Port and Harbour Structures.
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Module-3.
Lecture-14.
Berm Breakwater.

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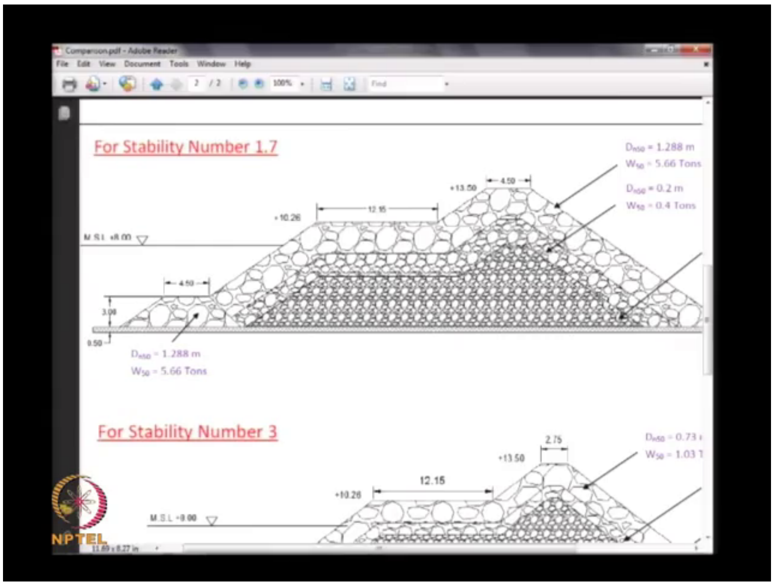

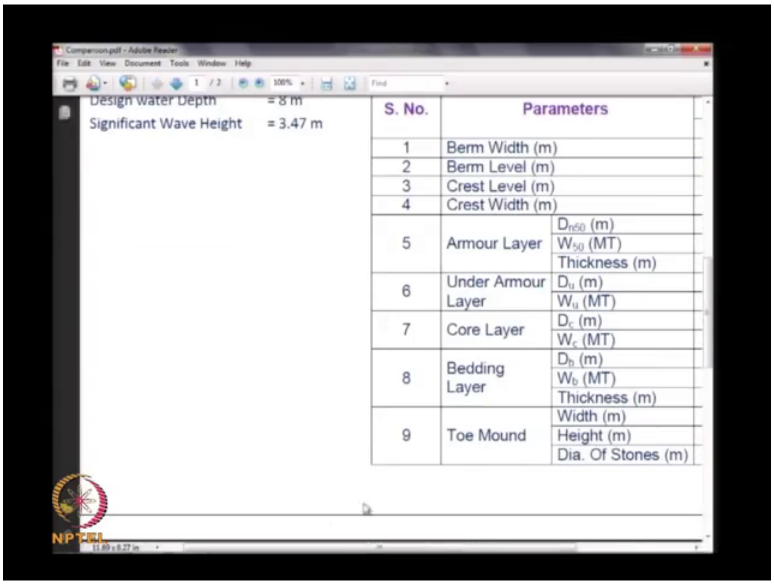

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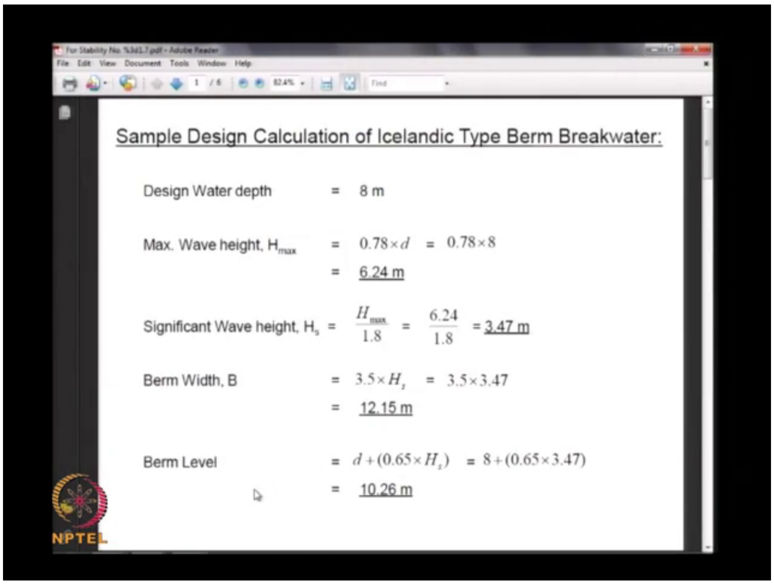
2	Berm Level (m)	
3	Crest Level (m)	
4	Crest Width (m)	
5	Armour Layer	D_{n50} (m)
		W_{50} (MT)
		Thickness (m)
6	Under Armour Layer	D_u (m)
		W_u (MT)
7	Core Layer	D_c (m)
		W_c (MT)
8	Bedding Layer	D_b (m)
		W_b (MT)
		Thickness (m)
9	Toe Mound	Width (m)
		Height (m)
		Dia. Of Stones (m)



In this class we will discuss about berm breakwater. The berm breakwater unlike conventional breakwater, there is a berm, this is called as a berm. So we will discuss about this in this class. We are going to discuss about 2 types of breakwaters, 2 different stability numbers, one is reshaped breakwater, another is non-reshaped breakwater. So the difference between them is the stability number 1.7 and 3. I will just give the wave breakwater. This is the sample design calculation, the water depth is 0.8 metre, some of the procedure is same as conventional breakwater.

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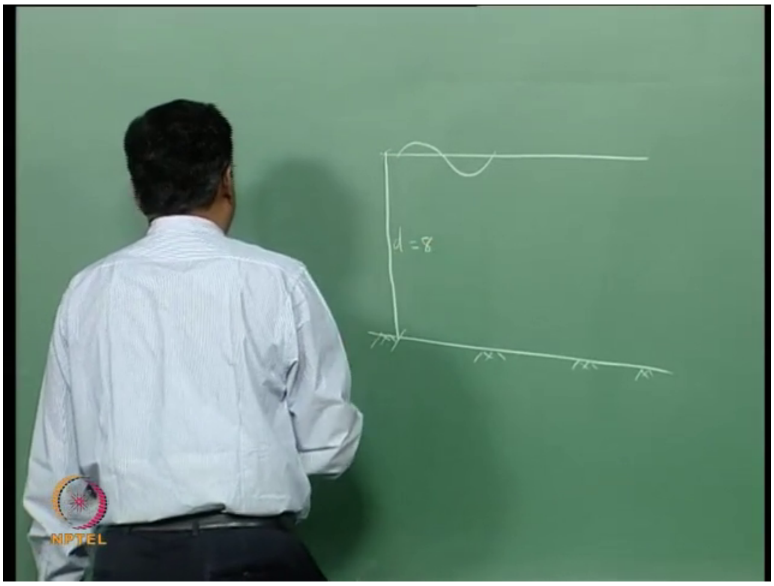

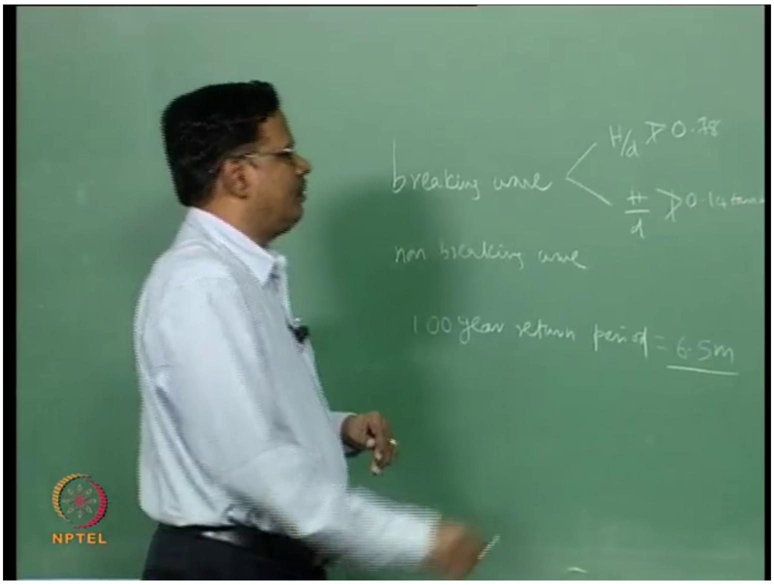

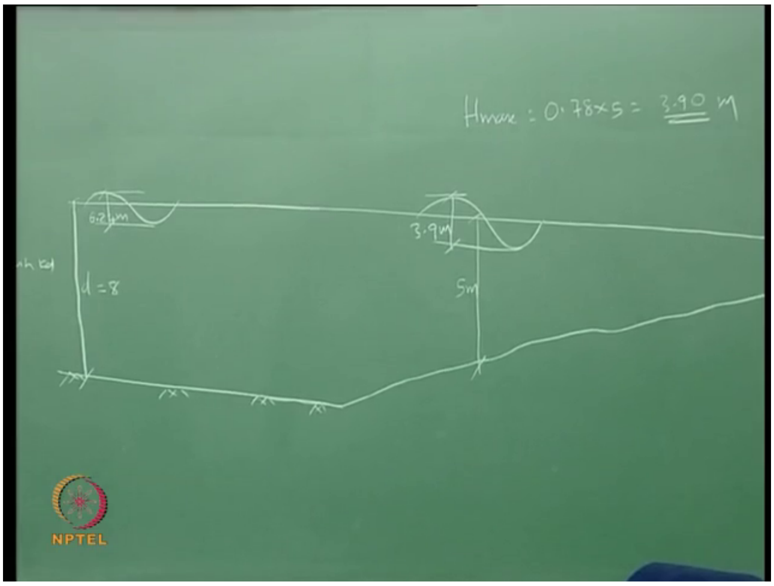

You calculate the maximum wave height, 0.78D, this wave, this 6.24 metre, what we are talking is the wave which is nonbreaking. Suppose you have the wave and you have this water depth, the stability number what we are talking is different for a breaking wave and a nonbreaking way. There are 2 approaches for wave breaking, that this H by d should not be greater than 0.78 and H by d should not be greater than 0.14 tan HKD, so if it is greater, then it will break. Then one of the classes I said, for a hundred-year return period, if the wave height is let us say for this case is 6.5 metre and this maximum wave is 6.24 metre.

