Coastal Engineering

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Module - 1
Wave Deformation
Lecture - 4
Wave Deformation (Problems – II)

Whatever we have seen earlier, it was more on the refraction, shoaling, reflection to some extent only the phenomena we just try to understand. Then we have also seen some of the problems related to the variation of wave heights, as it propagates from the deep to shallow waters. And you know what happens, we have already seen the worked out example. So here in, what we have try to understand is, if someone is asking you a question like what happens to the wave height in a water depth of 5 meters, given the deep-water wave height. So immediately, you might have a tendency of just calculating using just the shoaling coefficient and you might say whether it increases or decreases. But will it be correct?

Shall not going to be correct, because the shoaling coefficient is valid only for waves traveling over a ramp. You have to certainly include the effect of refraction, I mean the bending we have already seen the effect of I mean the phenomena of refraction. And you see that the way you calculate the refraction coefficient, there are several methods. One method is using a template, which was told in the earlier lecture or you can resort to some kind of a numerical methods etcetera. But, so you need to have the bathymetry etcetera. So it was a Dean and Dalrymple, it is a given in his book, the reference of which is given at the end of my lectures. So refer to Dean and Dalrymple book, he has come out with a nomogram given for refraction, and that makes a things more handy for us. We need not have to go through the recourse to so many other calculations you see. So in that way it is quite handy and that is what I am trying to explain here in this class. And then after which we will see some problem problems related to wave reflection, so things will be more or less clear.

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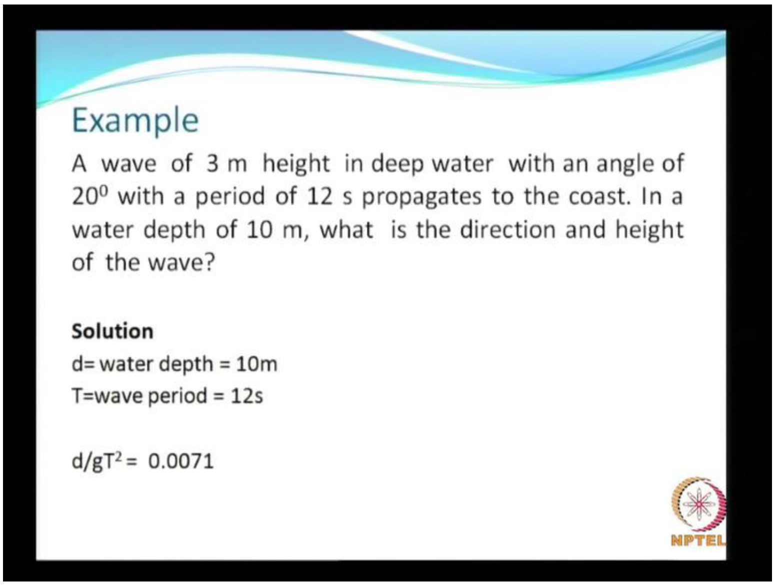

So, now the problem here is a wave of 3 meters height in deep water with an angle of 20 degrees with a wave period 12 seconds propagates to the coast. Now in a water depth of 10 meters, what is the direction and height of the wave?

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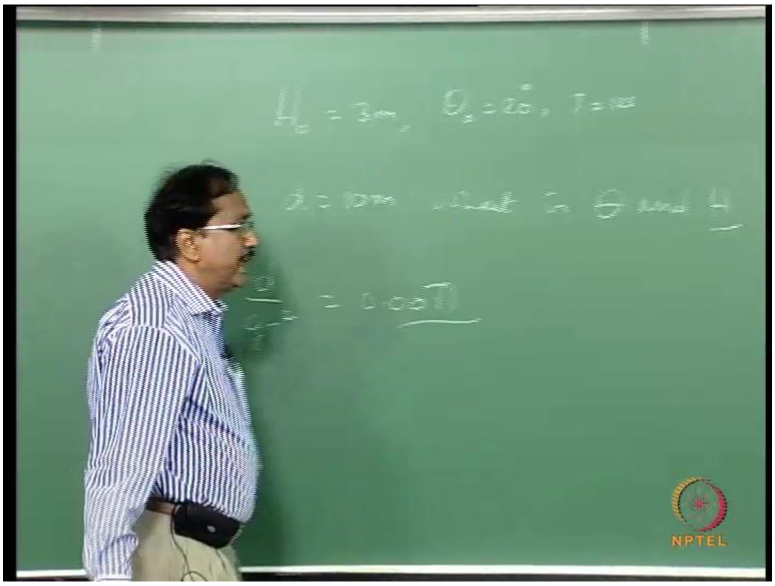

So you are given H naught as 3 meters, theta naught as 20 degrees and T is 12 seconds that is what is given. And what you are suppose to get is in 10 meters, what is theta and height? This is a problem. So this nomogram of a Dean and Dalrymple looks like this. So what you need to do is, you need to calculate d by g t square. So how much is that for the present problem, for the present problem, it comes out to 0.007, approximately 0.007.

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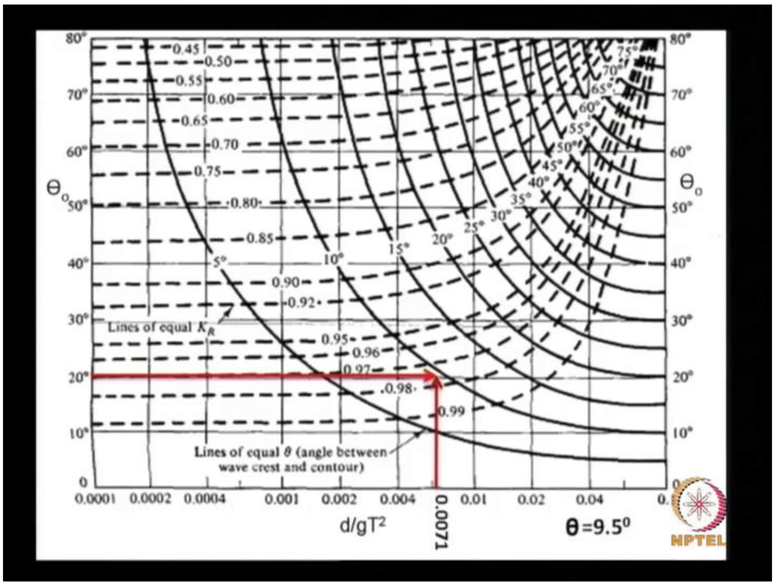

