not for the maximum wave height. Designing for significant wave height is like this, you have so many wave heights, you can either design for average wave height or maximum wave height but instead we are designing for significant wave height, that is average of top one 3rd of the waves.

But in shape design, floating body design, we design for H by 1 by 10, 1 by 10 means up 10 percent of the waves, that average we take. So it depends on how you do the experiment, present the result and derive the semiempirical formula. This is the formula which is being used, this is the weight of the individual Armour unit, it is based on the density of the individual Armour unit. Then the wave height, it is a significant wave height, KD is the activity coefficient, it depends on the type of Armour unit, SR is the ratio between unit weight of Armour unit weight of the water, cot Theta is the slope and we have to use 2 layers.

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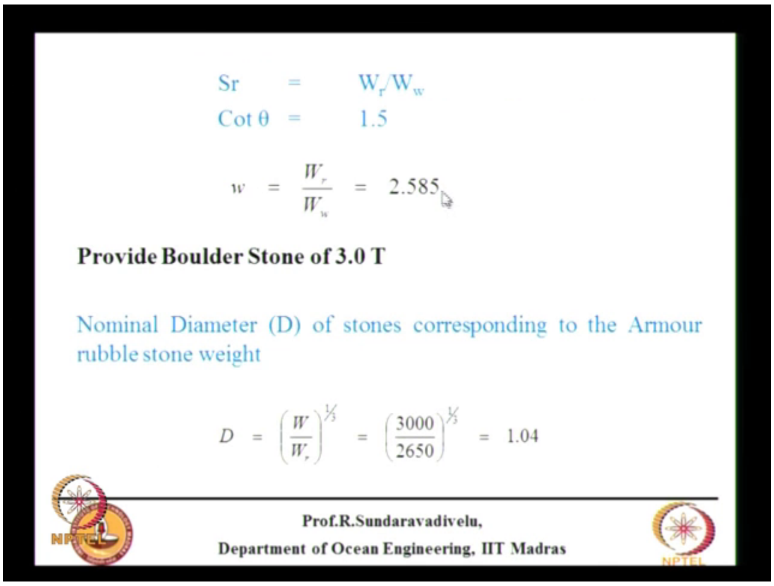

So we have substituted and we have got 2.585 tonnes and we are providing about 3 times. When we give like this, you should find out what is the size of the stone, the size of the stone is the unit weight of the stone 3000 KG divided by the unit weight of stone to the cube root. It is coming about 1.04 metre, sorry metre is not here, it is 1.04 metres, that is the size of the stone. 1 metre size of the stone, the typical size, you may get 1 by 0.9 by 1.1, it is not exactly one by one by one, it is not preferred, one by one by one also.

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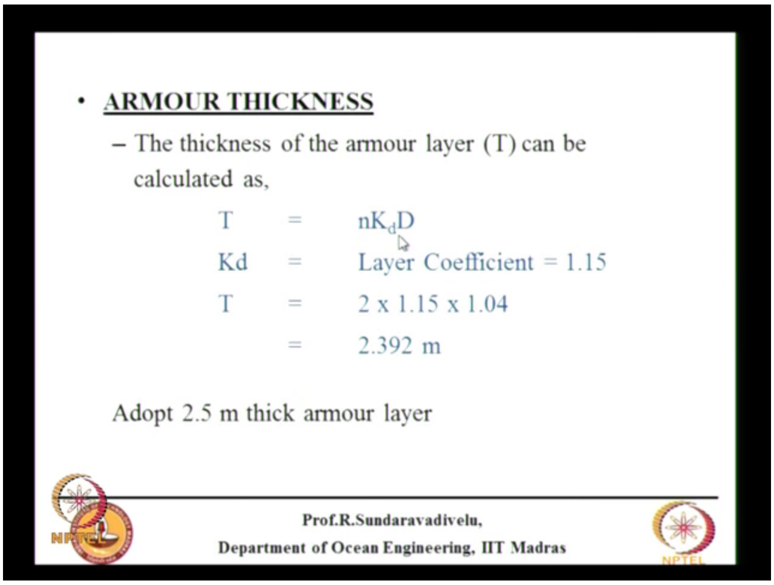

Then we have to see the 2 layer thickness, the number of layers is 2, KT is the layer coefficient, layer coefficient means when you stack one over the other, there may be some voids, some gaps, so the thickness will now be number of layers into size of the stone. And size of the stone also is not uniform, it is not 1.04 in all the directions. So to take care of this, we have a layer coefficient which is called as KT. This also changes depending on the type of Armour unit what you are using, that is a layer coefficient. This will be available in some textbooks or there is some shore protection manual in which this layer coefficient is available.

I will give this layer coefficient and stability coefficient in a table form towards the end of this lecture. So the thickness of the Armour player is 2.392 but we provide 2.5 metre thickness for the Armour layer. This is the main parameter what we are designing, we are designing the weight of the armour stone, diameter of the stone, that is the size of the stone and thickness of the armour layer. This is one of the most important design that we have to carry out for the breakwater.