Suppose you go to the coast the water level will go on decreasing. You take a water depth of 5 metres, then what will be your H Max, H max will be 0.78 into 5, so this is 3.9 metres. I am going to ask a question, this 6.24 metre is to be considered as a breaking wave or a nonbreaking wave, whether this 3.9 metre is to be considered as a breaking wave or a nonbreaking wave? Question is not clear? The answer is the same, for both the cases of 8 metre and 5 metre, whatever wave heights you are getting by using this formula H, breaking wave is H by d is equal to 0.78, then we have to calculate this, you have to assume these waves as breaking waves.

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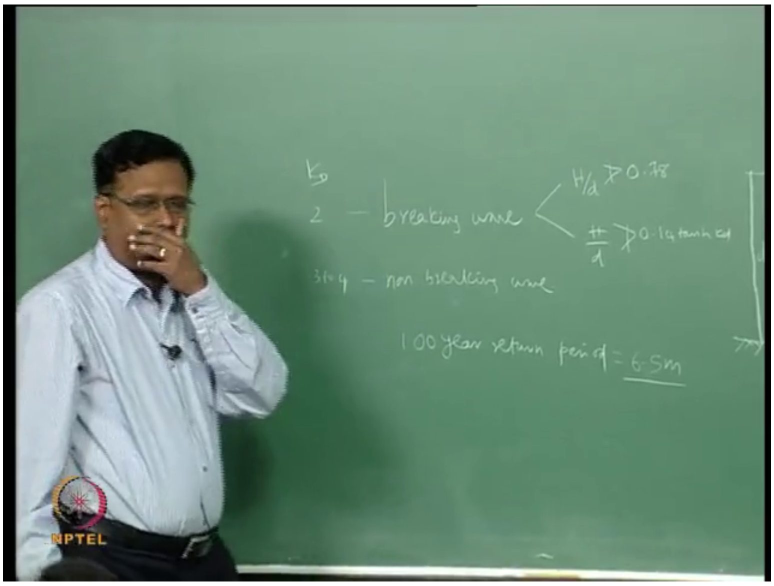

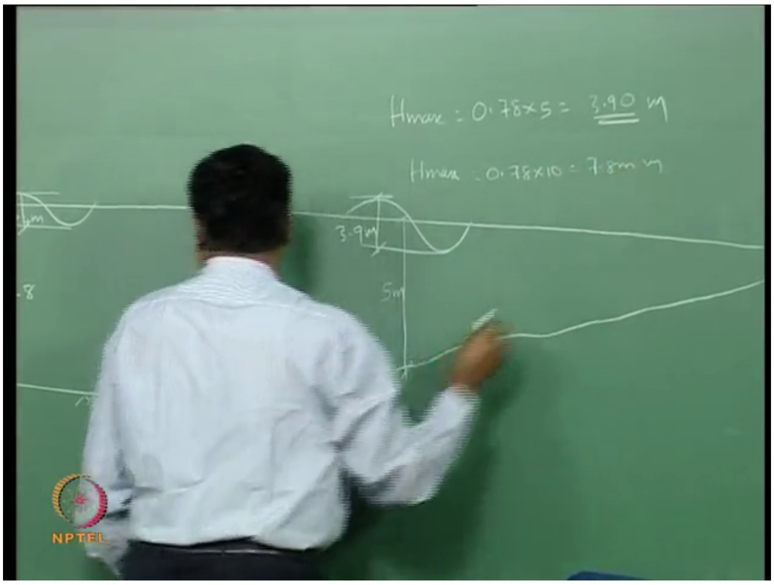

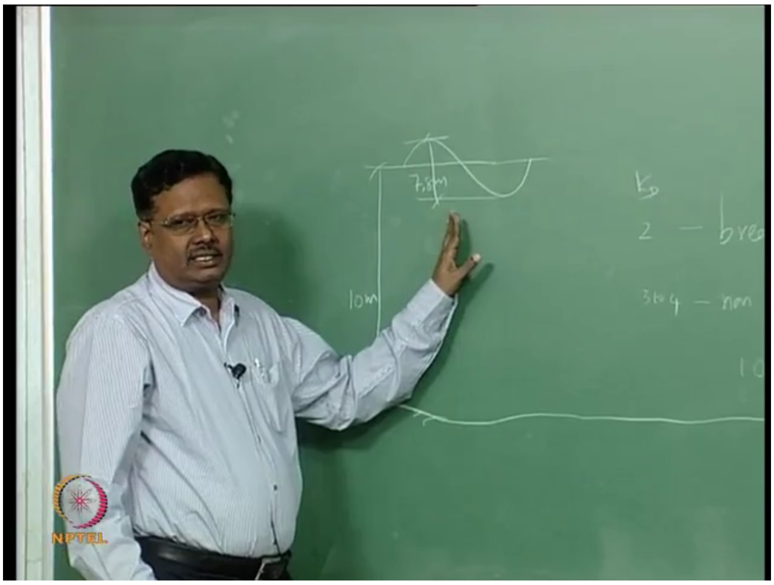

And the stability coefficient KD, for breaking wave it is 2, for nonbreaking wave it maybe between 3 to 4. If the 100 year return period wave height is 6.5 metres, if we go for water depth more than 10 metre, for 10 metre what will be the wave height, H max will be 0.78 into 10, that is 7.8 metre. Suppose you go to a deeper water, I will go to the other side of the board, then here is the water depth is 10 metre, here the breaking wave is 7.8 metre, but in this case you should consider only a 100 year return period wave of 6.5 metre, you should not consider 7.8 metre.

See in a 100 year return period, your waves of 6.5 metres only will come, right. 6.5 metre one is travelling here, when it comes to 8 metre water depths, it will break. If a wave of 4 metre comes, it will come and break at 5 metre, but at this location the wave of 7.8 metre or slightly more has to come to break, but wave of 7.8 metre will not come, then it will not break. Then we have to use 100 year return period wave of 6.5 metres. Is it clear, there should be a wave for this particular site, at Gopalpur, 100 year return period wave is 6.5 metre.

The 6.5 metre wave when it comes, it will break in water depths of about 8 metres, when lesser wave of 4 metre comes, it will break in a water depth of 5 metres. It can come anytime, 6.5 will come and less than 6.5 also will come. But there may not be any wave which will be coming more than 7.8 metre. And more than 7.8 metre comes only, the wave shall break, otherwise what you have to assume is, you should not assume this, you should assume only 6.5 metre, nonbreaking wave which can have a higher stability coefficient and in that case your weight of the stone will be less, compared to a breaking wave.

So this is the influence of breaking wave on design of breakwater. I am going to ask this question, you have any doubt, you ask me. All of you it is clear? Not clear? What is not clear you have to tell, then only I can tell. You know what is the return period design wave? What is the design wave? How the waves are formed, how is the wave formed?

Because of wind action.

So you need for a wind to have sufficient duration and fetch, fetch means the area over which the wind is acting and duration means number of hours the wind is acting, so based on that you have the wave height which is generated. For 100 year return period, that is over a period of 100 year it will take, the maximum wave which can be produced is 6.5 metre. Suppose 6.5 metre waves come in 10 metre water depth, will it break, it will not break. So we are not using a breaking wave height at 10 metre water depths, we have to use only 6.5 metre nonbreaking wave for the design of breakwater because 7.8 metre wave will not come. So you have to use this statistical information. What do you want to choose? You tell me.

I am just asking why 100 years…

I am asking you what do you want to choose.

If you would have taken 1000, it may not be greater than 7.8.

You can use that also, 1000 years also, 100 is a round number they have used it, there is a basis for that. The basis is generally you have to discuss about the life of the structure. You are from civil engineering or which branch? civil. What is the design life of your structure?

200 years.

