Costal Engineering
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Module - 6
Forces on Coastal Structures
Lecture - 1
Forces on Coastal Structures – I

In today's lecture we will look at the forces on coastal structures, evaluation of forces on coastal structures and in this case it is mostly a vertical structures. I will not be covering the piles wave forces on piles, because piles also come under the classification of off shore as well as coastal structures, but the wave forces on piles have been already covered under my lectures on this, on the subject wave aero dynamics. So, here I will be covering mostly the wall type structures, let us get started forces on coastal structures.

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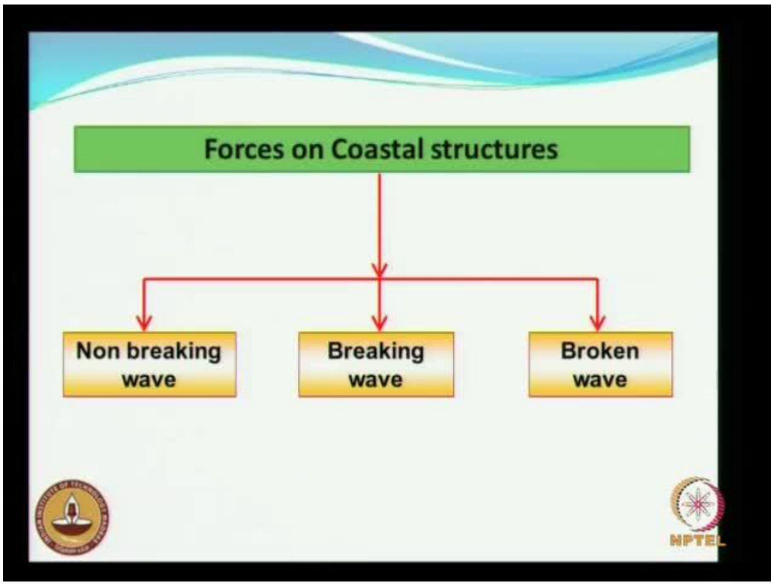

The type of waves that can act on coastal structures can broadly be classified as non breaking waves, breaking waves and broken waves. The breaking wave force is said to be about eight to fifteen times that of the non breaking waves. So, at locations where you expect considerable amount of breaking of the waves, it is very essential that you estimate the forces due to breaking waves for its design, this needs to be considered for its design.

Broken wave as you know that once the wave is broken, then there is not much of force coming on the structure, hence I will not be covering broken wave, but will be covering the non breaking waves and the breaking waves. What we will do is, initially we look at the methodology in brief, then in order to understand in a better way and in a easier way we considered some examples wherein two waves, I mean waves of two wave period one longer and one shorter have been considered, so that we get an idea concerning the effect of period also on the wave structures. Is that clear? So, non break non breaking wave forces.

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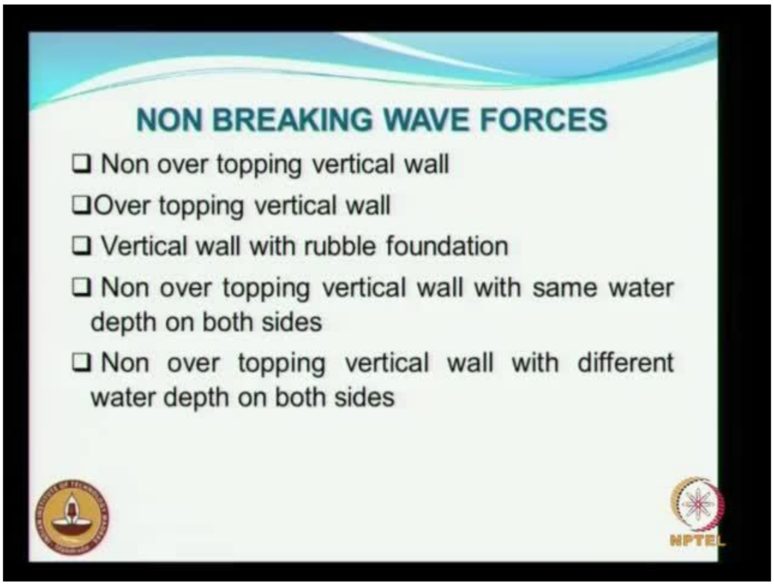

We will be looking at non over topping vertical wall, over topping vertical wall, if the waves are going to over top on the wall over the wall, then you would expect the force to be less. The force if it is a non over topping wall you have a force, but in a over topping wall a the force will be much less compared to that on a non over topping wall.

We basically work with kind of a reduction factor in order to estimate the force acting on an over topping wall, this we will try to understand with the help of an example, worked out example.

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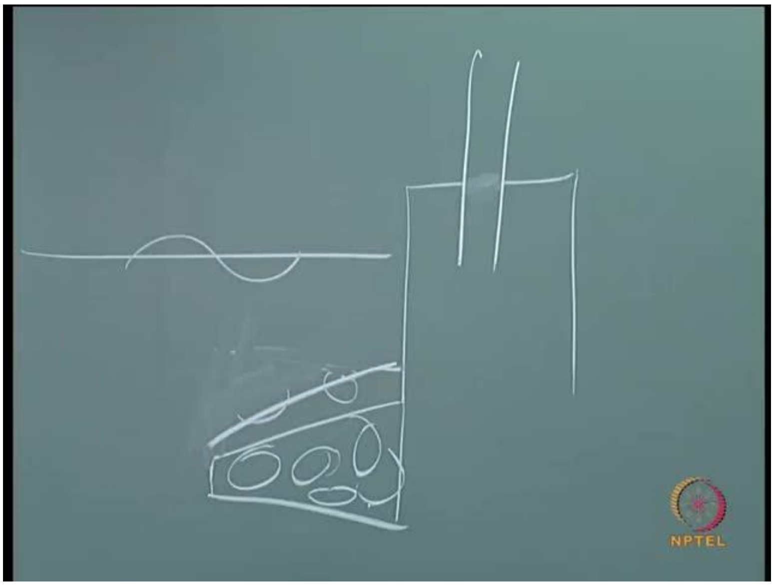

Vertical wall with a rubble mound foundation, this is very common because you would come across, you would like to have a vertical wall structure, then you have a a rubble foundation, may be like this or may be like this. So, mostly it will be a kind of a sloping structure, then you have the waves coming in this direction. So, it may be even a intake structure, when you have this kind of a rubble mound this is a sea bed, the force will be reduced in case you do not have this rubble mound. That is natural because it is going to offer certain amount of reduction, dissipation.