So this picture gives you the information or the lines of equal refraction coefficient as you can see here. This is 0.92, 0.9, 0.85 etcetera. And you see that this is the deep-water direction and the variation is let us look at this problem, this curve, the variation of this curve is more or less not much of variation is seen for very less d by g d square. So as your d by g t square increases, the variation is quite phenomenal. Now this shows the lines of equal theta, so you need only the wave period in order to arrive at this parameter, and this is also an input which is theta naught. So for 20 degrees theta naught, you see that the value is somewhere for the corresponding d by g t square. If the theta direction theta naught is something else may be the 50 degrees then you see that the angle will be somewhere here. So just used this nomogram, and you get more or less a reasonable result for your wave direction in any given water depth.

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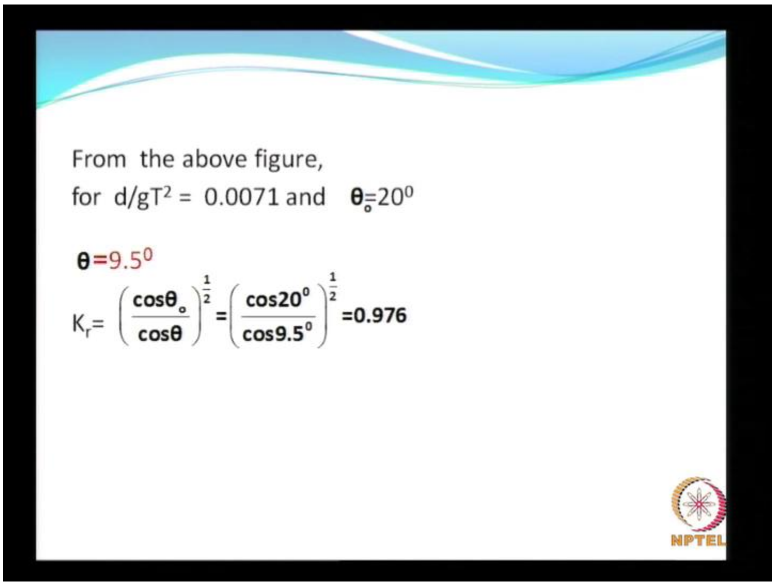

This is what is explained here, from the figure, we got the values d by g t square and then theta naught is so much. So you can also use your K r, what exactly is the k r refraction coefficient that is the formula just substitute the angles and then you get this value this is by after obtaining the angle, but straight away you can get from this also, the diffraction coefficient.

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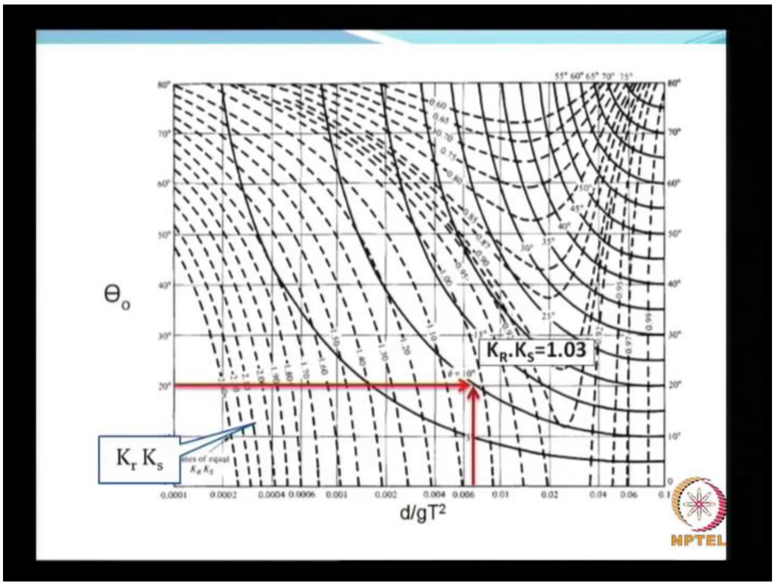

Now this nomogram gives you lines of the same product of refraction coefficient and shoaling coefficient. So, follow the same procedure here, and then theta equal to 90 degrees. So the K r and this value will be approximately, so you see here, this is 1.1 and the next one is 1.0, this is 1.0, this is 1.1, this value is coming somewhere here, is that clear? So, you get directly the coefficient of the product of K r, and K s. So, this of course, this gives the value of the angle in any given water depth, these curves you see this? So you see that this is more or less straight forward instead of going through all the other calculations.

So when you deal with some of the small, I mean medium size projects or small size a projects, you can straight away continently use this a nomograms in order to consider the effect of refraction as a first approximation, this is what is explained here. So naturally when a the product of K r and K s is greater than one, you expect the wave height in that particular water depth which are talking about that is a 10 meters water depth in the presence case to be slightly larger than, higher than the deep water wave height. So very simple problem in order to understand, what is refraction, what is the effect of refraction etcetera.

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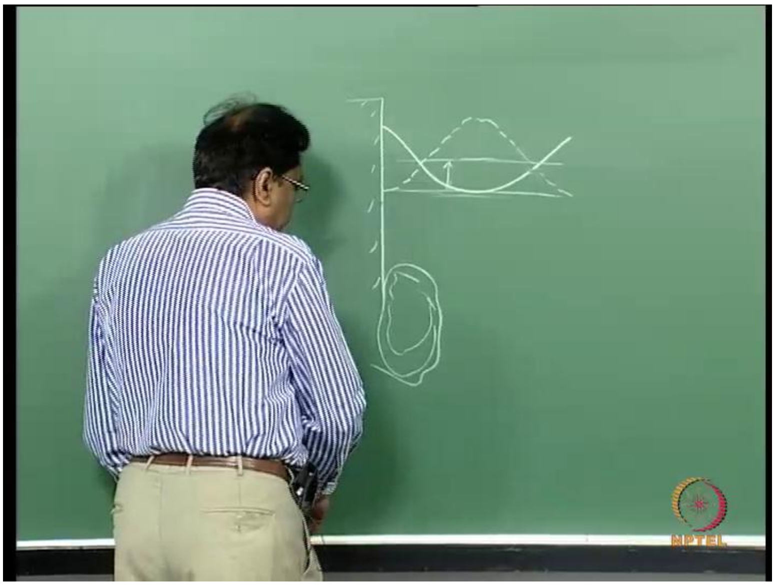