Incorrect. This is a very interesting topic, I will not spend time on that. The design life of your marine structure is between 40 to 60 years, onshore structure is 60 to 75 years, that is what is happening. In Singapore wave to consider design life is much less because every 10th year they demolish the structure and reconstruct the structure. That is a different aspect, design life depends on the durability of the structure, durability is about the corrosion and other aspects. Other thing is reclassification of structures, suppose you, if you are coming after 20 years to Chennai, you will be seeing at some places what was existing earlier it will be totally different now because the zones are reclass.

The typical example is the OMR road in Chennai, where some 20 years back were all villages, huts and all, now you have Hiranandani and all kinds of flats. That is what they are building because of the necessity of urbanisation. In Singapore every 10^{th} year or 15^{th} year they demolish the structure and then reconstruct it, except the heritage structures. We have so many kingdoms Chola, Chela kingdom, Pandya kingdom and all, none of the palaces you will be able to see, only temples we are seeing because temples are designed for with higher factor of safety and the design life is much more than normal residential building and palaces.

So 100 year is taken because twice the design life is considered as the life for which you have to design, there is the fatigue comes into picture. When you talk about the life of the structure, the fatigue design which controls, the fatigue design life will be twice the design life of the structure, that is why this 100 year comes into picture. So after 100 years the structure will not be safe because there will be so many storms it will be taking place, there will be some damages which will take place, so you have to strengthen the structure after 100 years, that is why we take the 100 years.

But to fix the top-level of the structure, I said we have to take 1000 years return period wave because in Katrina, in US Gulf of Mexico, when Katrina came, the top-level was much higher than 100 year way because the top of the jacket platform was damaged. So for that reason they want to fix the top-level considering one in thousand years. Suppose you want to build an atomic power plant, you want it to be very safe, you can take one in 10,000 years. There is no limit for this, it depends on what is that you are designing, what is the importance which you are attaching.

The design wave at 5 metre depth is 3.9 metres?

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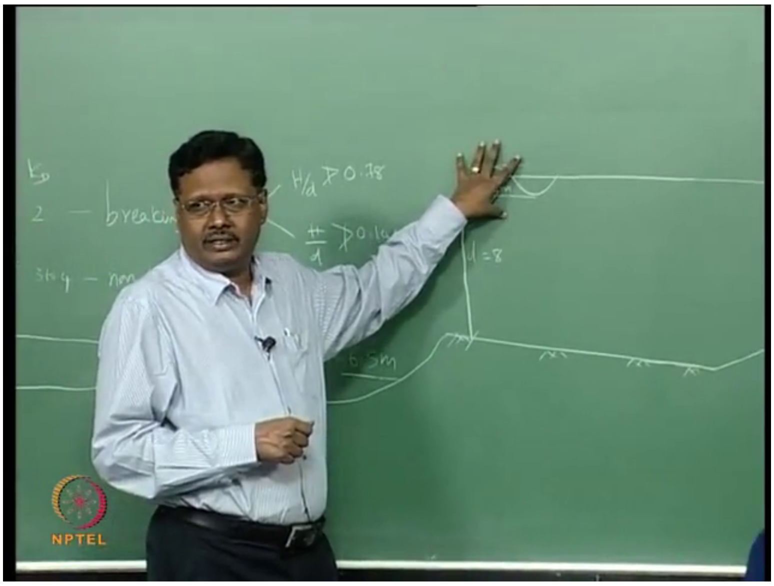

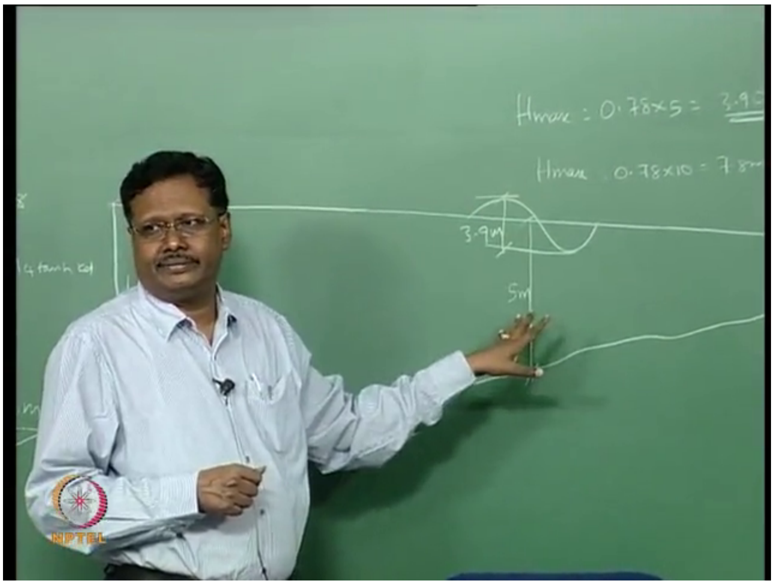

Yes, that is of breaking wave. When 6.5 metre comes, it will break at this occasion, a 4 metre wave when it comes, it will not break, you have to take 4 metre as an nonbreaking wave. It will travel here and goes to this place and it will break at 5 metre water depth. So we have to take this as a breaking wave. The stability coefficient in Hudson's formula is different for breaking wave and nonbreaking way. So breaking wave needs higher design. So another important parameter is this breaking, this is a significant wave height for which you are going to design.

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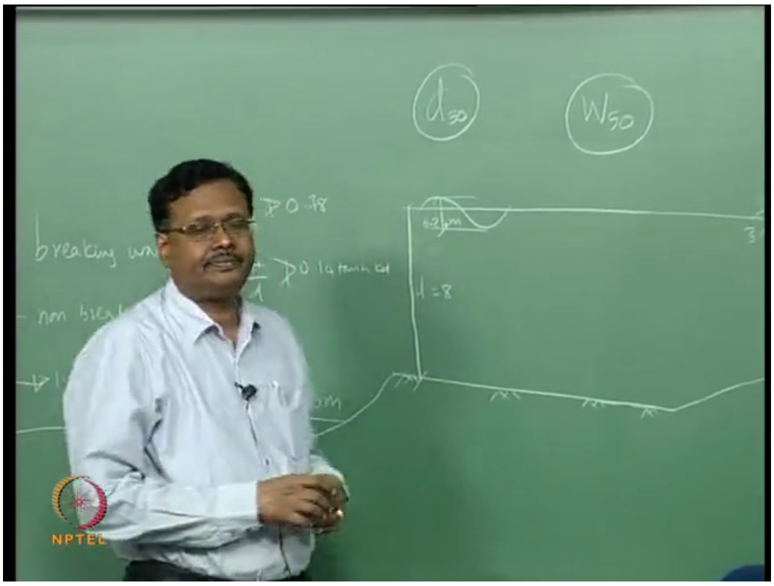

Similarly when we talk about the stone, the size of the stone is written as W 50, so soil mechanics we know what is d 50, do you know what is d 50? All of you might have completed soil mechanics course, you would have done laboratory sieve analysis. You have done sieve analysis? Sieve analysis you have done or not? Sieve analysis means in houses the housemaids in earlier days, they used that Jallade to separate the size of rawa, Maida and things like that, same thing is there in civil engineering laboratory to find out how much percentage of material is passing below, how much is retained. Okay.

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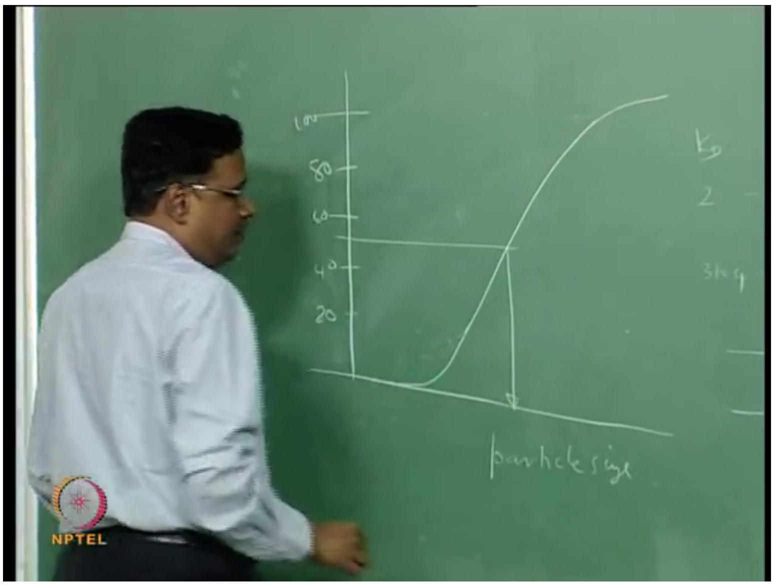

Yah And that and that curve, this curve is something like this, this is the particle size, this is the percentage passing, 10 percent, 20 percent, 30 percent, 20, 40, 60, 80 and 100. So you take this 50 percent and find out what is the diameter which is passing through. The curve is something like this, some kind of S type curve.