So, this also this is a common type of structure under and even in the case of composite break order you composite break order, vertical composite break order is nothing but this kind of a structure. This is nothing but in fact composite break order or you can have even as a a I mean intake well. So, this type of structure will also be considered.

Non overtopping vertical wall with same water depth on both sides that may be one condition, which may be the usual condition, normally what happens when you construct a vertical wall inside the ocean the water on both the sides will be same.

When water depth is same on both the sides, what does that mean? The static head, the pressures due to the static head is going to be same and it is going to get cancelled. But there may be some situations where you could have difference, different water depths on the sea side and on the lead side of the wall. Then in that case the differential pressure due to the difference in the static head will come into picture, will act on the structure. Is that clear? So, basically you have two components when a vertical wall is erected, you will have the static component acting on the wall, plus you have the dynamic component due to the waves.

So, you deal with both these components, remember when we did the dynamic pressures using the Bernoulli equation, linearize Bernoulli equation we considered, wherein we had a static head and a dynamic head, when you add these two we will have what is called as the total pressure item. So, when you want to measure the pressures in the lab for example, when you think of measuring the pressures in a lab in the lab, so for example, let me have a structure like this. So you have the pressure ports a different elevation and you want to get the pressure time is t acting on the vertical wall.

What will you do? You will install the pressure transducers and then fix the wall rigidly to the bed flume bed. And you leave it as it is and without the wave there will not be any wave. Now, you are connecting all these things to the data acquisition system or to a to a computer via the data acquisition system. Before you get started, before you generate the waves what you do is, you set all these pressure sensors to 0.

What does that mean when you set all these pressure sensors to 0? That means the static head of the water is nullified. You will not consider this static head, because static head is very easy to calculate. So, once you set the static head as 0 as the datum, for all the then you allow the waves to propagate and impinge on the structure. Then what are the pressure sensors going to sense? It is going to sense only the dynamic pressures, maybe even the even in the case of, if you want to have a the total force acting acting on this structure then also you will set it to 0, so the static head is nullified.

So, that will, so what you will be measuring is the, if your time is the of the wave is like this is a sinusoidal we would expect more or less the force or the pressure time history also to be sinusoidal, except may be somewhere close to the, very close to the free surface or above the free surface, above the free surface it would be quiet different, right.

Every time you may not have the crest reaching the structure it depends on the wave height that is considered for the measurements. So, in the case of non overtopping vertical wall you you can have a situation where you can have the water depths different on both the sides.

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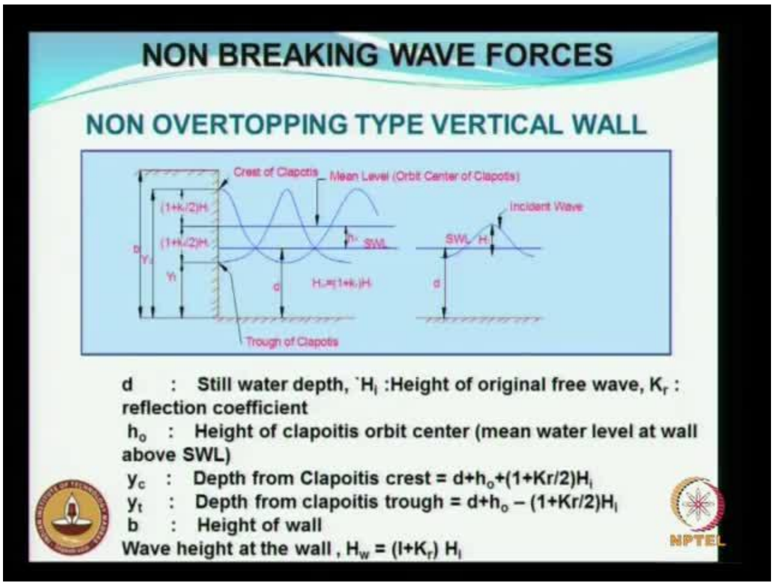

Most of the information which I am covering here today, is taken from the showed text in manual which is, which has been revised as the coastal engineering manual. You should also refer to the book by Goda, which gives the pressures exerted on a composite breakwater. So, non overtopping type vertical wall, here is the wall and this is the S W L or the mean sea level. When the waves come and hit the structure, in the vicinity of the structure there is a raise in the water level, by an amount h naught which is defined as height of the Clapotis orbit center mean water level at the wall above the still water line.

You know what is meant by Clapotis? Clapotis is nothing but 100 percent reflected waves. So, there is a raise of water in front of the structure, further thus, the wave would have a height of equal to twice the wave height that is away from, slightly away from the structure. If H i is the incident wave height, then the amplitude here, this is this is the this is the new water line new mean water line, so the amplitude will be 1 plus K r by 2 into H i.

If K r is equal to 1 then what will happen, if K r is equal to 1, in the case of a vertical wall that is reflection is 100 percent reflection, then you will have the height from here to here equal to two times the incident wave height. So, the wave height on the wall will be twice the incident wave height. Now, there are a few parameters which we need to consider, one is the height of the wall which is b.

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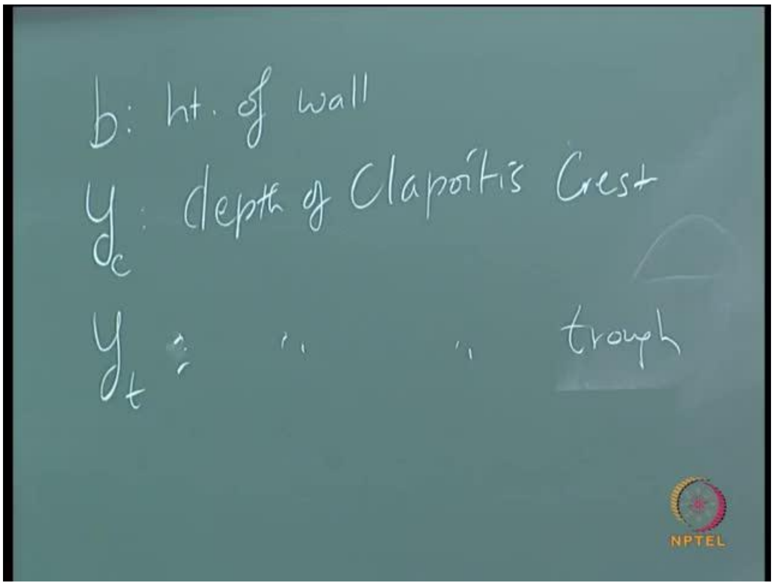

b is height of the wall, then you have y c, y c is the depth of Clapotis crest, from depth of Clapotis crest, this will be nothing but your d that is the water depth plus height of the Clapotis, then half of the I mean not half that is amplitude of the wave on the wall. Is that clear?