Now the next thing is the phenomena of reflection. In the coastal engineering, apart from the shoaling and refraction another important a thing is phenomena are your reflection. Why reflection is so important? Why reflection is so important? Reflection is so important, because when you have for example, a vertical structure which is impermeable then the water level in the vicinity of the wall will rise by some height, and the wave height which is impinging on the wall will get reflected. And this why the height near the wall will be twice the incident wave height, which partially, I think, you might have seen under wave hydrodynamics course or we will be seeing about the same thing about the reflection in detail when we are talking about the wave forces on a wall type of structures.

So you see that the incident wave height almost becomes the two times the wave height, because of which what will happen, the particle velocities will increase, and there will be a gradient and that gradient is going to change the sediments near the toe of the structure. And because of which, what will happen, there will be what is called as a scour hole being developed. And once this penetrates, normally when they going for any kind of structures, they make sure that all these things are considered. If they do not consider, what will happen, the scour will increase; the stability of the wall becomes questionable. So it is extremely important to take care of the reflection.

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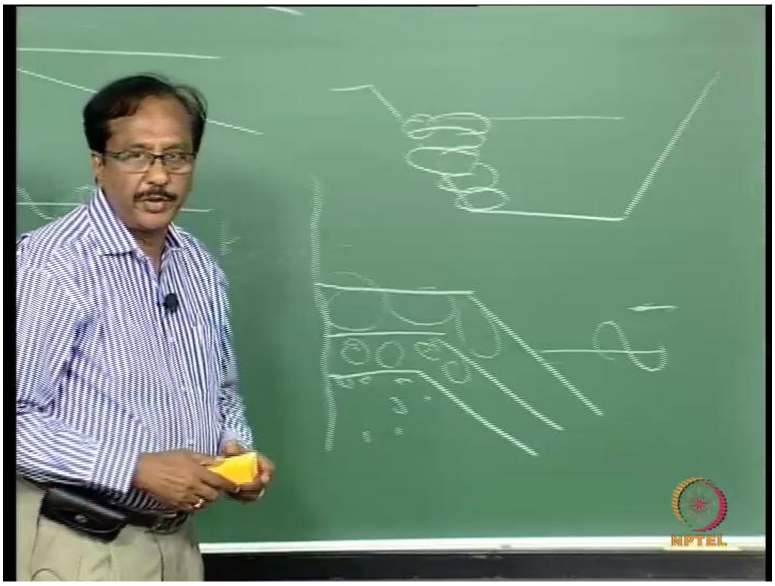

How does reflection, if you have a sloping wall of a flat slope and a sleep slope, what will happen here? The reflection will be more or less? Reflection will be more, because what is the reflection coefficient for a vertical wall – one, so this will certainly be less than one. What will happen, if it is flat beach like this, very flat beach, what will happen? Less reflection, less reflection. So if the same slope is still flat like this, wave is propagating. What do you expect? It is a good beach, excellent beach that is what we will always a think of right. Suppose if there is a tsunami, in all the three cases, which is the one which is going to suffer - first one. Why it is going to suffer, because the energy is not going to get reflected back, this beach is happily going to allow the free propagation of the long waves or the tsunami waves, and that is going to freely move freely move for how many may be even a kilometer or two.

So now you see here, if you had some kind of a reflecting structure or some kind of an obstruction, it would have reduce the tsunami speed. But, on the other hand, just now I said if you have reflection that also gives problems, because if you have reflection particularly when you are talking about a structures, you see the forces exerted on due to reflection is going to be more. See there has been a lot of research going on how to reduce the reflection, that is one aspect; how to reduce the reflection. In this kind of a situation, what would you think of doing? You would like to arrest a free passage of a tsunami like wave, by having some kind of an obstruction, by having some kind of a obstruction, you talk in terms of phenomena like reflection, diffraction etcetera. You do not care what happens but, as long the energy is dissipated, you are happy. You understood? So that is why this reflection is a very important phenomena which need to be considered.

Later we will also be, I am sure all of you must have seen a revetment. What is a revetment? I am sure all of you must have seen a revetment. What is revetment? What is the revetment? I am sure that there are some civil engineers here. What is the revetment? Have you not seen a canal? You have the water flowing right, this also a revetment. So, revetment can be even on beaches and sometimes it is also called as sea walls. Revetments on a smaller scale, we called it as revetment on a larger scale we called it as sea wall.

So when there is an excess flow, and when you see some kind of bank erosion taking place, what do you hear of, what do you here, when there is some kind of a flood taken place. And they say that the banks are getting a breaching is taking place breach has taken place, what is the first step, they what they do is they dump sand bags. The other way of doing, it is dumping of stones. Why it is a dump stones, they dump stones in order to reduce the velocity of flowing water, and that velocity may be even due to waves. The same thing when you talk about breakwaters. What is breakwaters? This suppose if there is a stretch of the coast, stretch of the coast is getting erode. Now what we do is, this is the waves, which is where you have lot of erosion taking place, and you want to protect this area. What you do is you construct a sea wall, when you construct a sea wall, you just the proper way of doing it is not dumping stones, the dumping stone was originally done that is the way they developed the break waters. Just simply it started from simply dumping the stones.

So, what they do is the idea is having smaller sized stones, I think, I have already told about this and then you have bigger stones. So you will have a layers, so may be up to usually common thing in number of layers is about two layers. Now what kind of a structures you can think of, you can think of a plane slope or a beach or a rubble mount structure, these are the commonly adopted structures in the coastal environment. So and we need some way of arriving at the reflection coefficient. If you want to have the reflection coefficient, it is only an estimate; cannot be it can never be accurate. Especially when you are dealing with a rubble mound structures, because it is not easy to model the porosity. So what I will do is, I will straight away going for the problems, so that the problems will make things very clear and please go in for additional readings for or referring to books or books given on the under reference.