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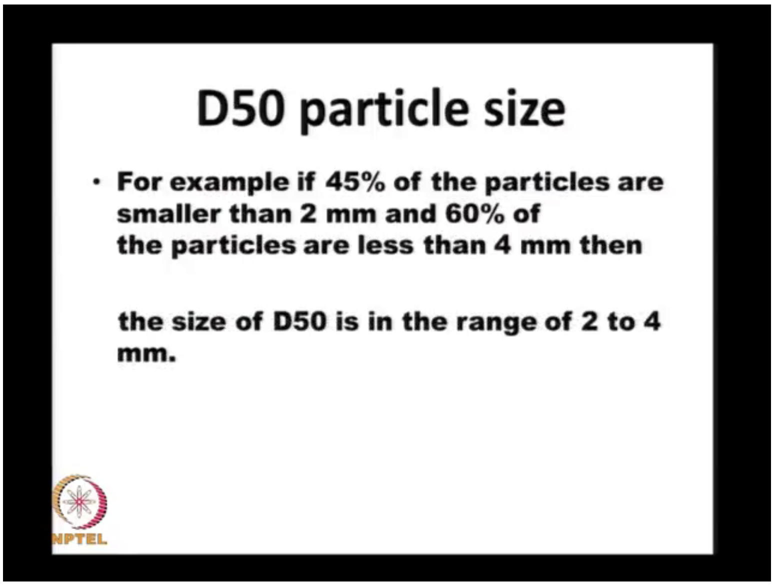

For example, if 45 percent of the particles are smaller than 2 MM and 60 percent of the particles are less than 4 MM, then D 50, it is between 2 and 4 MM, that is for explanation only it is giving. For this 45 percent this is 2 MM and 60 percent it is 4 MM. This is based on sieve analysis because for 2 MM particle size they found out what is the percentage passing, for this 4 MM they found out percentage passing, they say that this D 50 size is between 2 and 4 MM. The point is, if we take a sand particle, the size of the sand particle may vary from 0.1 MM to 2 MM.

If you take sand, wherever it is, you take it to your laboratory and if you want to find out the sizes of the particle, it may vary from 0.1 MM to 2. Then you have to designate which particle size to be used for design analysis. What will you use, 0.1 MM or 2 MM? For some cases you can use 0.1 MM, for some analysis you can use 2 MM. But representative is the 50 size. D 50 size means the 50 percent of the size of the particle will be below and 50 percent of the size of the particle will be above, that is what it says, separation.

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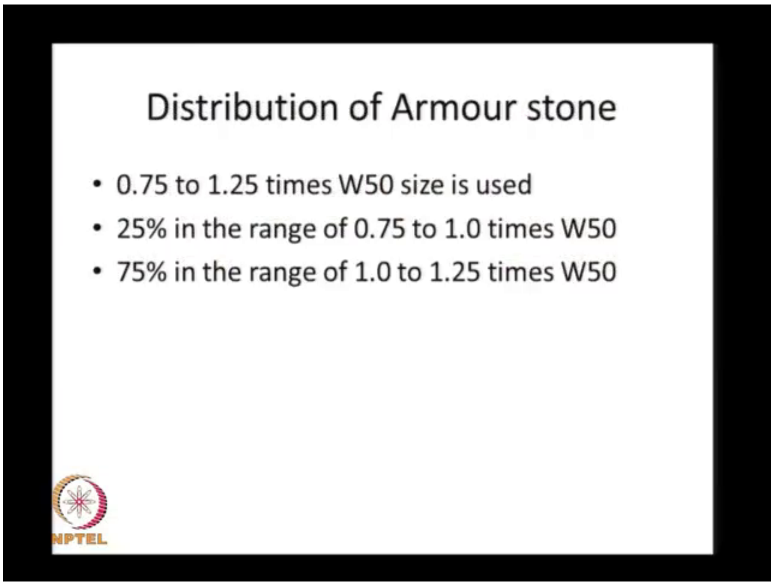

Similarly when you design this Hudson's formula, the weight, the weight is W 50, what we are designing, we are designing based on the significant wave height, it is W 50. It is based on weight, it is not based on size. When you want to place this weight, 25 percent should be the range of 0.75 to 1 times W 50 and 75 percent in the range more than W 50. That is a wave height, see we are designing for significant wave height, we are not designing for maximum wave right. When you design it for significant wave height, there is the possibility that one 3rd of the wave will be more than what you have designed for.

To cater to that, we use 75 percent of the stones what you using should be more than W 50, only 25 percent should be less than W 50, the minimum wave should be only 0.75. Generally the maximum wave should be 1.25, we do not recommend more than that. The another advantage of is if we have this gradation then only it will be well packed. The void ratio what we discussed will be about 30 percent, if we have uniform size, the void ratio will be 40 percent and all, it is not good for stability of the structure.

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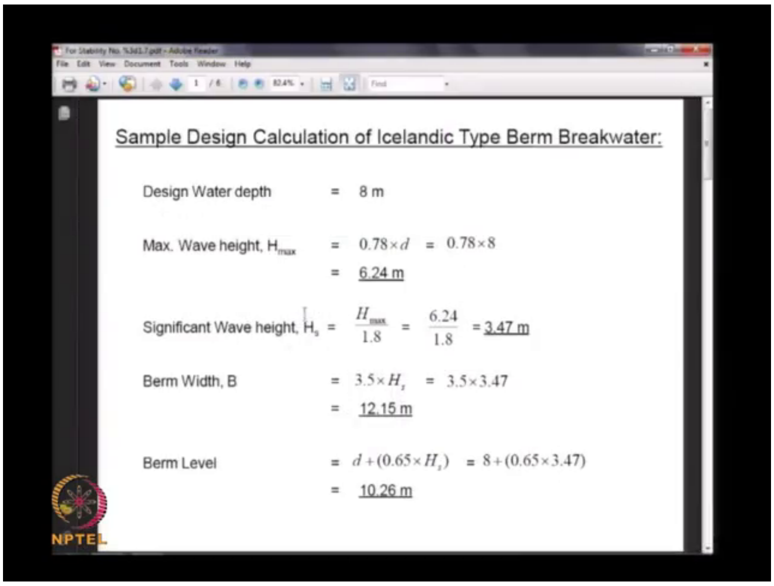

For energy dissipation, about 30 percent is required. So this is what we are designing, so when you are using a formula, what you have to see is, what you are getting from the formula, mostly will be based on a statistical information. So now we will go to the design calculation so we have to calculate what is the significant wave height, I have used 1.8, so I told the range for significant wave height is between 1.6 to 2, in some places we used 1.6 and some places we use 1.8, appropriate number is 1.8. If we use 1.6, it is more on the conservative side, generally we use it for very shallow water.

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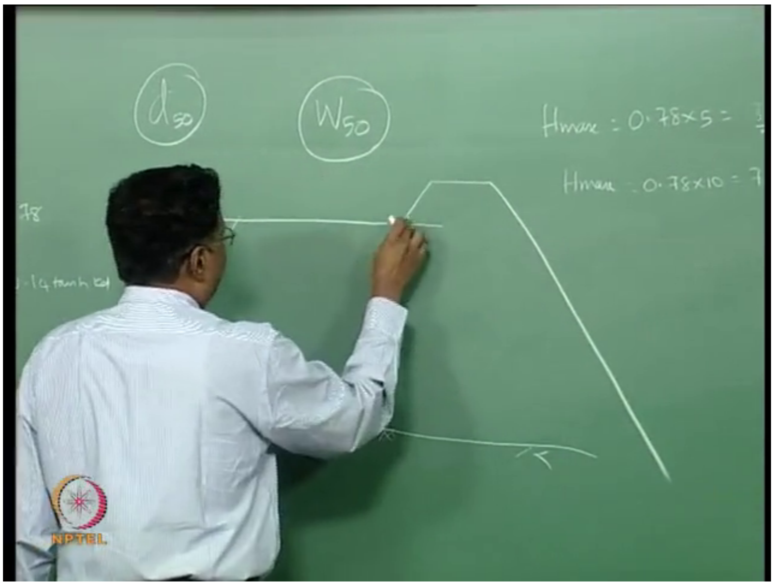

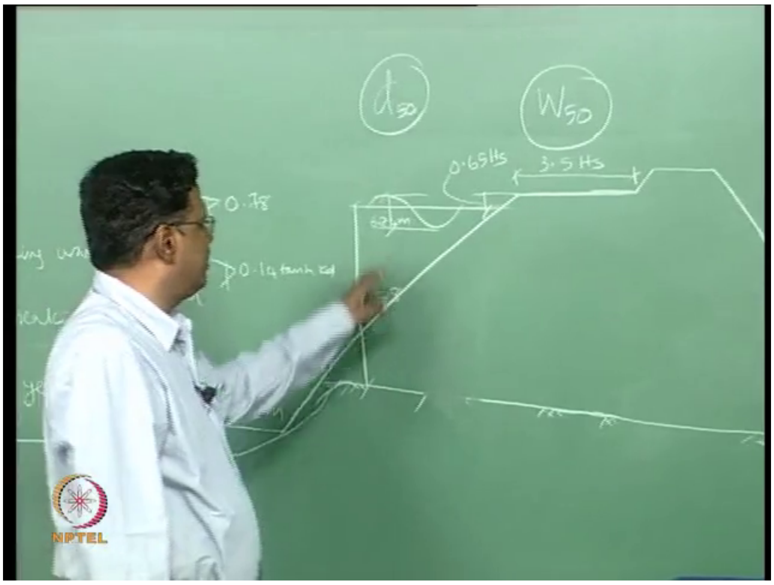

So 3.47 metre is a significant wave height, then we have what is known as berm width. So when you talk about the breakwater, so we will have, the breakwater will generally consist of like this. So this is called as the berm width, is equal to 3.5 times significant wave height. Actually there is a range, this 3.5 HS is not a common parameter, it can vary, maybe 3 to 4 HS or 3 to 5 times HS. So when you substitute in meters, you will get the berm width as 12.15 metres. Then we have to find out what should be the level of berm. The level of berm from the water level should be about 0.65 times HS.