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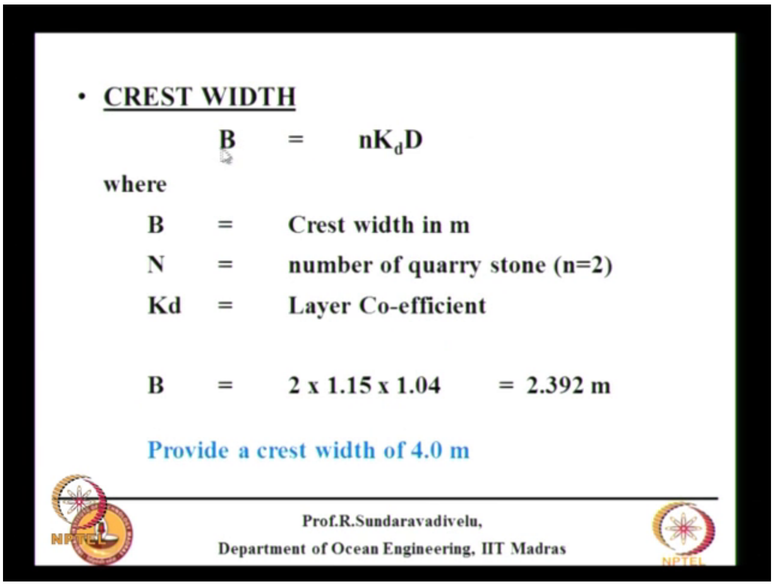

Next we have to find the crest width, that also depends on number of layers stones, quarry stones, layer coefficient and crest width in metres and B will be 2.392 but we provide 4 metre because for construction purpose, when you do it on the end on method, the lorry and other has to travel, that is why I give 4 metres. These are very small fishing harbours, whereas when you go for main port breakwater, minimum width required is about 8 metres because we need 2 lane highway. The fisheries Harbour, the water depth will be restricted to about 4-5 metres, whereas main ports, the breakwater will go up to 10 metre water depths.

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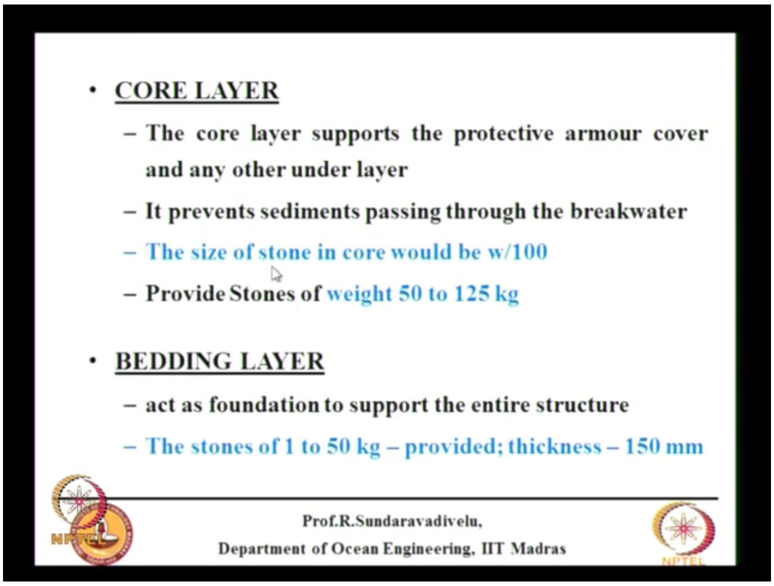

So though 4 metre width is sufficient come up to about 4 to 5 metre water depths, this acts as access, so you have to increase it for 2 lane traffic. So we were discussing that there are different layers, one is the armour layer, then we have the under layer, then core layer, then bedding layer. We will see how to design the core layer. The core layer, this supports the protective armour cover and any other underlayer. That is this is what is used as the foundation for the other layers. The other important thing is it prevents sediments passing through the breakwater. This is important, so whenever there is a sediment which is suspended in the water, that should not go through the breakwater.

What happens if it goes through? It will go inside and settle and you have to dredge. But it will go through the armour because armour has a lot of voids, it may go through underlayer, then also has voids, whereas core layer you make it in such a way that the voids are minimum. And it will not go through this, you cannot make 100 percent void free because we are stacking. The size of the stone in core will be W by 100, this W is the weight of the armour units, whatever is the weight of Armour unit divided by 100 and 3000 KG is the weight of the Armour unit, 3000 by 100 is 30 but we provide 50 to 125 KG, slightly higher values you can provide.

But this formula will be applicable for bigger armour size stones and for smaller armour size stones. When you do this civil engineering practice, you may not exactly adopt the formula because the formula is applicable for a wide range of water depths. The same formula, Hudson's formula is used, where it is 4 metre water depth or 10 metre water depth or 15 metre water depths. So but towards the end I will give a range of this, core layer stone. The bedding layer is between the core layer and the soil seabed, that is a soil types, depending on the soil type in the seabed, you have to provide the bedding layer.

The purpose of the bedding layer is to act as a foundation to support the entire structure and we provide the stones of size 1 to 50 KG and the thickness is about 150 millimetres. You cannot put it directly your core stone, top of the seabed, because core stone size is bigger, 50 to 125 KG. So when you put it, it will get into the seabed and it may get settlement also and proper distribution of ration will not be there, for that reason we put this. Sometimes below the bedding layer we use geotextile fabric. If the seabed is clay soil, we put a geotextile fabric, the purpose of the geotextile fabric is like a filter, like a coffee filter.

What happens in a coffee filter? You put a coffee powder and water pours in, with the coffee Dikashan it comes down. Same thing only the geotextile filter does, it allows the water to go either from the seabed to the this bedding layer or from the bedding layer to the seabed. But what it prevents is, it prevents the clay particle to get into the bedding layer, that since it is not cover, that should be avoided, we do not want the clay particle to get into the foundation layer or vice versa, that is why we put the bedding layer. Geotextile fabric is like netlon mesh and things like that, the aperture size is less than 75 microns.