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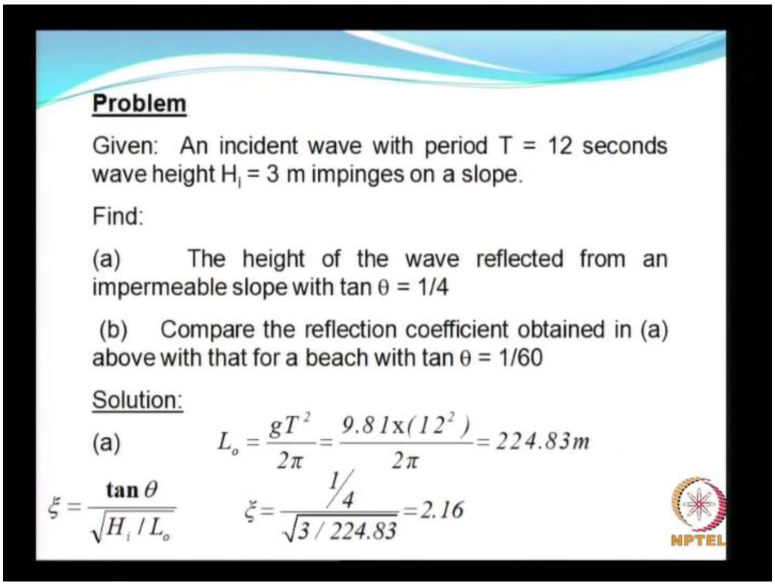

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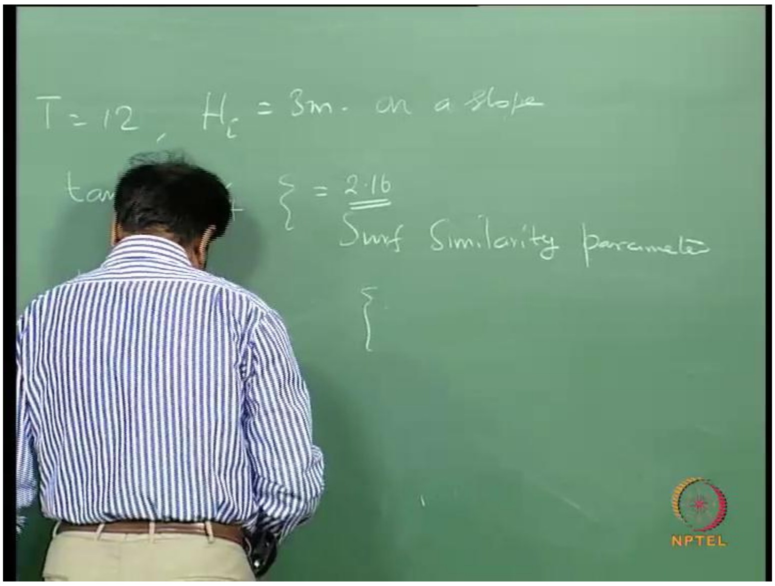

So now here you see T is 12 seconds, H i equal to 3 meters impinges on a slope. What is you have to find out? The height, the wave height of a reflected wave.

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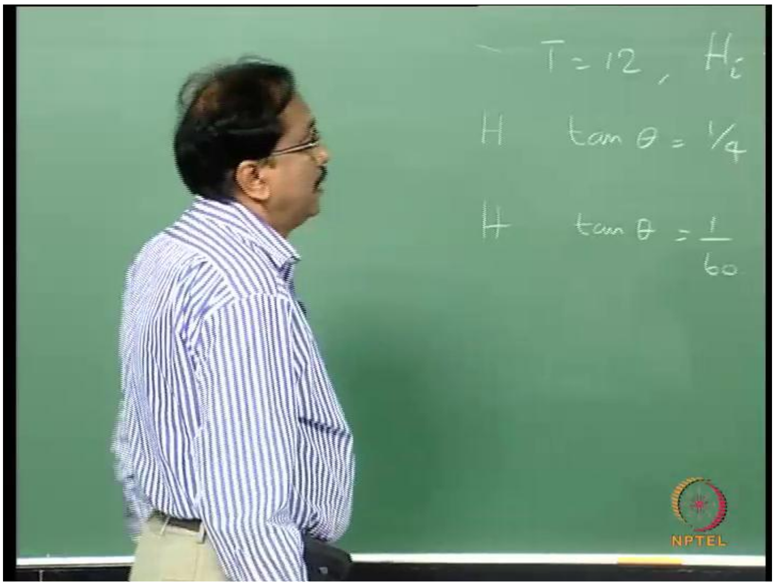

When it is traveling over a slope tan theta equal to one by four and we need to also do the same thing for tan theta equal to 1 by 60. But, you know already for a flat slope the reflection coefficient is going to be small. We are trying to estimate this, for this you know you have to estimate what is the deep water wave length, and then calculate what is called as the surf similarity parameter. Surf similarity parameters indicated as given as tan theta divided by square root of H i by l naught. So, for the first case wave period is 12 seconds, so you can calculate the wave deep water wave length and in this case you get your surf similarity parameter as equal to 2.16.