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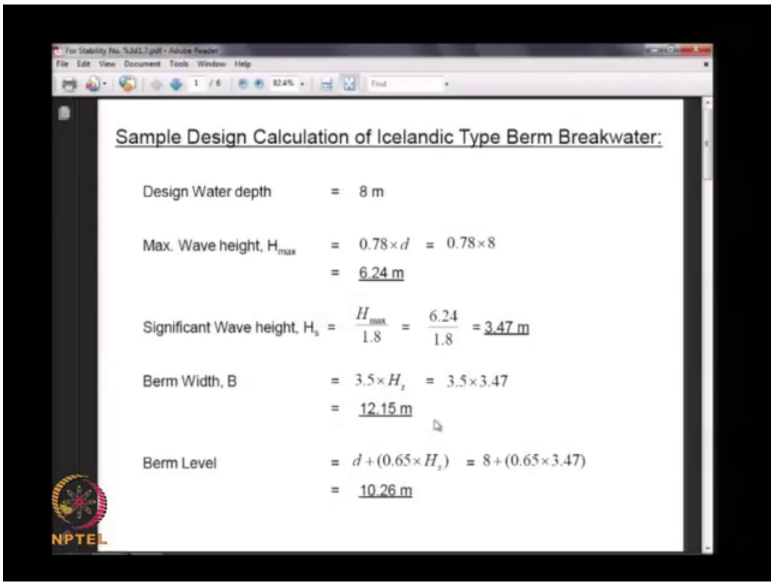

The idea behind that is the top of the wave will be about 0.5 HS. So this berm top will be higher than the top of the waves, that is why we want to put 0.65 HS. So this depth will be about 10.26 metres. Then next is we have to find out what will be the run-up. Run-up depends on a parameter called surf similarity parameter. You please memorise this formula, surf similarity parameter is tan Theta divided by divided by root of H I by L0. What is the unit for Theta? It is dimensionless. What is H I by L0?

It is the slope.

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It is the slope.

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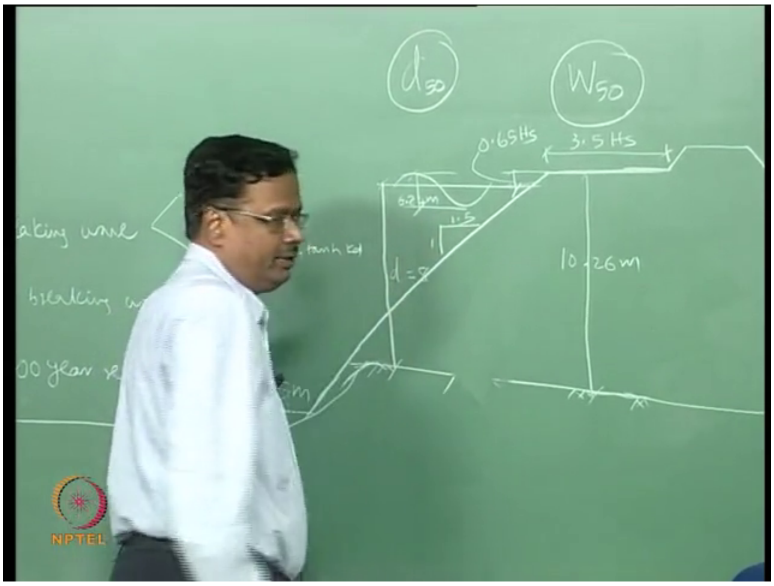

It is called as wave stiffness. So we have to calculate the deepwater wavelength, the limit is D by 0.5, based on that you can get the L0 as 16. D by L0 is equal to 0.5, L0 will be D by 0.5, that will be 16 metres and the berm side slope, if you are assuming 1 is to 1.5, the slope you assume 1 is to 1.5, then you can substitute these values tan Theta divided by HI by L0, this surf similarity parameters comes as 1.43, it is less than 2.5, this run-up by HS is given as 1.43.

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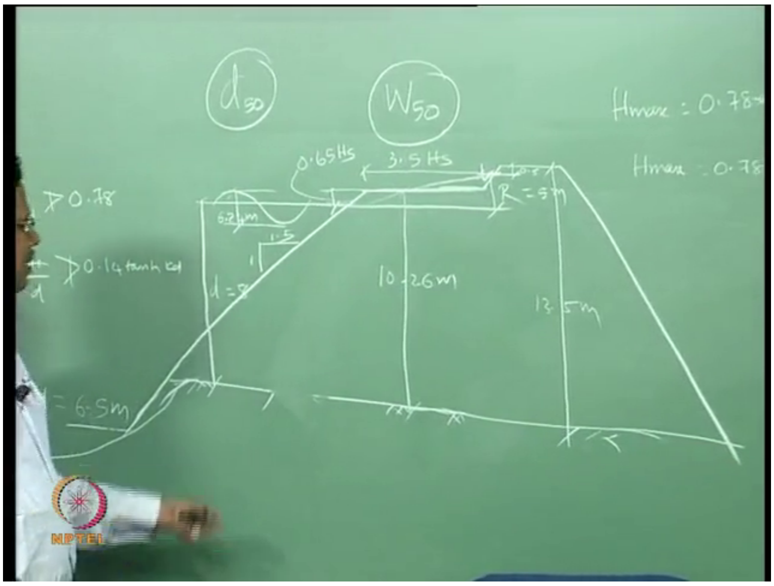

So when the wave is coming, when it is going, it goes and it runs up here and reached this point. This point with reference to this level is called as R, this R by HS is about 1.43, this is given from some tables. The other side will be about 5 metres, so you have to keep the crest above this level. So what we are giving is, we are keeping this level as, giving a clearance of 0.5 metre, this depth is, from this point it is 8, 13-13.5. This is what is given here, 13.5. So now what we have completed is, we have fixed the slope and we have fixed the width of the berm, we have fixed the top level of the berm, we have fixed the top level of the breakwater, this is what we have done.

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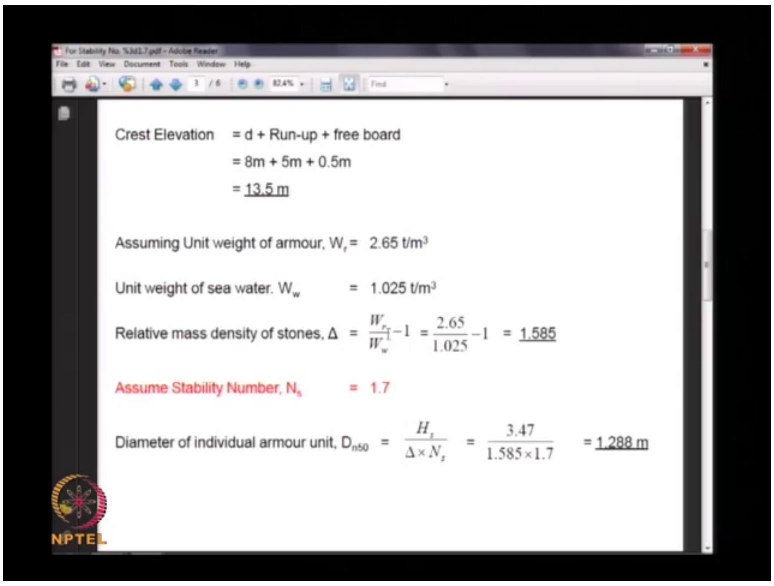

The parameter which is used for all these purpose is HS, that is the significant wave height which is used to fix all these parameters. Once you fix these parameters, then you have to use the formula to calculate diameter of the armour units. That formula is given by HS by Delta into NS. This Delta is nothing but Wr by WW - 1, there is a similarity between what we have done in the breakwater design, that is SR -1 is nothing but Delta. Hudson's formula and this are one of the same, only it is given different kind of dimension. WR is the unit weight of armour, WW is the unit weight of seawater, so you get Delta which is 1.585.

The stability number is the one which you have to get based on model studies, that is what we are doing in our wave flow. Most probably next week we will be seeing that procedure how to get the stability coefficient. So you use this stability coefficient and calculate DN 50, substituting HS which is 3.47, SR - 1 into stability number 1.7. These numbers, this is having the unit of metre, so your DN 50 will be 1.288 in the unit of metre.