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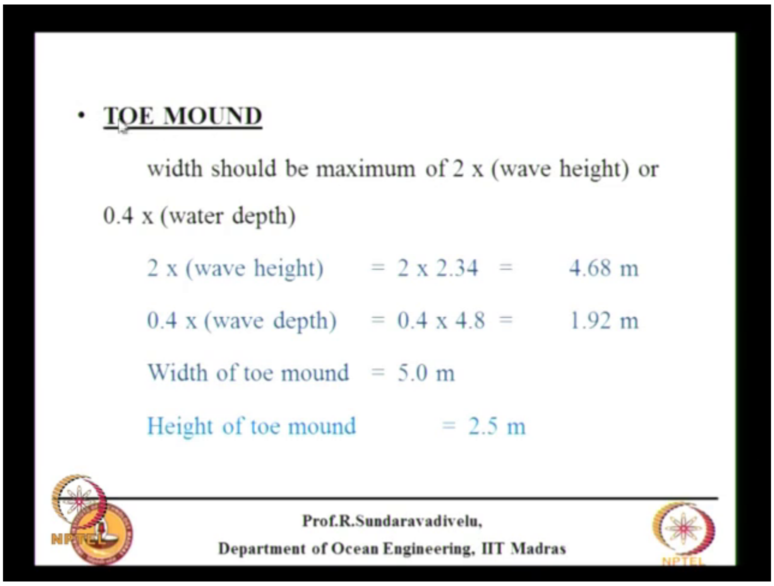

Then we have another important parameter, that is called as the toe design, I was repeatedly telling, most of the failure is because of the failure of toe mound. There are 2 things that are to be designed, one is the width, another is the height. The width of the toe mound is based on 2 criterias, it is a maximum of twice the wave height or 0.4 times water depths. Use 2 considerations, how much is twice the wave height and how much is 0.4 times the water depths. Water depth is already given 4.8, wave height based on the water depth we arrived as 2.34 metres.

So twice the wave height is 4.68 metres, 0.4 times water depth is 1.92, you take the maximum of this, so you take about 5 metre as the width of the toe mound. Typically 50 percent of the weight width is taken as height of the toe mound. It may look little bit odd to you, we are giving like this but this is the practice because some of the parameters what we are using is based on so many years of experience and design. Okay, which we, we know what factors is critical for the toe mound design but we give some empirical relations.

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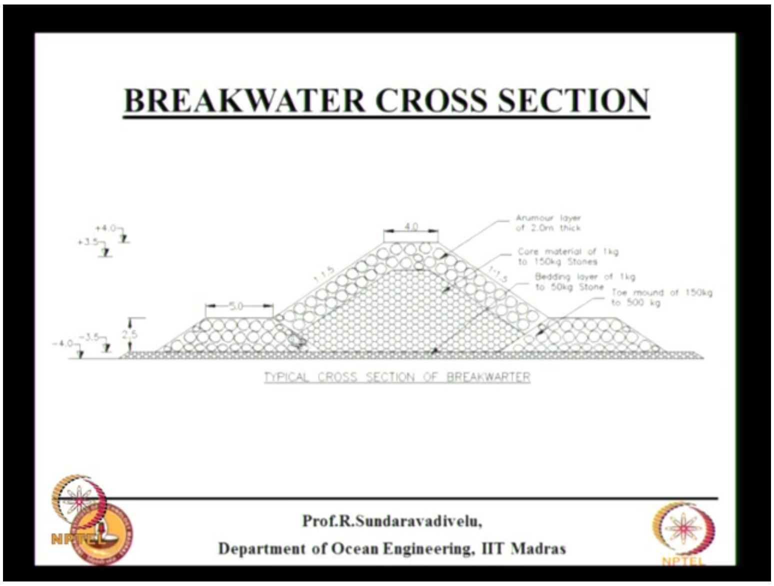

So this is the final structure, I may ask this question in your, we will be conducting 2 cases, one of the case I may ask, if this is a problem which is given, you have to calculate whatever has been given so far. I may change the water depth, based on that your wave height will change, the weight of the stone will change. So now I will tell you what from the bottom, here we may put a geotextile filter, the seabed consists of clay but even if it is sand, we may put a geotextile filter. Here it is not shown, with advancement in technology, recently we have started using the geotextile feature.

Once you put a geotextile filter, the whole unit acts as a single piece, otherwise geotextile filter is a continuous thing. It is available in 3 metre width, but when you are laying it, you stitch, 3 metre by about 200 metre may be available in a road but if you are putting 3 metre in this direction or another direction, you overlap and stitch it and lay it. That means we have a continuous layer here, whereas foundation is discontinuous. So we are providing the continuous layer, makes it to act monolithically and it also provides the cover to take place. Then we have the bedding layer, given as 1 KG to 50 KG stone, then we have the toe mound, 150 KG to 500 KG stone.

The width we have designed as 5 metres, the depth we have designed as 2.5 metres, the bed level is - 4.0, this is marked as 3.5, I think they have given 500 MM, but originally written about one day, maybe this increased it further, but we can put 150 also. Then the core layer is 1 KG 1 KG to 150 KG stones. Why this wide variation of 1 KG to 150 KG is, the particle size will be different. 150 KG will have a void in which let us say 100 KG will get into it. 100 KG will have a void in which 50 KG will go, 50 KG will have a void in which 20 KG will go, 20 KG will have a void in which 1 KG will go.

Concrete is also like that, concrete consists of cement, sand and coarse aggregate, coarse aggregate is 40 MM, in that you put the sand, particle size is very small, in microns, that will fill up and in that you put the cement, that will fill up the void. So here also the core is like that, so that the permeability in the core is negligible, it will not, if it is the seaside, if the water is coming, sediments are there, it will not get penetrate through this. Larger width is there, it may penetrate but it may not go to the other side. And the wave disturbance outside also will not percolate through this, that is another thing.

Then this is armour layer, the thickness we have defined as 2.5 metres, sorry 2 metres I have written, I think there is a mistake in this, this is 2.5 metre. And the stone size is given a 3000 KG, you have to put 2 layers for this, typical cross-section of breakwater. Any doubts in this? One of the major design, what now we have now done, we take a typical port, today it is being developed, it will be developed for 10 million tonnes because the viability will not be there if we do it for a Greenfield port less than 10 million tonnes.