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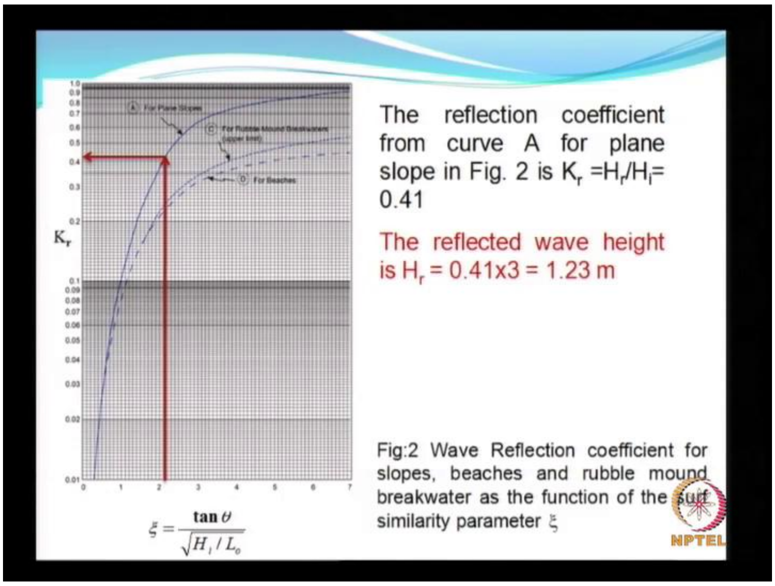

The coastal engineering manual, this is prepared by US army corps of engineers. Most of the costal engineering manuals or the nomogram etcetera, it is all being released by them. It comes in two volumes, you can have a complete look at this volumes if you are more interested. So you see that we have three curves here; one is for the beach then this is for the rubble mound break waters, and then this is for plane slopes.

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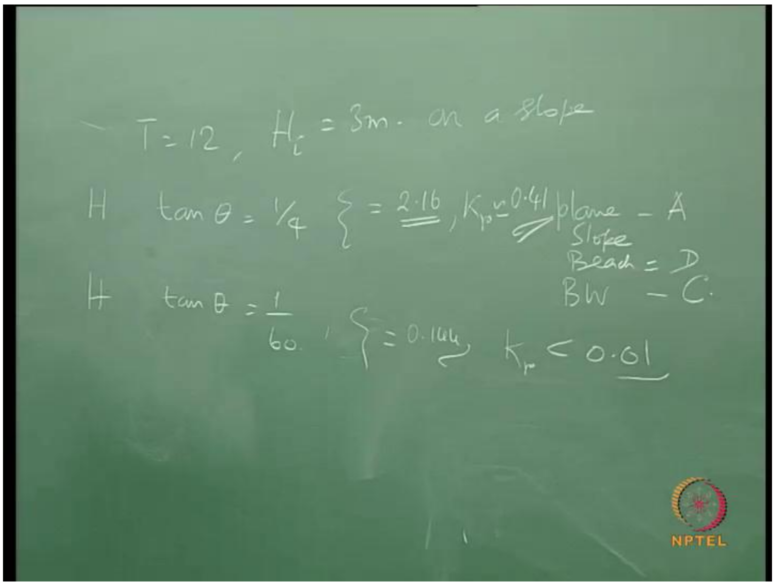

So for plane slopes, curve-A plane slopes; then for breakwaters, it is C; and then for beach, it is D. So you have the surf similarity parameter calculated for this case, and then just use this nomogram and get the value of K r. So here K r equal to 0.41. Repeat the calculations for this, wherein when you do that you will have the surf similarity parameter as 0.144. When you look at this, you see that the reflection coefficient is almost negligible; this is what I explained earlier. What happens, when you have a flat slope very flat slope and what happens when you have a steep slope, so this two so here you see that it is K r is approximately or less 0.01 that is entire energy is going to be propagated when you are having a slope of 1 is to 60.

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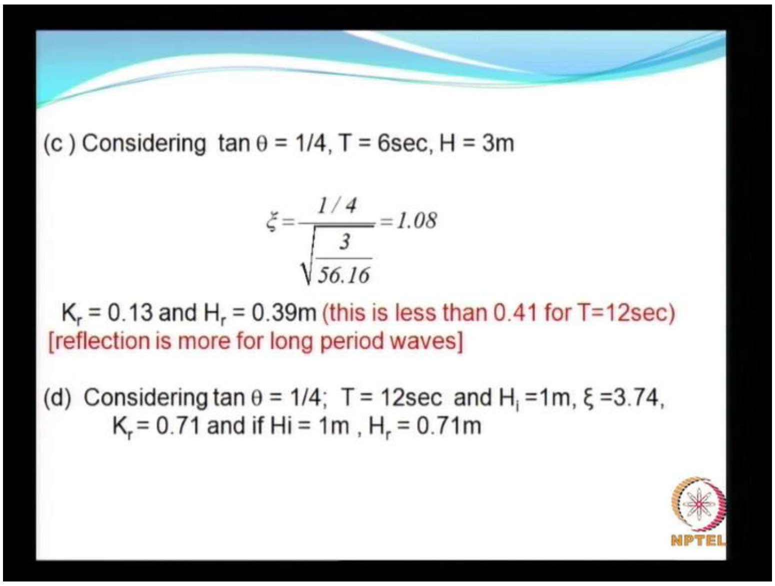

Now let us consider this one, for here, we considered T equal to 12 seconds; maintaining all the other same I am just changing this as six seconds, tan theta is same, wave height is same as three meters. Now I calculate my epsilon, I mean the surf similarity parameter which works out to 1.08. So 1.08, when you use the earlier picture earlier, nomogram, you get a value of 0.13 for the reflection coefficient. What does this covey; it clearly conveys that for a long period wave, the reflection coefficient is more. So you earlier you saw that the pressures exerted by long period waves are more, now you see the reflection from long period waves are more, and when you looked at the wave diffraction the problem is quite severe, when you have a long period wave enter into the harbor.

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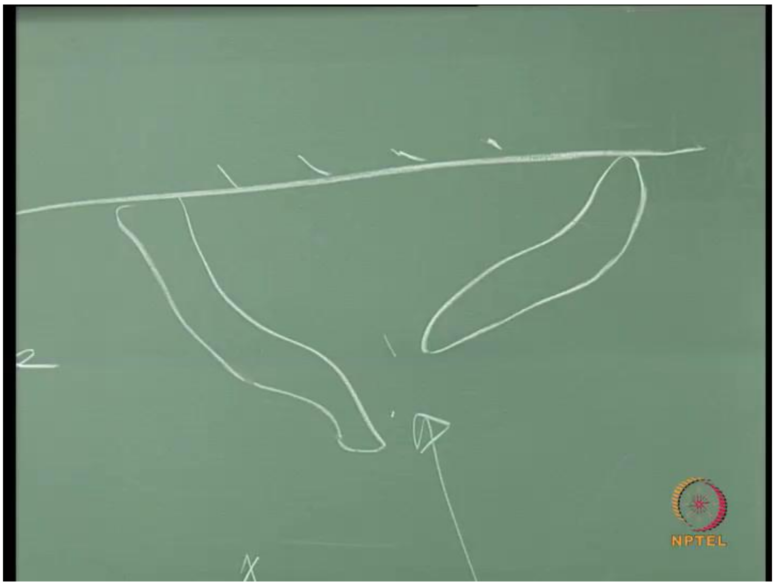