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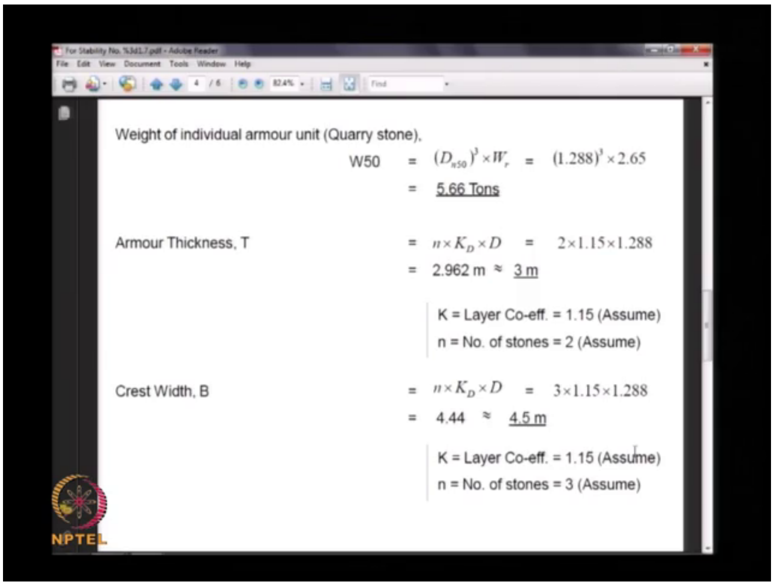

Then you have to calculate the individual armour unit stones, the weight of the stone is DN 50 to the power of cube into W s which is about 5.66 tonnes. Suppose you are using not a berm breakwater, some other type of breakwater, in that case this weight will be at least 3 times more, right, that is what we are discussing. So if you use a conventional breakwater, this weight will be about 18 tonnes. So by providing, but the number, the quantity of stone required in a berm breakwater will be almost twice because normal breakwater and berm breakwater if you see the quantity that is required, it will be almost twice, but the weight of the stone will be lesser.

And getting a bigger sized stone in a quarry is very difficult, getting a 6 tonnes stone is very easy. Then you have to find out the armour thickness, that is given by this formula N into KD into D. The same formula can be used for normal breakwater also where N is the number of layers, that is 2, that is to be assumed for stone. KD is the layer coefficient, the layer coefficient depends on the armour type what you are using. This is given in some standard text book. There is a coastal rotation manual by U.S. Army of cops, it is available on the net also, you can get this value from there.

So these values are available but you memorise these values. You have to find out, get these values and then you calculate the armour thickness, that is about 3 metres. And the crest width also is a function of N into KD into D where D is the size of the stone what we are using. DN 50 and D, this D and DN 50 are one and the same, 1.28, the number of stones width required is about 3, so what is required for the design purpose is 4.5 metres but we can provide slightly more also.

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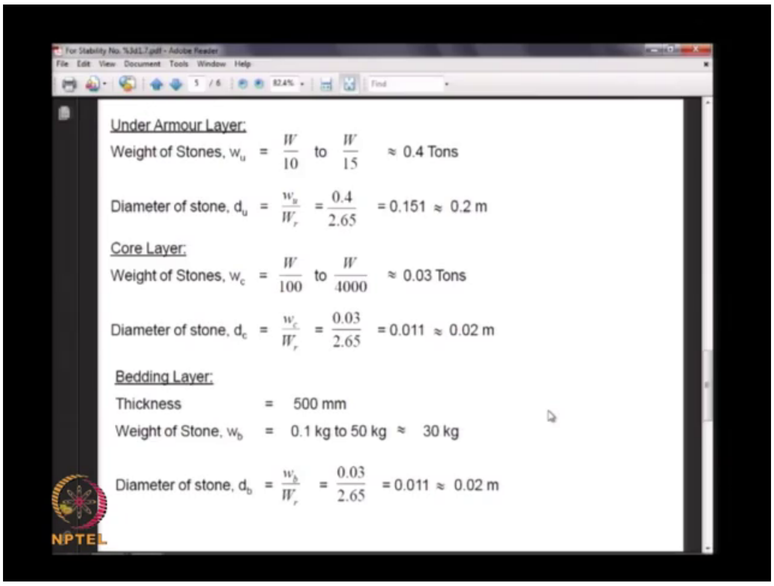

So now what we are designing is we are designing the armour, what I have told you is we should have at least 2 layers and you should have at least 3 here. It will not be like exactly like this but some odd shapes is preferable. The stone what we using here is W 50, that weight is about 6 tonnes. So the weight of the stones for under armour layer, that is the next layer which will come below this, there will be one more layer which will be coming below this, that we call as the under armour layer, this is varying between W by 10 to W by 15, that is given.

Then we have the core layer, here we will have the core, that is W by 100 to W by 4000, wide variation is required because it will get packed and there will not be any sand particle moving from one side to the another side. Then we have the bedding layer which is 500 MM, the weight of the story 0.5 KG to 50 KG, the average size is about 30 KG. We are calculating the diameter of the stones also.

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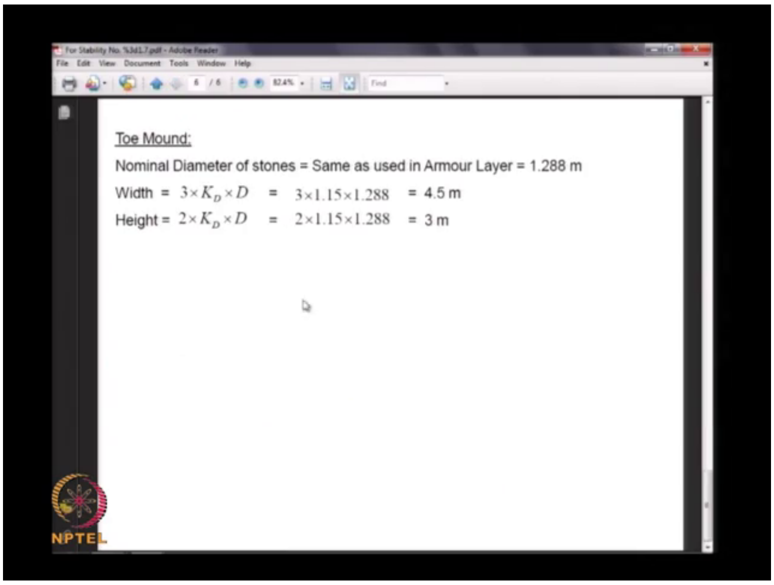

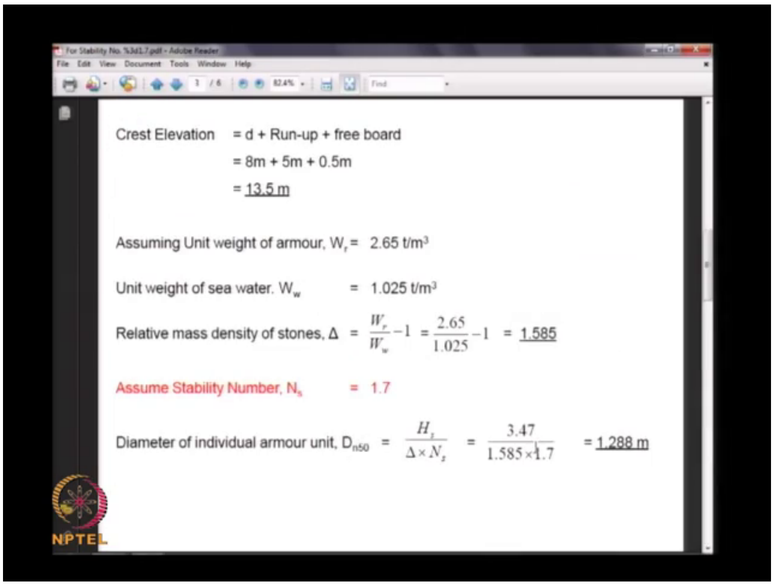

Then we need a toe mound, here earlier we have given some other formula but here we are giving 3 times KD into D. KD is nothing but this coefficient, layer coefficient, this K and KD are one and the same. This layer coefficient is 1.15, so you can get 4.5 metre is width and 3 metre is the height, that is 2 into KD into D, where D is the DN 50, what we are using here D is nothing but DN 50, what you have calculated, which is 1.8 metre. So to summarise, what is required for the design purpose for a berm breakwater is the diameter of the individual armour unit which is a function of HS, Delta and NS.