To develop 1 million tonnes of cargo, to develop a port, to handle 1 million tonnes, it will cost 100 crores. This is some block cost estimate, so far 10 million tonnes it will be 1000 crores, out of this 1000 crores, breakwater will be about 30 percent, one 3^{rd} cost will go to breakwater, one 3^{rd} cost will go to working structures, other one 3^{rd} cost will go to dredging. These are typically the 3 components. The other 10 percent will go for other miscellaneous structures navigation, light, stockyard area, godowns, things like that. Is it clear?

If you want to develop a port, 1 lakh 25,000 crore is the estimate that we are going to build in the another 10 years, that is what we are going to spend on this. So if you are specialising, you have good great opportunity in India. So 10 million tonnes means it will be 1000 crores, breakwater is 300 crores. It is a very simple structure, you have seen how the various parameters are designed, but we have to do a physical model test to confirm, but this is at the undergraduate level, how you design. Now the coming slides I will be giving you what all the other parameters which are to be critically examined before finalising the breakwater design.

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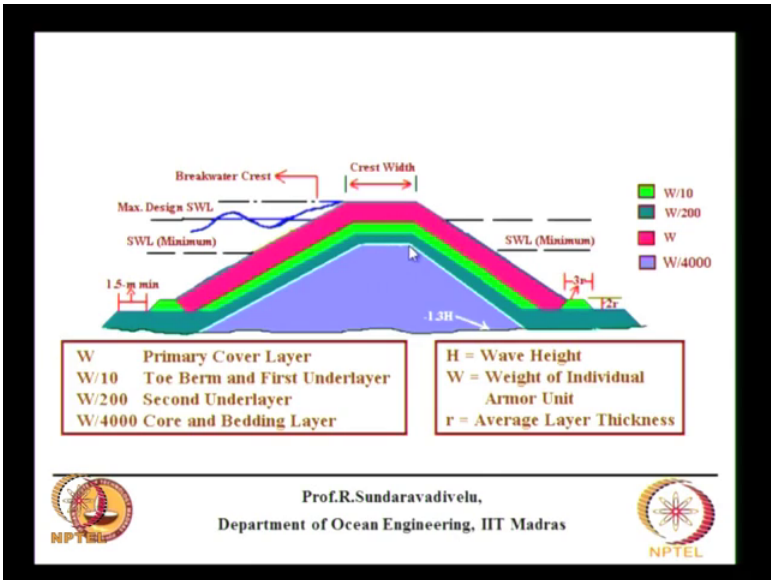

This is a textbook design what you can learn, but if you want a professional design, you should know the parameters what are there in the other slides. So this figure, you please draw and write down all these parameters. I will ask how will you determine the weight of core, under layer, armour layers. Only (())(15:40) you do not have to do any calculation but this figure is important. So now we will see the 1st layer, that is armour layer, armour layer is given here is W.

This W is calculated from Hudson's formula, when we have this under layer, that is W by 10, under layer 1, then we have this layer, this is W by 200, then we have this layer that is given by W by 4000. So these are the various things, W is the primary cover layer, that is the armour layer, W by 10 is used both for the toe berm as well as for the 2nd underlayer, I am sorry, toe berm and 1st underlayer is W by 10, I think there is, this is the, I am sorry, this is your 1st underlayer and this is your toe berm. This is the foundation for the toe berm and this is the 2nd underlayer, that is W by 200.

Then W by 4000 is current bedding layer, the parameters that are governing is the wave height, weight of individual armour layer and r is average layer thickness. In the earlier design I have given this width based on some other, there are various formulas available Hudson's formula, VanderMeer's formula for armour layer design, it is not one formula which is available in the industry practice. We want to calculate W, W is based on Hudson's formula. But we have another formula called as VanderMeer formula.

I am not teaching you in this class, similarly for calculating the toe berm width and depth I have given some parameters, but it also depends on the average layer thickness. Typically the thickness of any layer is twice the thickness of armour units. So the average or layer thickness of armour unit or bedding layer or to berm layer, if this is 1.5 metre, you have to provide twice that. To make it very simple, suppose this 2^{nd} underlayer, let us say we are using 75 MM metal size, then what you do is, twice 75 MM is 150 MM. So the layer thickness to be used is 150 MM since we are using 2 layers. So minimum thickness is 150, you can provide more also.

The point is clear to you, what are using it, you know the thickness of the stone that is used and there are some coefficients to get the average single layer thickness. You multiply twice that will give you the thickness of toe berm. Then the width is about 3 times r, that is for the toe berm. Right, like this you have to calculate. So here this formula is for very big water depth, the other formula what I have given is also correct only, that is for 4 metre. This formula is correct only, we have this is for larger water depth, you have to go in for W by 4000.

Sometimes they give you a range, W by 1000 to W by 4000. It is not normally, we cannot use one size, obviously if the core layer has to be impermeable, you have to use wide range. So they may use W by 100 to W by 4000 also. So here what they have given is - 1.3 H, that means further doing is this is your seabed, there are different concepts, suppose this is your seabed, the extra weight below seabed for 1.3 times the wave height and then fill this with foundation stone. Foundation means, in civil engineering practice it is below the seabed, so what this slideshows is they excavate below the seabed, how much you have to excavate, 1.3 times the wave height.

Sometimes it is very difficult to do 1.3 wave height if the wave height is very large, but for the major breakwaters, the soil is very bad, they may excavate even up to 3 to 4 metres. The point is clear no, you have a seabed, below seabed they excavate 3 to 4 metres, then start filling the core as well as the foundation stone, not put it directly on the seabed. But if the seabed is very good, it is Rocky strata or different is a very dense sand, you can directly put it on the seabed also, you do not have to excavate. See this civil engineering design is mostly site-specific.