So, this will be height water water depth plus height plus this one plus 2, that is the depth of the crest of the wave or Clapotis. And similarly, you have yet another parameter which is depth of the Clapotis trough.

When do you know that it is going to be an overtopping structure or a non overtopping structure? There are two situations one you have a wall or you fix the crest elevation and then later calculate your y c, to find out whether it is going to be a overtopping structure or a non overtopping structure, that is one way. The other way is for a given wave climate, you calculate your y c and then fix the crest elevation.

Why why do you do that? Occasionally, if there is there is a wave which is extreme even which is going to occur once in a while, which you may not be interested in considering that. Because if you keep on raising your vertical wall the crest elevation, then the site you lose the site of the sea also from the land, so there are so many considerations and it depends where you want to construct a vertical wall. Certain cases, certain amount of degree of overtopping is permitted, so for this what you do is, you look at the wave climate for any project you are suppose to look at the probabilistic description of the wave heights.

How frequently it occurs? Normally, you do not look at the mean wave height, either you look at the design wave height or you look at the probabilistic description of the wave, what is the probability of a wave height, of so and so occurring of this particular site.

If a wave height is say about, two meters which is frequently occurring, its better you consider that. But if the probability of a wave height greater than three meters is just a ten percent, then you decide whether you really want to accommodate that because for for a wave height of two meters and three meters, you know that the for three meters the height is going to be high. So, you do the calculation and you also know the percentage of occurrence of that particular wave height of may for this example I am saying three meters and then you decide whether you want to accommodate that, so that the wall has to be raised further, this kind of exercises have to be done based on the knowledge you gain from what we are looking at now.

So, wave height at the wall is given as h w is equal to 1 by 1 plus K r into H i.

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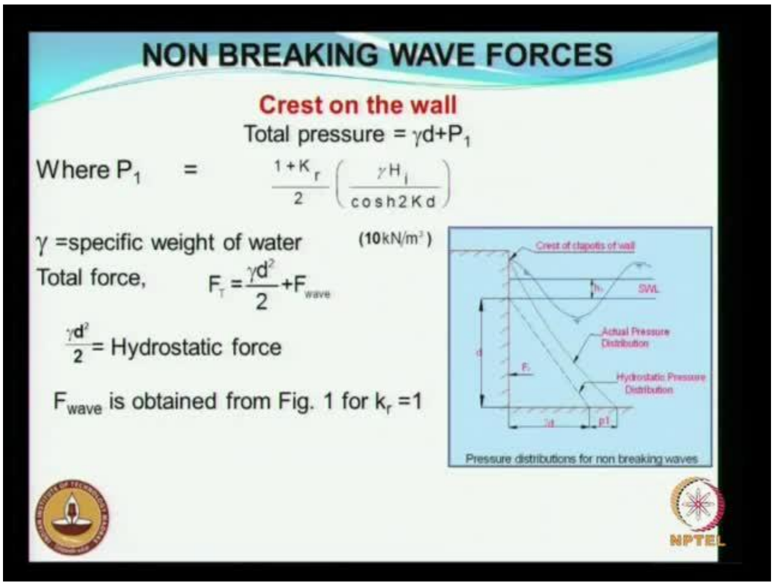

So, now let us look into the details on the non wave non breaking wave forces on vertical structures. As I said earlier, there can be a situation when a crest is coming on the wall or when a trough is coming on a wall. When a crest is on the wall, naturally expect more pressures compared to when the trough is acting on the wall. For both situations we need to calculate the pressures.

So, you see here when the crest is acting on the wall, the expected pressure distribution is shown here, this is the actual pressure distribution. And this is your dynamic component and where as this is the static pressure head. Now, the total pressure will be a summation of gamma into d, that is the static part plus your dynamic part P 1 and specific weight of water is also sea water is also given there.

Now, F t the total force will be gamma d square by 2, plus F wave. Gamma d square by 2 is the hydro static component and F wave has to be obtained from a figure figure one and here in we are considering the reflection co-efficient as one meaning that the wall is impermeable and vertical, it is very important. If the wall is sloping or if the wall is not impermeable when I say not impermeable, even if there is slight amount of permeability, you will not have reflection co efficient of one. So, this is the kind of a pressure distribution you would have when a wave is, when a crest is acting on the wall.

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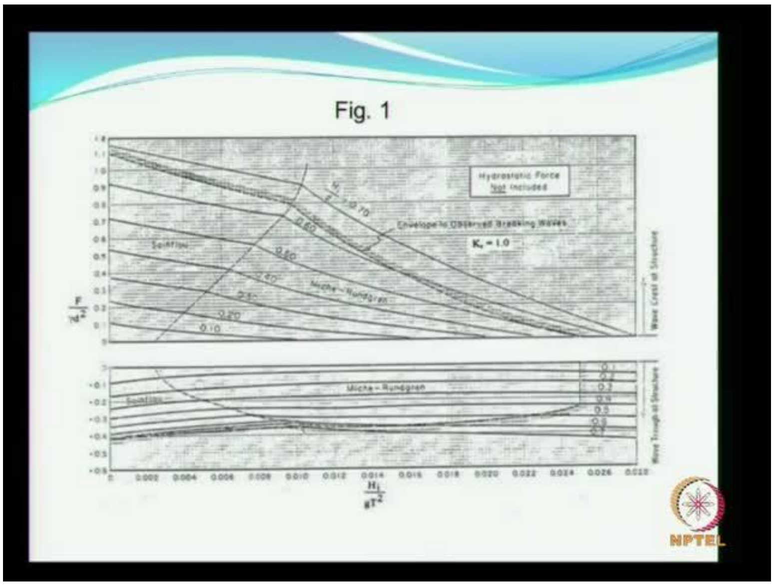

What you would do here, you see you see the F wave, F wave is obtained from this nomogram.