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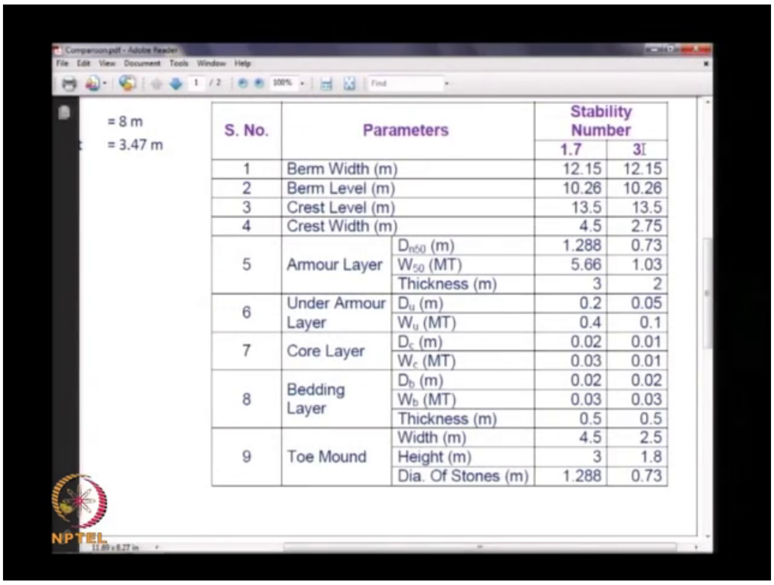
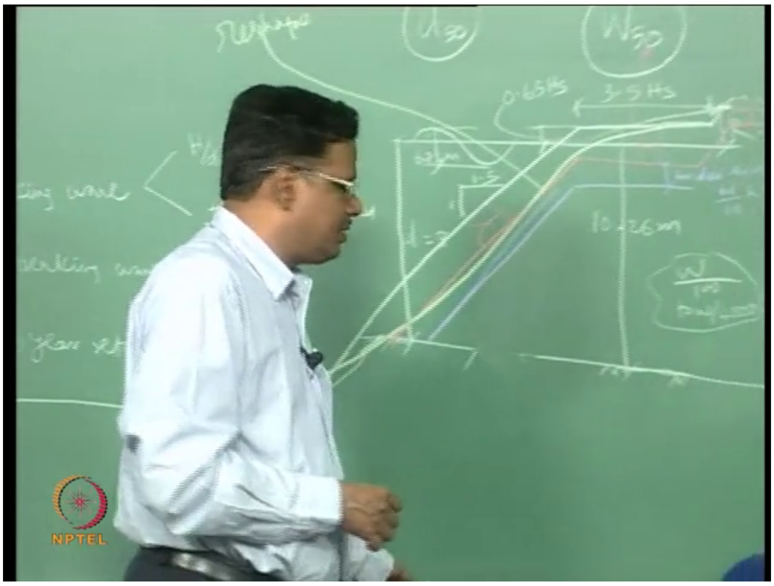


= 8 m
= 3.47 m

S. No.	Parameters		Stability Number 1.7	Stability Number 3
1	Berm Width (m)		12.15	12.15
2	Berm Level (m)		10.26	10.26
3	Crest Level (m)		13.5	13.5
4	Crest Width (m)		4.5	2.75
5	Armour Layer	D_{n50} (m)	1.288	0.73
		W_{50} (MT)	5.66	1.03
		Thickness (m)	3	2
6	Under Armour Layer	D_u (m)	0.2	0.05
		W_u (MT)	0.4	0.1
7	Core Layer	D_c (m)	0.02	0.01
		W_c (MT)	0.03	0.01
8	Bedding Layer	D_b (m)	0.02	0.02
		W_b (MT)	0.03	0.03
		Thickness (m)	0.5	0.5
9	Toe Mound	Width (m)	4.5	2.5
		Height (m)	3	1.8
		Dia. Of Stones (m)	1.288	0.73



HS is the wave climate for which you are designing, Delta is the property of the armour unit what you using, Ns is the stability coefficient. The stability coefficient is having a wide range, so you can have a stability number of 1.7 or 3. If we use stability coefficient of 3, your weight of the stone is 1 tonne, if we use the stability coefficient of 1.7, the weight is 5.66. See there is a design philosophy, we allow the breakwater to take a shape, some kind of S shape, so we allow it to reshape itself like this.

This is, it will take a shape, this reshaping is not done by artificially by us, the waves which are attacking the breakwater will take the reshaping. If you want to have the reshape, then you should use a higher stability coefficient, then the weight of the armour unit will be less and then it will take a reshape. If we use 1.7, it is non-reshape, whatever you put, it will remain almost the same. The advantage of using a reshape type breakwater because the waves which are attacking makes it compact and makes it alright. So you have to do a design procedure for this and accordingly design this.

But if you want to be very conservative, you have to use their lowest stability coefficient and non-reshape type of breakwater. So here we have given the comparison, the HS will not change, the berm width will not change, berm level will not change, crest level will not change, the crest width will be reduced but for construction purpose we will increase into 8 metres. That is another thing when you go for the civil engineering or harbour engineering design, there is a formula which gives the width.

For construction purpose you have to revise it, for construction as well as for maintenance. Then this harbour layer and other thickness and all is given. This is for a design water depth of 8 metre and significant wave height of 3.47 metre. Similarly you can get for different water depths and different wave height. Any doubts in this? No doubts.

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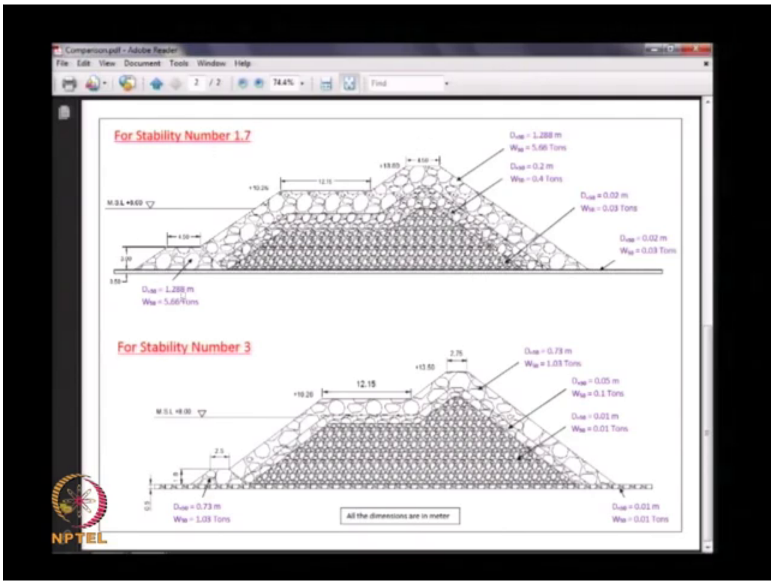

So this is the type of cross-section what finally we will get. So this is the called as toe mound height, this is the toe mound width, the slope of the breakwater and this is your core layer, this is the under armour, I am sorry, this is the armour layer, this is under armour layer and we have this core. Below the core we have this 50 centimetre of, 500 MM of bedding layer. We assume this 500 MM will go below the seabed and we will have the 8 metre depth, from here

I have marked this as mean sealevel but this level is depends on the tidal level and storm surge and other things what you have to consider.

This is as per design purpose we need 4.5 metre but anyhow, for construction feasibility we may raise it to higher values. Similarly the berm height also we may increase because during construction when the waves are breaking, the lorries have to move in this, so this level, see you will be 1st dumping the core, then you will be dumping the secondary armour, then you will be dumping the armour units.

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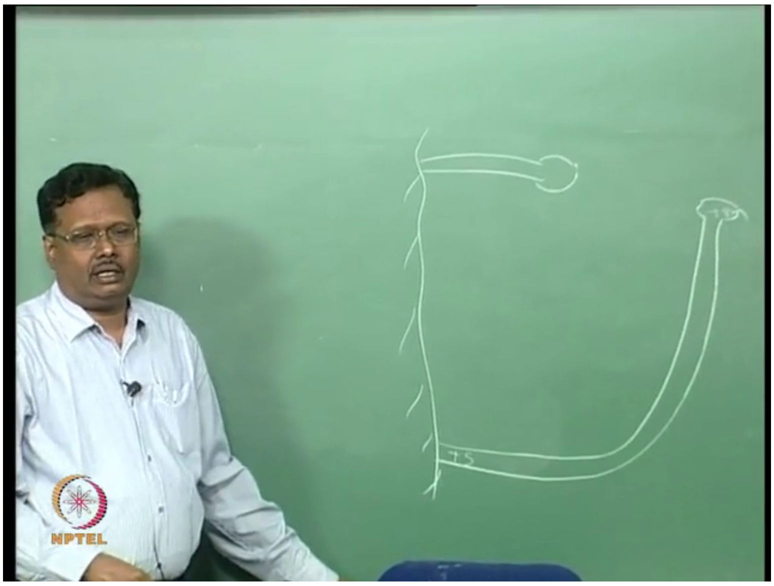

So what they do is, if we have the, suppose this is your shoreline and you have one short breakwater, Gopalpur where we have the short breakwater, then we have the long breakwater. What they do is they start the construction from this point, then they go towards the end. They do not put the armour stones until they reach this point. Then they will put the armour stones, then they will come back, is it clear? Sometimes they may not even put the under armour line because if we put these armour stones, your trucks will not move.

See your, your trucks are going and dumping the stones here, if you put bigger stones, 6 tonnes stones and all, on top of 6 tonnes stones you cannot move your vehicle, that is one of the reason they do not put this armour. What they do is they go all the way there up and then comeback. Since the wave heights are higher, as we go to deeper water, they will start with a 7 and they may go up to + 8 metre. Right. Your armour thickness, in this case is about 3 metres in 8 metre water depths. Your armour thickness in this case is about 3 metres in 8 metre water depths, whereas in 6 metre water depth the thickness required will be 2 metres.