That is when you have a harbor usually formed by a pair of break waters and say for example here. As long as the wave period is within some a level it is ok, because the opening the harbor designed for that particular the entrance will be designed for that particular handle that kind of waves. Again going back to tsunami in order to understand the physics, what was one of the problem during the tsunami most of the harbors like Nagapattinam, Chennai harbor, Tutucrion all this places, what happened the long period waves entered into the harbor. Once the long period waves enter into a harbor, the reflections form the break waters because it is going to be more as we have already seen if you have a long period wave, the reflection is more. So what will happen when a long period wave enters inside, there will be propagation this side, there will be propagation this side and there will be a lot of agitation and this will take a long time to settle down. When you have such a long period waves entering into the harbor, and when you are not able to really take care of the reflection, what will happen all the vessels which are inside will lead to will have the you will have lot of collision taking place that was one of the serious problems during the last tsunami.

And another thing is when you the break waters are normally and usually the multilayered structure, for the simple reason the dissipation is gradual. The dissipation has to be gradual. So what they do is that is the one of the reason why you have layered structure, in which case the energy is slowly dissipated and the reflection also is reduced and this is how all the break waters are designed.

Now you see that we have considered this now. If you consider for the same tan theta, here what did we do, we changed only t and found that the reflection coefficient is higher for a long period wave. Now in this case under d, we are keeping that wave period constant, but we are varying b we have changed the wave height, we have reduced the wave height. So you can follow the same procedure then you have your surf similarity parameter 3.74 and k r as 0.71 leading to a higher reflection coefficient. So when the wave height is less, we have a higher reflection coefficient.

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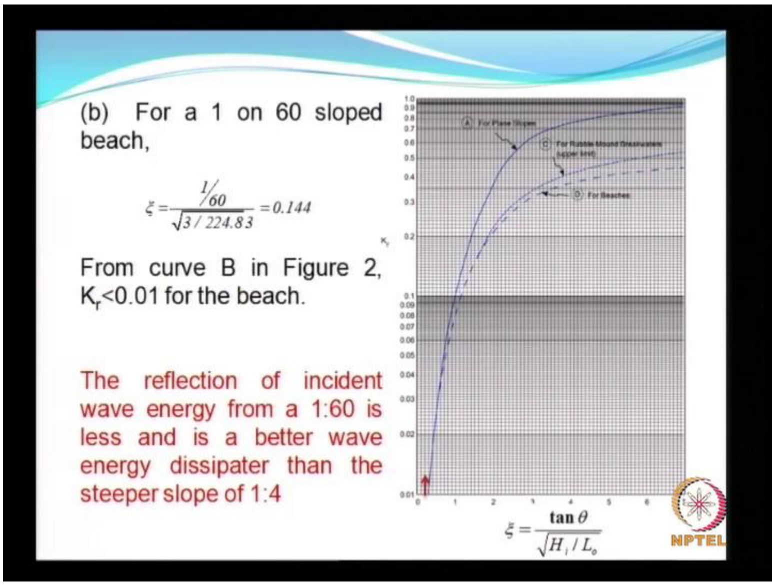

So usually reflection coefficient as we have seen in the earlier plots as we have seen here. How is it plotted, it is plotted as the function of your H i by L naught. What does that mean, here H i is the incident wave height and L naught is I am measure as a function of wave period.

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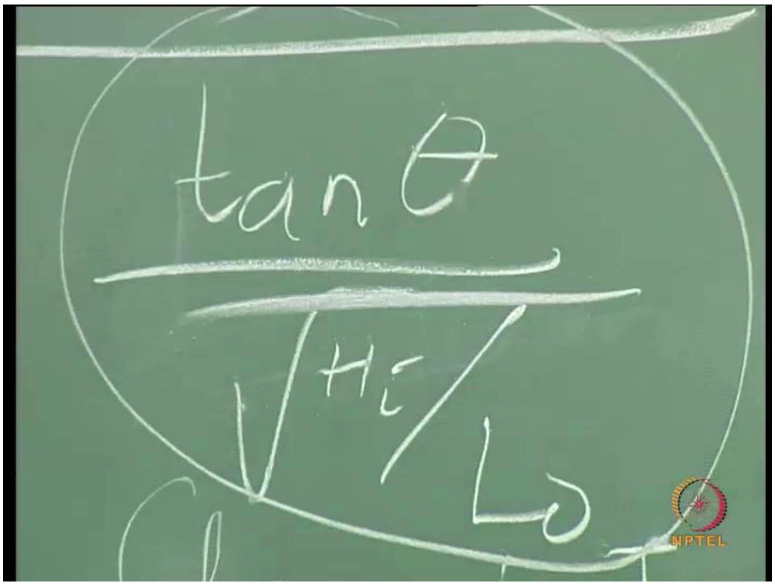

So see, when you are dealing with any kind of a wave structure interaction problem, you have to make sure that all the parameters are included in your presentation, that is very important. So in this case, you have what we are talking only about a sloping structure and we are talking about L naught. So this parameter takes care of most of the aspects, but of course, it does not include the permeability of the structure, that is the reason, why in this picture you see that for the break water it is the upper bound. Upper bound means what, the highest value for a rubble mound structure, so that means if you are using a if you are having a structure with a rubble mound formation, and if you use this if you go as per what is given in this nomogram then you are in for a conservative estimate as far as reflection coefficient is concerned. Understood, so but in order to arrive at a correct reflection coefficient more or less close to reality mostly it is pretending to carrying out experimental investigations in the lab etcetera.

So now coming back to this, here this is how it is presented. Do you have the depth parameter here? You do not have a depth parameter here, so what in case we have a a problem related to the depth also, which is very common. And you want to carry out some kind of tests in the flume and you would like to present the results what do you do.