Suppose you are designing a building in Chennai and same loads, that is the configuration, dead load, live load, everything is same, suppose you want to build the same thing, let us say in Guwahati, what you have built in IIT Madras you want to build in IIT Guwahati, can it be used? Yes or no, what answer? No means, why we cannot do, what are the factors you have to consider if it is in Guwahati which will govern the design? Somebody said soil, soil is one consideration, what are the other?

Earthquake.

Earthquake, that is the main parameter, Guwahati is in Seesmic zone 5, Chennai is I think it is in 3. So the force will be enormous, similarly wind also will be different, so we cannot use. Same way here also, depending on the seabed, the foundation requirement will be different.

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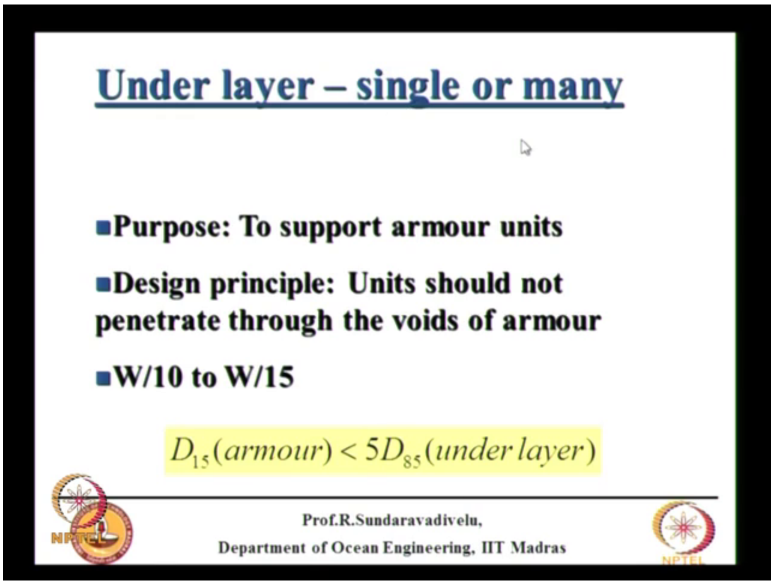

Now we will go in some more details about this underlayer. Single or many means you can have single underlayer or 2 underlayers or 3 underlayers. Typically 2 underlayers are used, underlayer so this one, this colour and this colour, these are the 2 underlayers. Purpose is to support armour units. Suppose you want to put about, armour unit weight is let us say about 12 tonnes, 12 tonnes if you want to support on the seabed, it is not possible. So you go and build so that you can be to a considerable height with gradually increasing size so that you can use the armour stone, place the armour stones. That is the purpose of these underlayers.

The design principle is unit should not penetrate through the voids of armour, that is the thing. Suppose there is voids in the armour, they should not penetrate through that. That means the weight distribution, see when you do the breakwater consideration there are 2 issues involved in this. One is transportation of these rock materials from the quarry, another is placement. So when you transport, you transport armour layer separately, under layer separately and then core layer separately.

You segregate in the source itself, do not bring it from the quarry all sides and try to aggregate at the Port construction site. When you transport itself, you transport giving different batch names and bring it to the site and stack it separately. Do not break it and dump it into the breakwater, there will be logistics problem. So you will be constructing, the lorry may not come and you will stop. You should, you can never stop the breakwater construction. If you stop the breakwater construction without the head, I said there is a head for the breakwater, then it will get washed away in a storm.

Suppose there is nine-month period only available, for 3 months you are stopping, you have to stop because you may not work in a very bad work condition. You have to provide temporary head where you have stopped, otherwise whatever you have built will get washed away. It has happened in some other projects also where we have executed. Normally cyclone starts in Kerala Northeast monsoon, when does it start, I am sorry Southwest monsoon. Which month it starts? How many are you from Kerala? Which month you have the monsoon?

I am not sure June, I think it is in May, sometime in May it starts, maybe I have to check. But one month ahead of the monsoon, scheduled monsoon, in one year it has started, if it is June, it has come in May 4, then one breakwater what we are building in Kanyakumari, we are building for 250 metre, 100 metre got washed away because we were not expecting the monsoon to come one month ahead, that is a problem. Here we have seen, given D 15 size of the armour unit should be less than 5 times D 85 size of the underlayer.

What is D 15 and D 85, civil engineering students?

Effective diameter.

Not effective diameter. How many of you have done sieve analysis in the laboratory, civil engineering? What is sieve analysis? What is sieve analysis? You have physically done or you had somebody else to do? What is sieve analysis, how did you do it, you really sieved different particle sizes? Sieve is nothing but a Jallade, Jallade is what is, we use it onto the wheat flour and Maida flour in earlier days, in the house we had that round thing with filter fabric, house ladies used to do that to segregate certain impurities and sometimes some insects also. Same thing only, we have sieves of different size, whatever you are getting from the sample, you do the sieving in different filter filter aperture size then direct.

Normally when you give the particle size, we use D 50, D 50 size means if we have the sieve of that aperture size, we put the soil particle, 50 percent will retained and 50 percent will go below, that is called that D 50 size okay. D 15 means 15 percent will go out, 85 percent will be retained. D 85 means 85 percent will be going out. So we have to have D 15 to D 85, point is clear no, 50-50 is clear to you. 50 means if we have a sieve of aperture size D 50 and if you pour the sand particle, 50 percent will be retained and 50 percent will go through, D 15 means 15 percent will go through an 85 percent will be retained.

So this is what we have to do, we have given some general guidelines but there is a basis also for this, that is what I am explaining this to you. If you do a major project, you have to calculate what is the armour size, that you can cannot do in a sieve, you have to do separately, it is not possible to get this.