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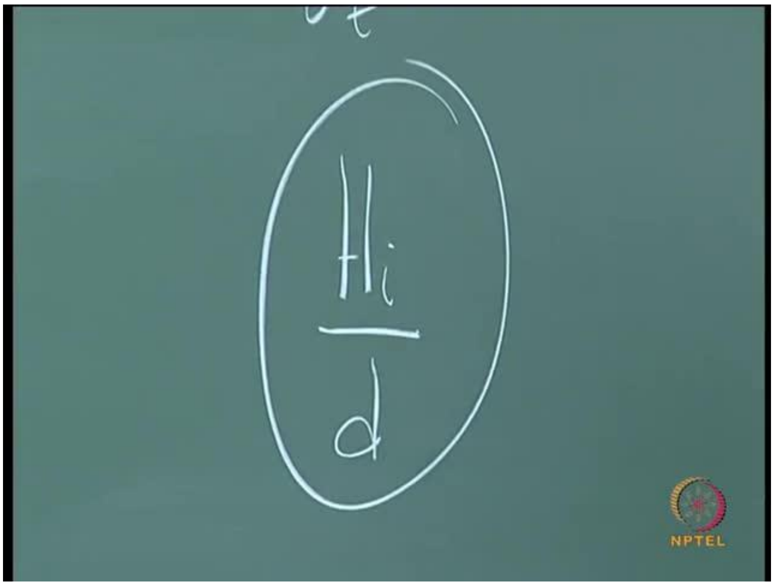

When a wave crest is acting on the wall or when a wave trough is acting on the wall, you have contour lines of H i by d contour lines of H i H i is incident wave height divided by d.

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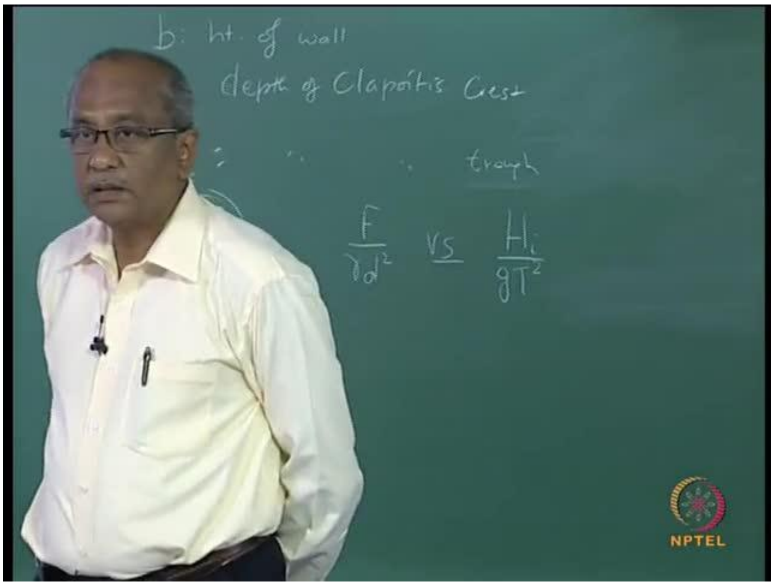

Now, the other parameters are F divided by gamma d square versus you have… What is this H i by g T square? What is H i by g, g T square? Most fundamental you know, what is H i by g T square.

What are the two parameters which are involved there? What is on the numerator, numerator is the wave height. What is there on the denominator? Please think such a fundamental thing you are not able to answer. What is it? Wave wave wave length denominator, wave length. So, numerator is wave height denominator is a measure of the wave length. So what is it? H by, H by l and what is it called? Wave oh my God, wave steepness, it took so much time for you to say this.

So, the dimensional less force is plotted as a function of wave steepness for different relative wave height. The dimension less force, this is dimension less force is plotted against wave steepness for different relative wave height. Understand? Relative in the sense, it is divided by a parameter we here in which case it is d, it can be whatever it can be any other parameter, any other variable sorry. This picture we try to use, this picture for obtaining the force acting on the wall, it is quite straight forward. Is it not?

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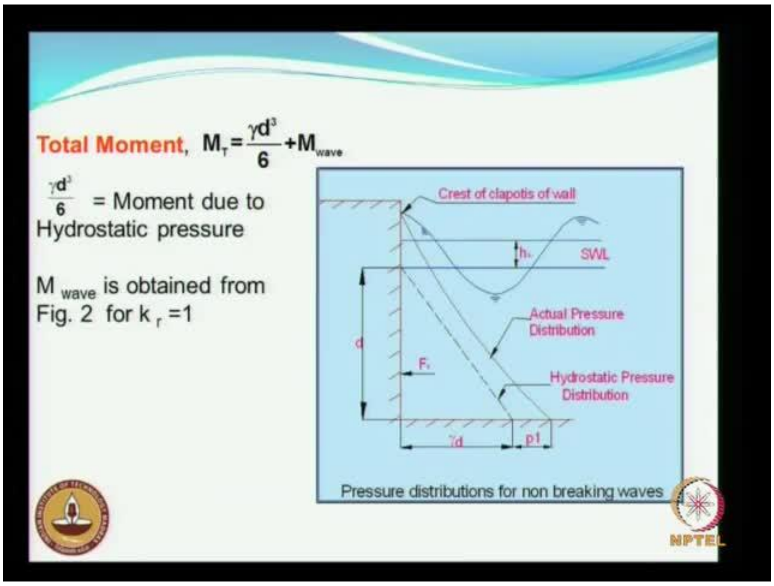

Now, total moment acting on the wall, that is at this point at this point will be gamma d cubed by 6 which is due to the static head plus moment due to the wave. Moment due to the wave is obtain a similar wave what we have done for F wave, this is by using again a nomogram.

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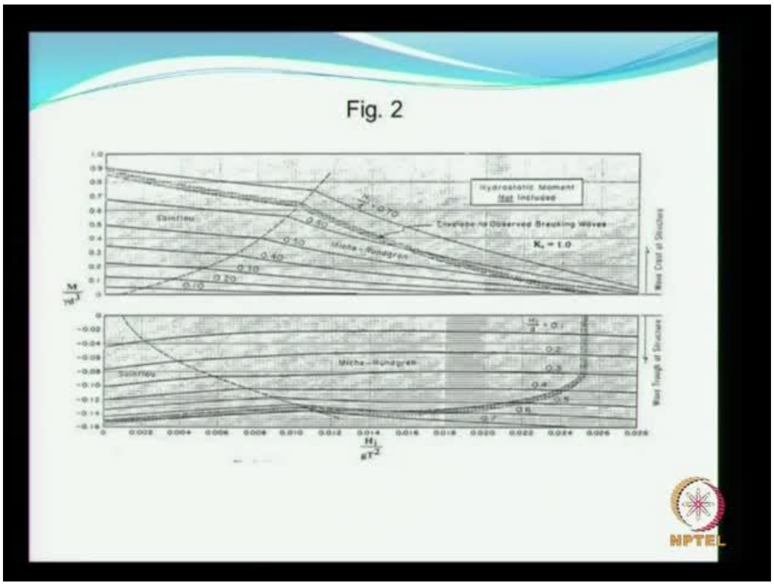

As shown here, the bottom is bottom one is for the trough and the top one is for the where the crest is on the wall. Is that clear? Once you have your moment r F wave add it up with the respective hydro static part to get the total.