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You can present the results if you are talking about K r you present in the form of H by L - wave steepness; it is a dimensionless parameter. And so my results may be varying like this. So you see that as the wave steepness increases, the reflection coefficient decreases. But again there is one parameter which is missing that is the water depth, so I can have a series of curves for different d by l value. And naturally you would expect for a lesser d by l value, for a lesser d by l value, K r will be higher. K r will be higher, so because if you assume that it is a constant water depth you subject this to a long period wave or a short period wave, then you know for long period waves the reflection coefficient is going to be higher, is that clear? What we have seen so far is the effect of wave period on reflection coefficient that is comparing a and c that is the subdivision. You see that this is a, this is b, and this is c and then finally, we have done for d.

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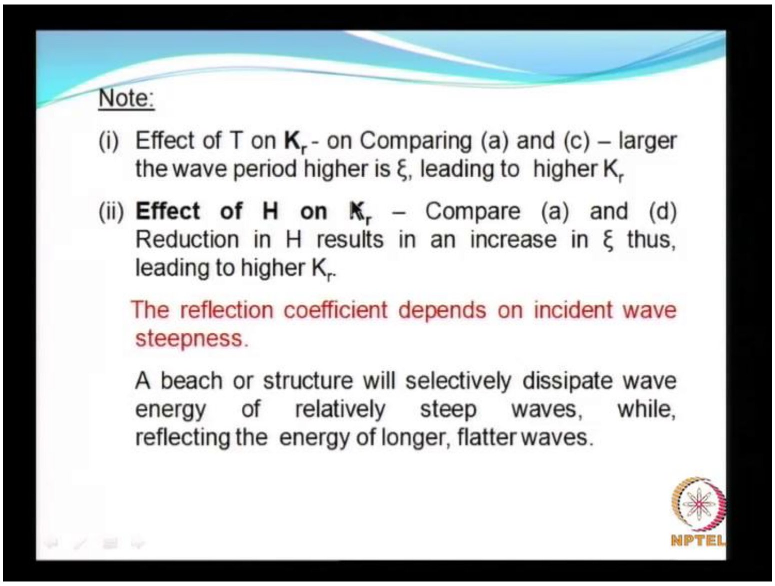

So when you compare a and c then we see that larger the wave period higher is a, higher is the surf similarity parameter leading to a higher reflection coefficient. The next is effect of wave height on reflection coefficient; compare a and d, that is a last one. You will see reduction in H, that is the wave height resultant and increase in the surf similarity parameter, and thus it a leads to an increase in K r. Reflection coefficient depends on incident wave steepness and that is what I have explained here. A beach or structure will selectively dissipate wave energy of relatively steep waves that is the reason why the results would look like something like this. When you have steeper waves then the dissipation will be more, while the reflection of energy of longer sorry a beach or structure will selectively dissipate wave energy of relatively steep waves. So when you have a larger steepness, the reflection coefficient is expected to go down. Are there any doubts, is there any doubts? And everything is clear? Hundred percent, because it is not a big a problem. So that explains to some extent the usefulness of the nomogram, and we took a condition just to examine, what happens when a long period wave is propagating etcetera. Just to understand the effect of the different variables associated in the problem on the reflection coefficient.

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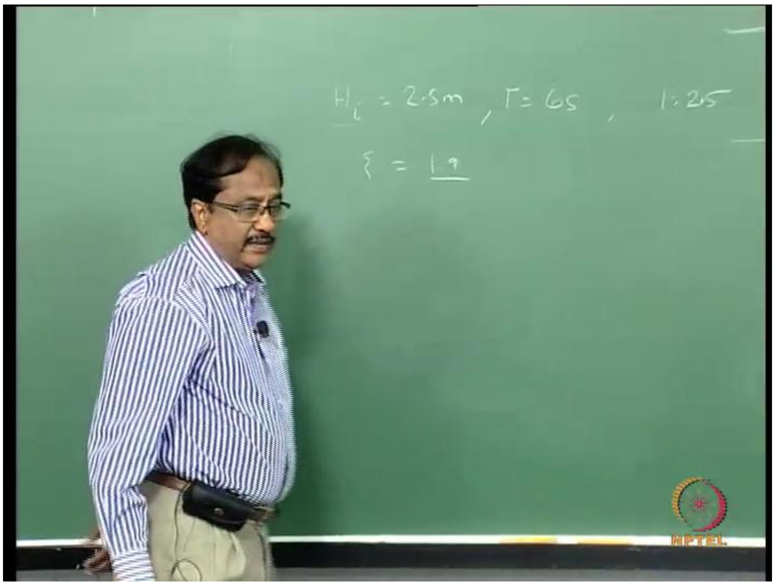

Now waves with a height of 2.5 meters, 2.5 meters then period is 6 seconds or intersecting a rubble mount breakwater, rubble mount breakwater of 1 is to 2.5. I am talking about a rubble mound breakwater will be something like this. Find an estimate of upper bound for the reflection coefficient; it is a very straightforward answer. When you have to calculate all those things, so in this case you get as 1.9 that is the surf similarity parameter and then get into this curve.

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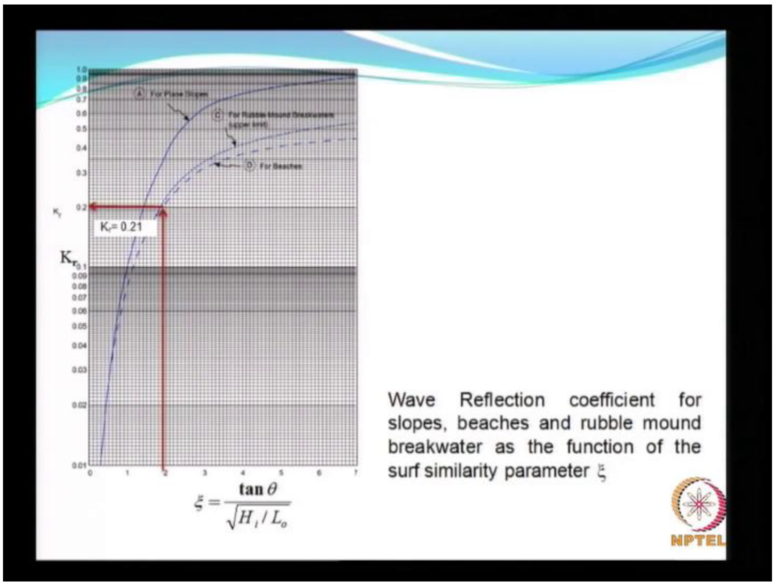

And now we are talking about a breakwaters. So we are this curve the second one gives the upper bound for the rubble mound break water. So use this reflection coefficient the surf similar prime 1.9, and you see that the reflection coefficient is approximately of the order of 20 percent. So now, what does this give, this give, this gives only the upper bound have that in mind.