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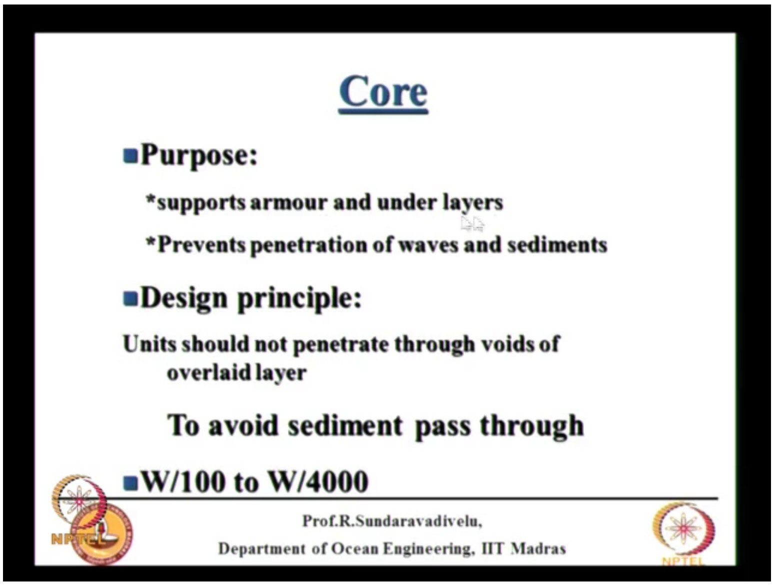

So core layer, it supports armour and underlayers, this prevents penetration of waves and sediments is the purpose. Design principle, units should not penetrate through the voids of overlaid layer. To avoid sediment passthrough, the range should be W by 100 to W by 4000, this is the range. I am not purposely telling all the ranges in the beginning itself, otherwise you will get confused, what is this region, why it should be done. I have put this at the end of the class. Slowly I am trying to bring this level of this breakwater design on a scientific basis.

We tell in the beginning, mostly you will get confused, why there should be a range of stone size. Right. We need range of stone size, it is preferable. The toe berm, this stability against scour and sliding, scour means if you go to the beach and stand in the water, what happens below your feet, it gets scoured away around your place. Same way we if you build the breakwater, what will happen, it will get scoured away, so to prevent the scour, we need this toe berm, sliding we will discuss later, it is having some force calculation. The whole breakwater, stone what you are putting in the armour layer, the toe berm is not there, it will go down, for that only we need this.

This dissipation is between W by 10 to W by 15, it is not uniform. If you see the core layer, the distribution is wide, W by 10 to W by 4000, whereas if you see here, it is W by 10 to W by 15. Even armour layer, there is some variation, if you calculate, armour layer is W, armour unit weight, you may not put W, you may put 0.75 to 1.25 times W. You may not put the single sized stone, it is not possible.

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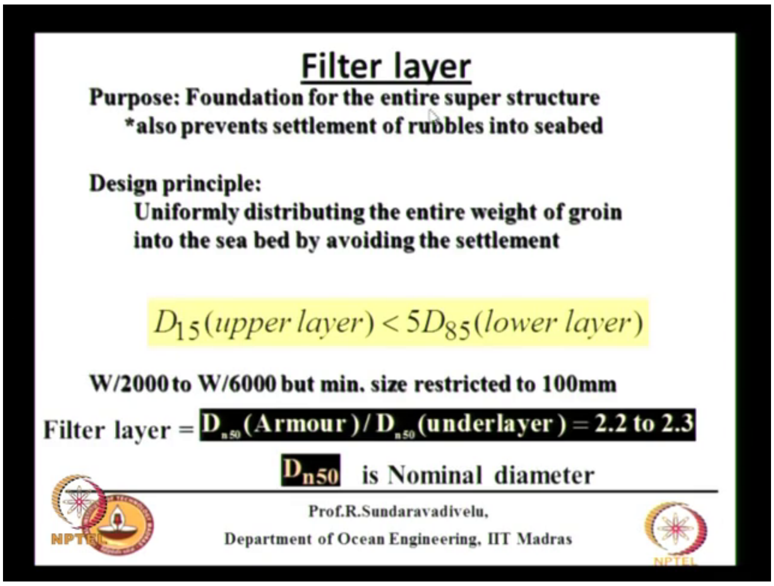

The filter layer, foundation for the entire superstructure, this is the one and also prevents settlement of rubble into seabed. If you have the rubble of couples, that is called layer stones into seabed, that will also accelerate corrosion, I am sorry scour. The design principle is, this has to uniformly distribute the entire weight of the groin or breakwater into the seabed by avoiding the settlement. So what we are trying to do is we are trying to distribute the total weight of the breakwater unit for a larger and wider area, for that only we have to use the foundation.

So if the soil has a bearing capacity, bearing capacity means how much load it can take. Suppose the total weight is X and the bearing capacity is usually in kilonewtons per metre square, that is Y, your distribution should be X by Y, X is kilonewtons, that is the weight, total weight per unit weight. And the bearing capacity is kilonewtons per metre square, so whatever you get will be the width because you are taking 1 metre along the length of the breakwater. Suppose there is a breakwater, along the length of the breakwater you take 1 metre, then calculate the total weight, that is X.

Bearing capacity, based on soil mechanics testing and other things you get as Y. X by Y will give you the width of the breakwater. So this will be D by 15 of upper layer, should be less than D by 85 of lower layer, this distribution will hold, W by 2000 to W by 6000 but minimum size is restricted to 100 millimetre. This, there is a very good reason not to put very small size stone. You are putting it in the seabed in open sea condition, if you put very small size, where you are putting it will not be there. If you are putting at the Gajendra circle, it may go to Kaveri hostel.