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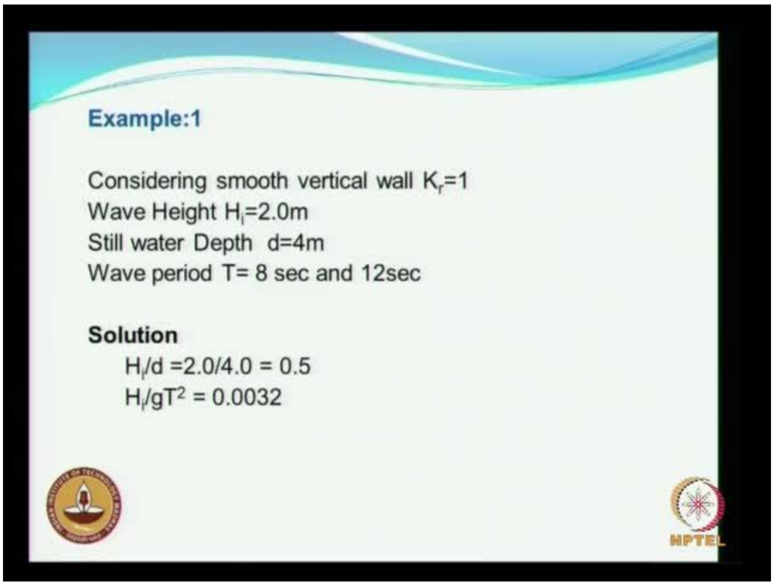

Now, we take an example, please remember all these variables which we have used y c y t b, a K r is 1 that is, okay.

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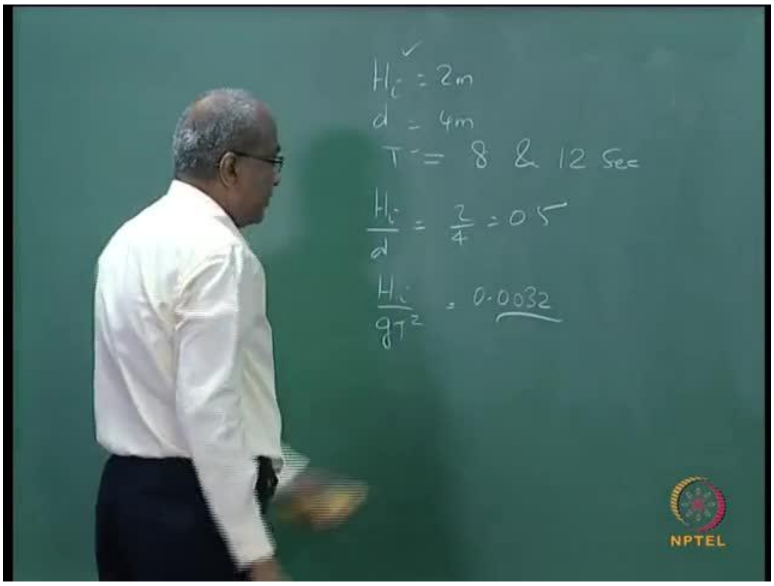

H i equal to 2 meters, water depth is equal to 4 meters, T equal to we consider in this example two’s wave periods one is 8 seconds and another is 12 seconds.

So, we calculate H i divided by d is going to be 2 by 4 equal to 0.5. Then H i by g T square is worked out as 0.0032, because H i is known T is known you can calculate initially for the 8 seconds H i by g T square.

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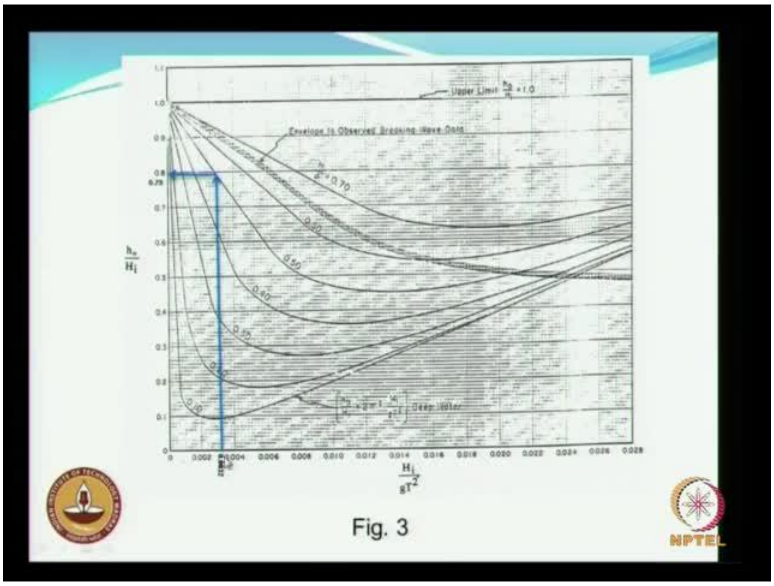

So, when you look at this picture you see that, H i by g T square you will have h naught by H i.