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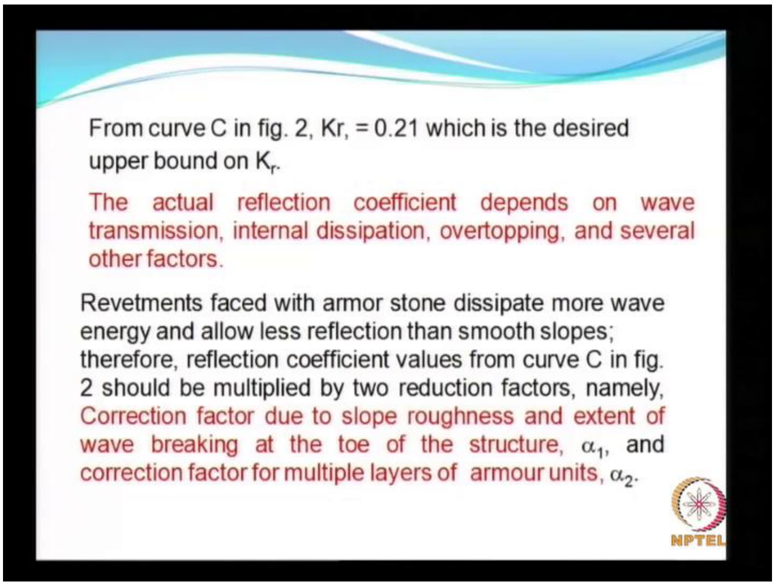

The actual reflection coefficient would depend on what, actual reflection coefficient would depend on wave transmission, internal dissipation, overtopping and several other factors. So when you are talking about a structure like this, what will happen, this is going to have internal dissipation; it depends on the number of layers, the kind of permeability you are achieved by placing the stones there. All this things are going to govern the reflection from this structure. If the height of the structure is less, what will happen? There will be overtopping; if there is overtopping, naturally there may not be much of reflection. So it depends on overtopping. Internal dissipation as said transmission also.

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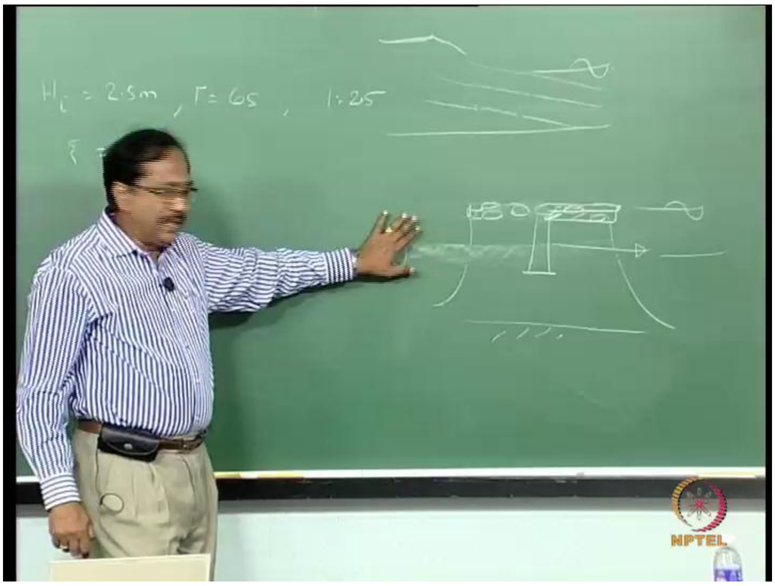

For example, if I have a structure, a structure may be something like this, and you have a wave propagating. One such a structure can be even a floating breakwater, which we will see later when we talk about types of breakwaters. In such a case, what will happened, if the wave is very, if the wave length is very small, this structure will keep on riding over the waves. And if the structure length is very small compare to the wave length, most of the energy will escape, most of the energy will escape, so the reflection will be less. In such kind of a problem, what we want, we want this side energy should be less.

Why energy should be less? See this kind of a floating break water is constructed at locations, where you want calm area, and you want to have some kind of a sheltered area from the incident waves. So you have some kind of a construction made, and this is the floating breakwater which is anchored here, and the characteristics of the floating breakwater should be in such a way that the reflection is less or more that is a different issue, but at least the transmission should be less. So what they have to do, they have to assess the characteristic of the waves in the field and then just because you have to also take care of long waves can you have a indefinitely long a structure. No, so there are other kinds of mechanism for which can through which you can dissipate the energy. How that is possible? May be you create a kind of a porous structure here, this also is possible, this also is possible.

One typical example is for a few projects in the US, they have used the used tires, used tires. You just put it one above other and then tie it and make it as a structure. Now you see lot of preparations, what will happen, when the waves come dissipation takes place, because of the type of structure you have installed there. So this is what I am trying, so it depends on several other factors. Now you have examples for you need to listen reflection, mostly reflection should be less. For in such a situation, you may not really worry about reflection much, because you can have some structure like this, wherein this structure attached to this, the idea is to reflect back the energy and allow the minimize the transmission, you understood?

So whether you want reflection or whether you do not want reflection depends on the type of problems you are discussing about. So revetments faced with armor stone dissipate more energy and allow less reflection over the smooth slopes, this we have seen. Reflection coefficient from the figure c, which we have seen earlier should be multiplied by two factors. What are the two factors one is, the one, there are two factors, which I will come back to this later. I will stop here.