So even here, when you put a filter layer, only about 50 percent or 60 percent will be at the place where you wanted to put, even we put 100 MM, otherwise it will get dragged away to some other place. If you a trench, that is why they make a trench for foundation, then you can dump it in that. That is why they prefer to have a trench of at least 1 metre and put the foundation layer on that. We make a trench and if you drop it, it will not go elsewhere. So this, Dn 50 is a nominal diameter but you please understand this that Dn 50, normally we use this Dn 50, it is a nominal diameter when you talk about any different layers.

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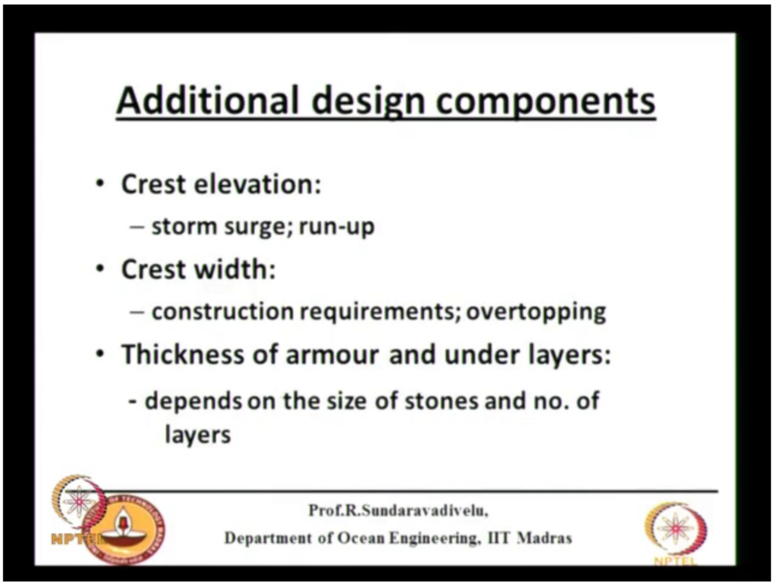

The additional design components are crest elevation, so when there is a storm surge and there is an up, I will explain about this later, your top of the breakwater should be above this. The crest width depends on consultant requirements as well as the overtopping. The thickness of armour and underlayers, this depends on the size of the stones on number of players. So these are the design components out of which the top 2 is very important, the top of the crest. So if you see the order of failure reasons, the 1st one is the toe, the 2nd one is the crest elevation. If you have not provided a crest elevation properly, then also it will fail.

Sometimes the crest elevation is not based on significant wave height, it is based on maximum wave height, and again based on return period. Whenever I talked about the significant wave height or maximum wave height, this is based on depth dependent. Suppose it is dependent on steepness, what you do is you calculate the significant wave height, that will be different for different return period. Suppose you take a 25 year as a design period, return period, if we take the significant wave height as 5 metres, if we increase it to 100 metres as return period, it will go to 6 metre or 6.5 metre. You understood no, if the return period is 25, you are extrapolating, you get about 5 metre as a significant wave height.

Suppose you may get 100 metre, you may go to 6 metres, hundred years. If we take it to 1000 years, it may go to 6.5 metres. Based on the return period only you have to design what is the significant wave height. This is not based on only the wave climate at a particular location, the particular location based on return period. What is the return period of tsunami, tsunami return period if you want to take, it is once in 500 years. We had tsunami recently, 2002 or so, 2004, then the previous tsunami was about 500 years back, not recently. Some of the earthquakes, the return period may be about, not return period, in a 100 years, you may get an earthquake.

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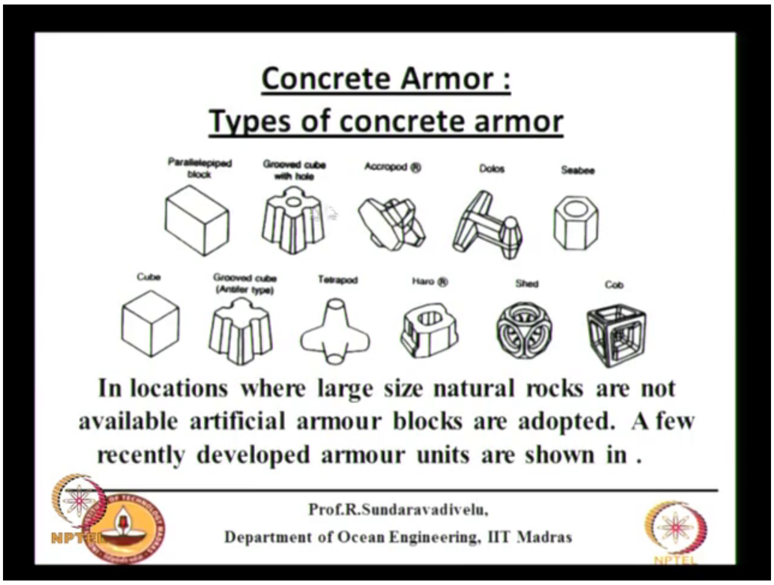

In 1000 year you will get much higher earthquake. So if we take Andaman Nicobar Island, hundred-year return period, your intensity maybe about on Richter scale 7 or 8, if we take thousand years, it may be nearly 9.5-9.8, return period is very important. So these are different types of armour units, this is a block, grooved cube, acropode, I have shown that in the last one of the things, Dolos, Seabee, cube, grooved cube, tetrapod, this is most commonly used in India this tetrapod, and acropode also we have used. The difference between acropode and other things is acropode is single layer, we do not have to provide double layer.

But placement is important, acropode, we have to use a GPS and position the acropode. This tetrapod and other armour units are randomly placed, you can just place it anywhere. So in location where large sized natural rocks are not available, artificial armour blocks are adopted.