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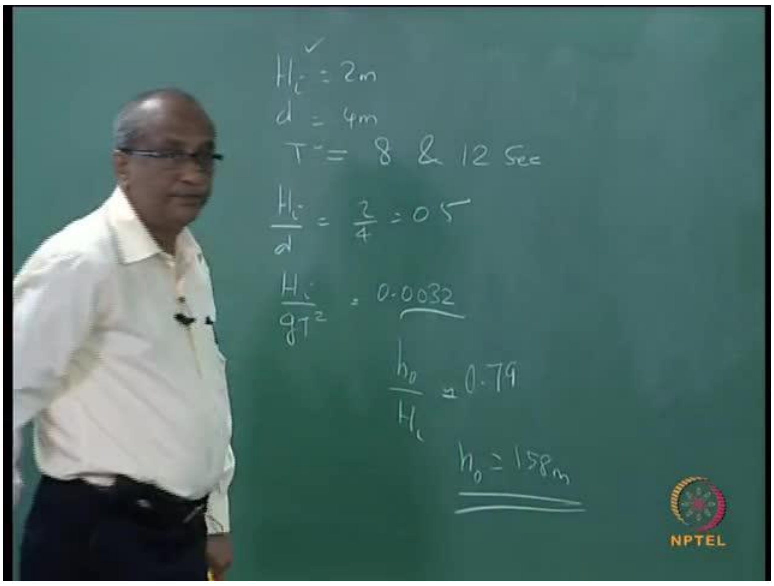

H naught by H i is approximately equal to 0.8 or 0.79. So, in this case your h naught is going to be 1.58 meters, so this is your h naught. Can you calculate your y c?

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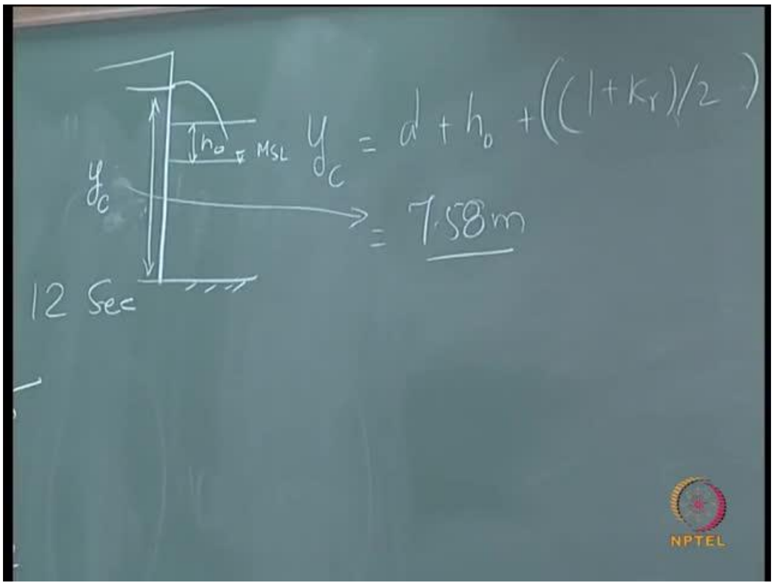

What is going be a y c? y c is d plus h naught plus 1 plus K r divided by 2. Once you calculate this you will have, so this is going to be your y c. y c means what is y c? You have the wall, you have the Clapotis, so this is the, so this is your original m s l now this is your h naught and this is your y c, so in this case it is 5.78.

So, naturally if you do not want to have overtopping to take place your b, that is the height of the wall has to be certainly greater than 7.58. In case the wave the waves with period 8 seconds hit the wall. But you have to consider the longest wave that is likely to hit the structure, because a longer wave is going to have a larger value of y c.

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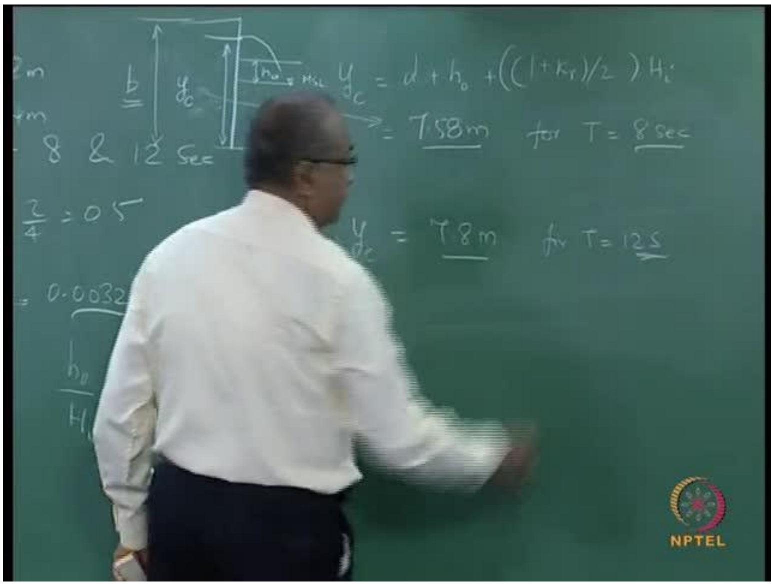

When you calculate in the same way for this is for T equal to 8 seconds you follow the same procedure, you get y c equal to 7.8 meters for T equal to 12 seconds. But you know that waves can have period up to about 30 seconds. There are locations where you can have long period waves and if you are talking about a a structure where may be a birthing structure, where in you do not want to have the overtopping then you consider the longest wave period as I have said earlier.

So, this is only to demonstrate the effect of wave period on your y c, but when you do the calculations, you do it for automatically for the longest wave period that would that is likely to occur.

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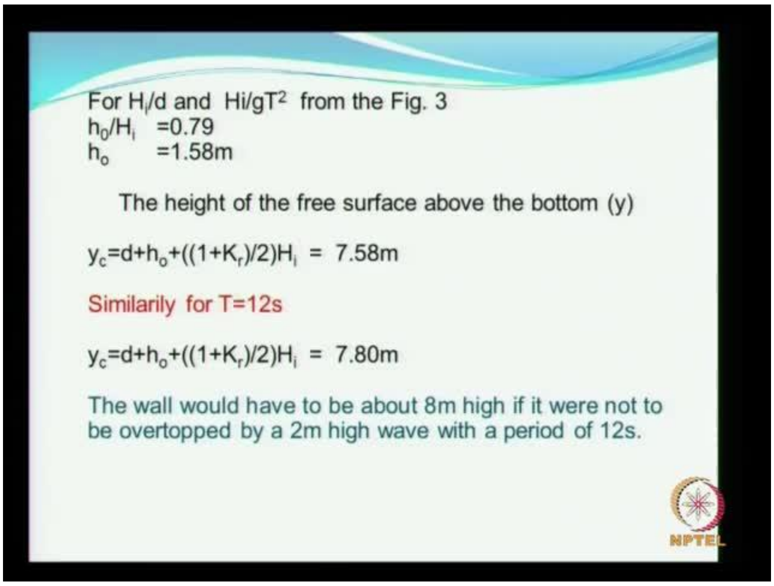

So, the wall would have to be about certainly 8 meters in order to cater to both the long waves, I mean for including the wave with the longer wave period of 12 seconds. And here we have considered a wave height of 2 meters. You have to repeat this calculation for a higher wave height or whatever maximum wave height that occurs.