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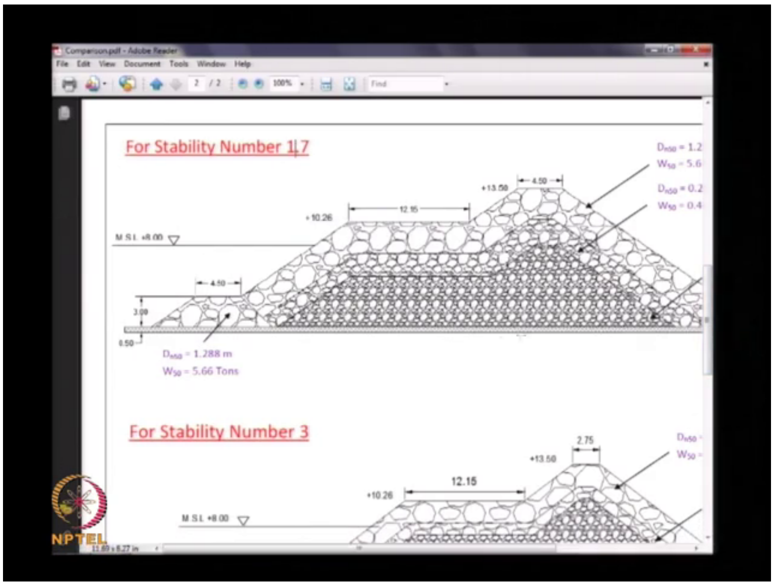

So if you maintain this level as constant, this secondary armour level, this level should be slightly above the water level. See this top of the secondary armour, what is shown here, this is the top of the secondary armour, this level should be above the water level, as per the drawing it is not above but this level should be above the water level, that is one of the practical considerations you have to see. Even if that level is constant everywhere, in deeper water, the armour weight is high, armour stone size is high, so the top level also will be very high.

And that is why they go in for differential level, this level is not uniform, this level will be increasing as you go.

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They will put some smaller sized stones to make the trucks to go, it may not go but they will packet. But generally it is not desirable to take the armours, if you place the armours, this dissipation will not take place, energy dissipation. Actually they will, see we are discussing see this is the point what we are discussing. We can put this layer as well as here, this width also has to be increased, this width actually should be 8 metre, not this width. So you can pack this area and area here for enabling the truck to move.

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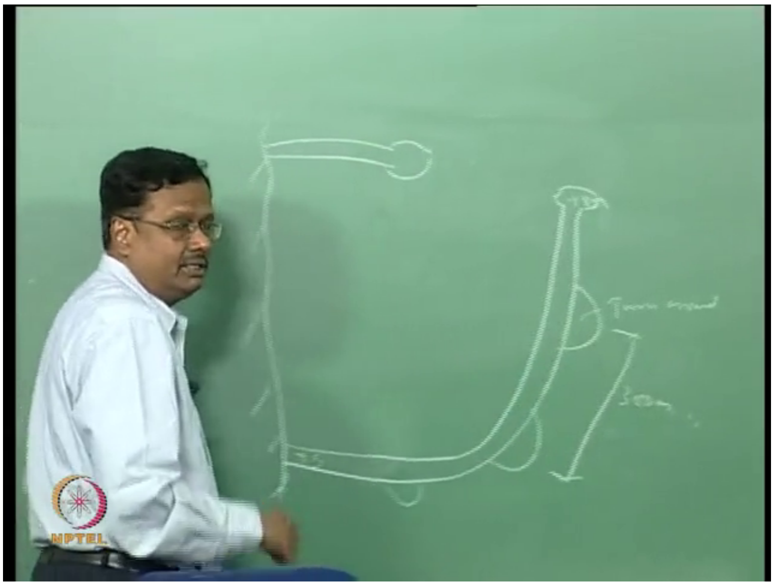

Through this distance, through this with the truck will go forward, through this width it may come back also. One of the advantage of berm breakwater is you have a place to, one road width to go forward, another road width to go back, to return and this road width is also sufficient for going up and down. But if it is a conventional breakwater, they will be constructing some areas where the vehicle can, turnaround areas. Typically every 500 meters or 300 metres in the Centre, they will have these turnarounds for the vehicle to go and turn and come back. These are all construction requirements what you have to do.

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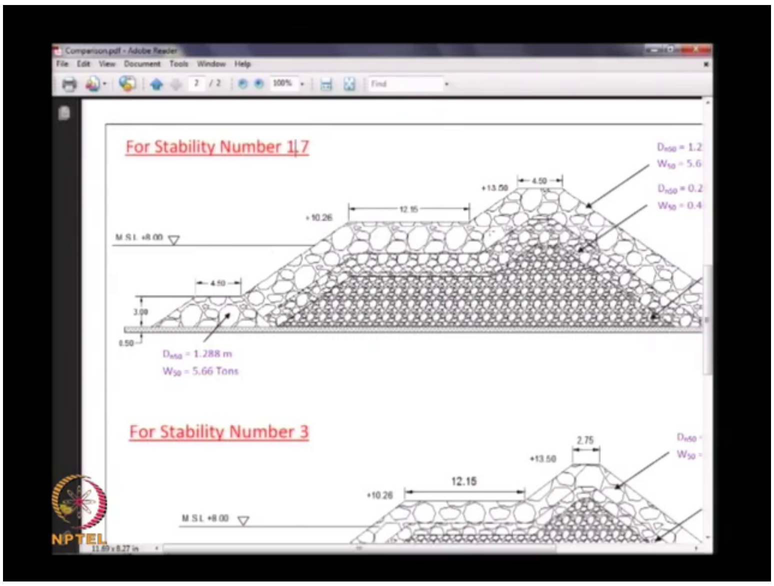

It can be same or it can be different also. Generally we provide the same but generally the slope above the berm is flatter compared to the slope below the berm, because the wave energy is concentrated only in the top region, not in the bottom region. We were discussing why it should not be packed here, so it is desirable not to pack this area because when the waves are coming, it will go over this and then run up over this. All this face, it is preferable not to pack it. Whatever drawing they have shown is also not correct, it will not be like this, it will be like this or it will be like this, there will not be small stones coming here and all.

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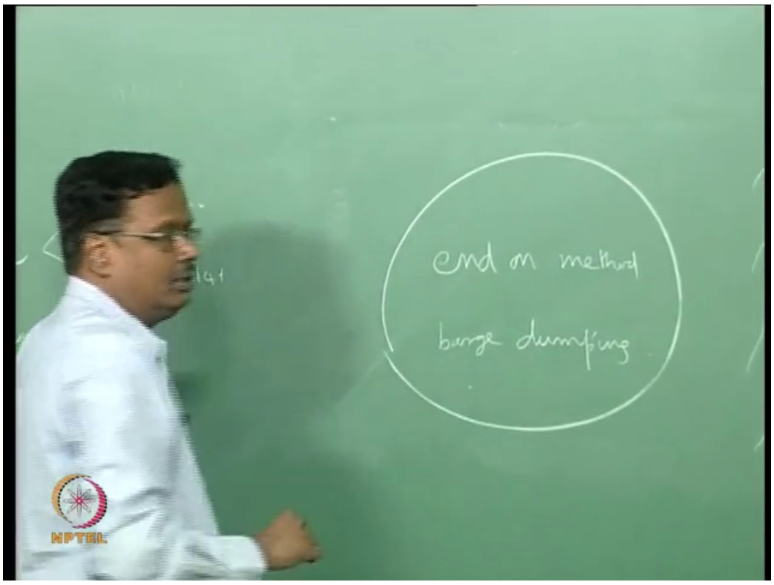

Armour stones will not be packed, they should have sufficient void ratio so that we can allow the wave energy to dissipation. There are other methods also to construct the breakwater, one is called as end on construction, end on method, another is by barge dumping. Sometimes a combination of these 2 will be used, it is preferred to use both the methods, end on method as well as the barge dumping. Barge dumping means you transport all the material into your barge, it is a split barge which will open at the bottom. Suppose there constructed up to this point, the barge will go and dump at the bottom.

The core layer, the filter layer will be dumped by the barges as well as the toe mound, because it is very difficult to use a crane to dump it. But barge method of dumping is preferable, it is not cost-effective but it is very, construction wise it is very what is called as robust and you can get what you want to desire. What is desirable can be achieved by barge dumping. But as far as the end on method is concerned, this can be used for some portion of the core, as well as under armour as well as primary armour layers.

And you have to use some cranes to dump the stones. Suppose you calculate the width of the breakwater at the bottom, the width of the breakwater may be as high as 10 metres, 100 metres. From here to here the width maybe 100 metre because it is 8 metre into 1.5, that is around 20 metres, this is 12, 32, then here it may be around 6, 38, 42 and another 25. It will be around 67 metres. Suppose your crane is moving on top of this, the crane should have a reach of about 30 metre to dump the toe mound. It is very, you see 30 metre is very, very huge reach that a crane has to do and then dump it and then it is a very slow process also. So with this I complete this lecture on berm breakwater.