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K_D values : depends on the type of the armour Block, number of layers, n, type of placement, types of waves (breaking or non breaking)

Table 1. Suggested K_D values for use in determining armour unit weight[1].

No - Damage Criteria and Minor Overtopping							
			Structure Trunk		Structure Head		
			K_D		K_D		Slope
Armour units	n	Placement	Breaking Waves	Non-breaking waves	Breaking waves	Non-breaking waves	Cot θ
Quarrystone Smooth rounded Smooth rounded Rough angular	 2 >3 1	 Random Random[4] Random	 1.2 1.6[4] 	 2.4 3.2 2.9	 1.1 1.4[4] 	 1.9 2.3 2.3	 1.5 to 3.0 5 5
Rough angular	2	Random	2.0	4.0	1.9 1.6 1.3	3.2 2.8 2.3	1.5 2.0 3.0
Rough angular Rough angular Parallelepied[7]	>3 2 2	Random Special[6] Special[1]	2.2 5.8 7.0-20.0	4.5 7.0 8.5 -24.0	2.1 5.3 --	4.2 6.4 --	5 5
Tetrapod and Quadripod	2	Random	7.0	8.0	5.0 4.5 3.5	6.0 5.5 4.0	1.5 2.0 3.0
Tribar	2	Random	9.0	10.0	8.3 7.8 6.0	9.0 8.5 6.5	1.5 2.0 3.0
Dolos	2	Random	15.8[8]	31.8[8]	8.0 7.0	16.0 14.0	2.0[9] 3.0
Modified cube	2	Random	6.5	7.5	--	5.0	5
Hexapod	2	Random	8.0	9.5	5.0	7.0	5
Toskane	2	Random	11.0	22.0	--	--	5
Tribar	1	Uniform	12.0	15.0	7.5	9.5	5
Quarry stone(K_{RR}) Graded angular	-	Random	2.2	2.5	--	--	

So we will see this table, this table is not simple table, it is, but I will explain what it has. This 1st column, it gives what is the type of armour unit, whether it is a quarry stone or whether it is a tetrapod, was it is a Dolos. And the placement is random placement or special placement. The structure trunk, structure head, you know what is trunk and head, I have shown the figure, head is at the nose of the breakwater, trunk is that any section. You have this KD coefficient, trunk there is a KD coefficient, head there is a KD coefficient. And this KD coefficient is very strongly depends on slope of the breakwater. The slope is cot Theta, it can vary from 1.5 to 5 for a quarry stone, but typically it is between 1.5 to 3, that is the slope of the breakwater, what here you see.

And we have 2 types of waves, breaking waves and nonbreaking waves. When we say a particular wave, when it reaches a water depth where the water depth cannot sustain that ways, it breaks. Sometimes the waves break on the breakwater itself. Suppose the maximum wave height that is coming at a particular location with a hundred-year return period, is only 6 metres, in 10 metre water depth it may not break. That means it is nonbreaking waves, is it clear to you? Suppose I am designing a breakwater, breakwater is designed for a water depth varying from 0 metre to 10 metre.

For 100 year return period, the significant wave height is 6 metres. 6 metre wave and it will break, 6 metre wave will break, H by D is equal to 0.78. So 6 by 0.78, that water depth only it will break, maybe 8 metre it will break, 10 metre it will not break. If you are using the same unit, let us say this tetrapod you are using, for a nonbreaking waves, the stability coefficient is higher. Stability coefficient is coming in the denominator, if it is a breaking wave, it is less.

That means the stone weight will be more if it is a breaking weight and if it is less, it will be a nonbreaking wave.

And in head, it will be much less, because you are getting the waves from all the directions. Point is clear no? Stability coefficient is not constant, though the formula is simple, stability coefficient depends on the slope, it depends on the whether it is ahead or trunk or it depends on the breaking nonbreaking waves, it also depends on type. Suppose I am using 8, for stone I may be using, angular stone only, half of that, 4. If it is breaking, we will use only half of that, 2.

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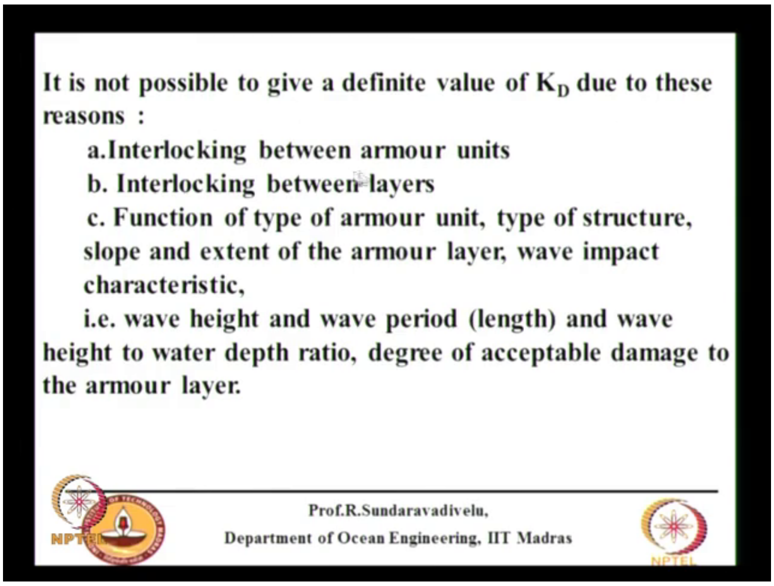

Why we cannot give a different value of KD, this is because interlocking between armour units, interlocking between layers, function of type of armour unit, type of structure, slope and extent of armour layer, wave impact characteristics, wave height, I have not told wave period, wave period also is a function, wave height to water depth ratio, degree of acceptable damage to armour layer. So this we will continue in the next class.