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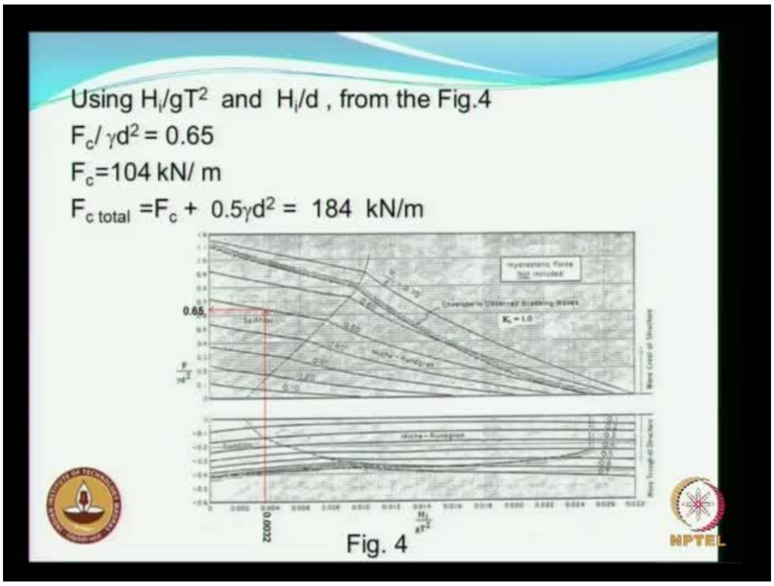

Accordingly you calculate this and then once y c is obtained then go into this picture you have already calculated your H i by g T square and H i by d is already calculated. So, H i by H i by d is this contour line you see here, this is the contour line for H i by d equal to

0.5. Then get into the value of the H i by g T square, which will hit this contour line and you get F divided by gamma d square, that is the force when a crest is on the wall.

After getting that value, since it is the curst I have a subscript F subscript c, c indicating crest, when you this calculate this, this is coming to 104 kilo Newton per meter. F c total can be easily calculated, F c plus 0.5 into gamma d square. That means the total force acting on the wall when a crest is hitting the wall, it will be 184 kilo Newton per meter.

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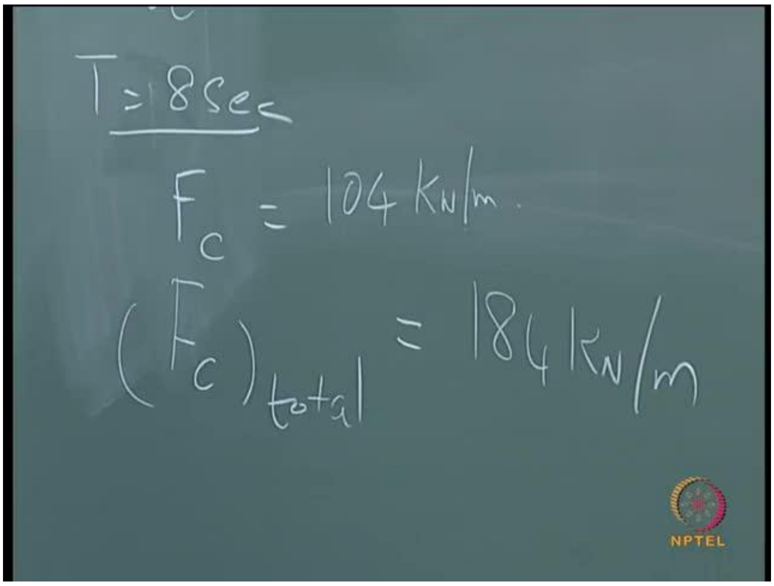

So, you see that for T equal to 8 seconds, F c works out to 104 kilo Newton per meter and F c total including the static static component is… Is that clear? Shall we proceed? Next, we move on to M c that is the moment about the base of the, flow of the structure.

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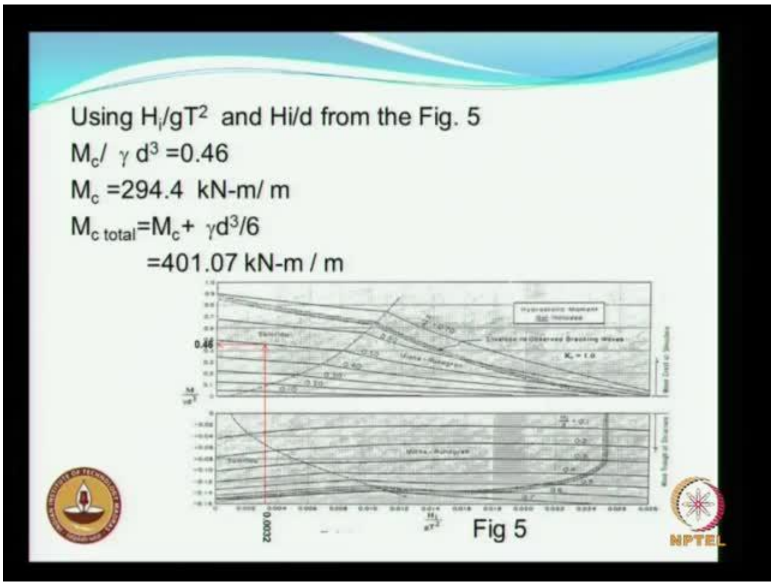

M c will be use the same procedure, H i by g T square equal to 0.032 0032 and you have to take this 0.5 H i by d and this works out to 0.46, and M c now works out to how much?

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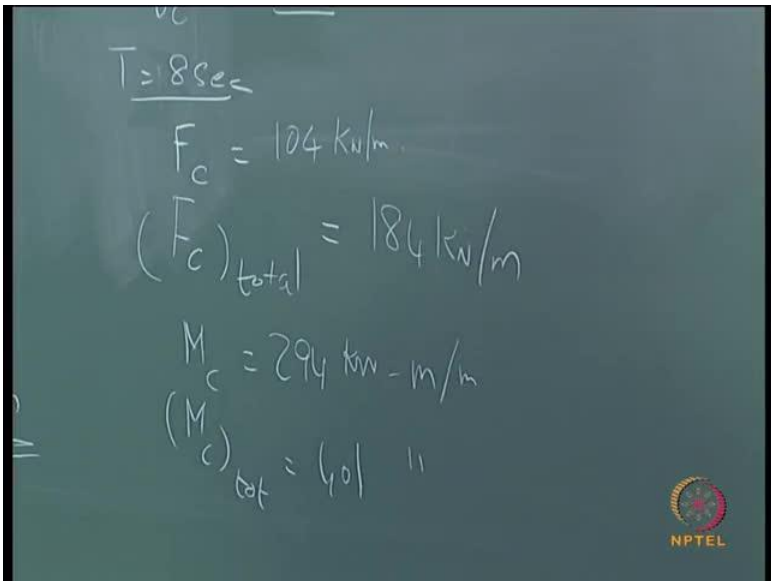

294 kilo Newton meter per meter. Note that due to the static component, it will be gamma d cube by 6. So you need to add that, so the M c total will be 401. Is that clear?

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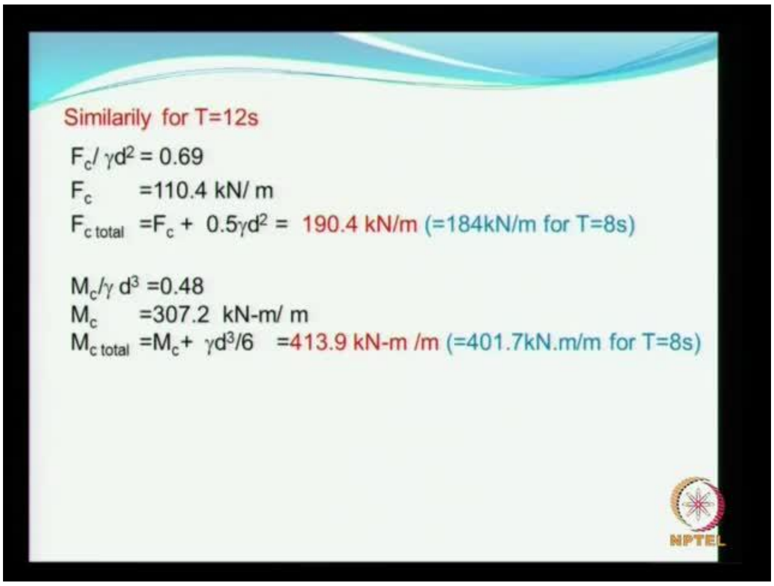

Similarly, when you do it for t equal to12 seconds, this exercise you should do it on your own, try to take that picture as an exercise you can do and get yourself familiarized. F c will be 110 kilo Newton per meter slightly more than the 8 second which you know, because the reflection in fact will be more and the pressures exerted by long period waves are more. As we have already seen, we have made some calculations when the wave for example, even under Tsunami also we had a discussion yesterday. When you have a very long wave period the pressures exacted will be much larger.

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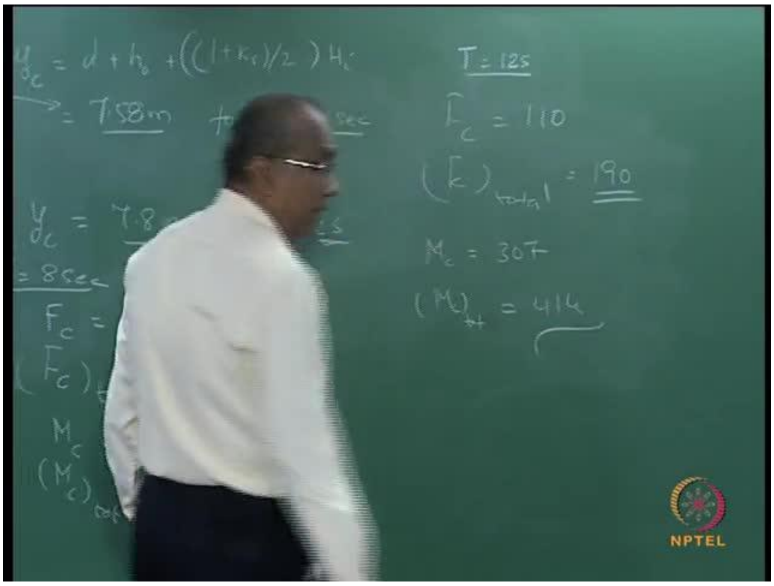

Naturally, the forces is supposed to be greater so you will have here, F c is equal to 110 and F c total 190. The same you carry out for M c, this will be 307 and M c total will be 414 approximately. Are you all of you are following? It is quite easy and quite straight forward. Anyway I have indicated here, corresponding values for T equal to 8 seconds just to give you an an indication.

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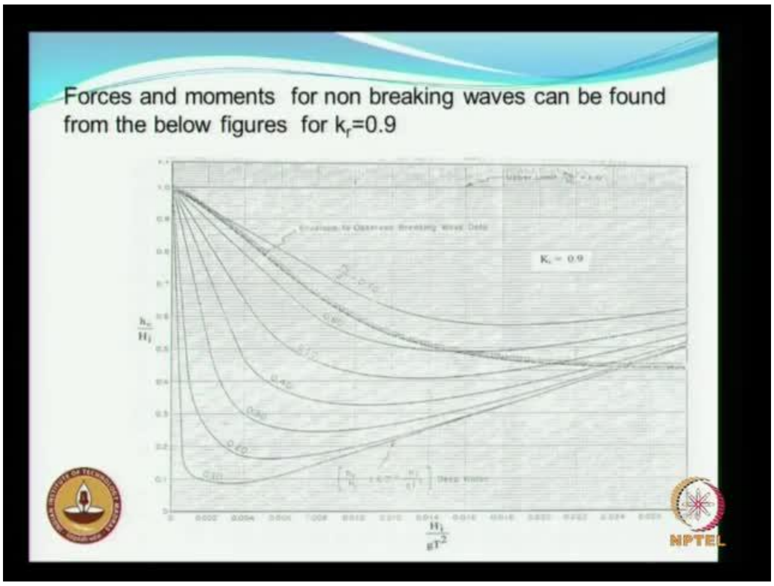

So, all the figures which we have used is for the case of a vertical wall. For other situation for slopping walls etc, you cannot do such such calculations. The manual permits almost a similar kind of exercise that could be carried out for a wall, which has a reflection co efficient of 0.9. So, the respective nomograms are presented here. The procedure is almost the same.

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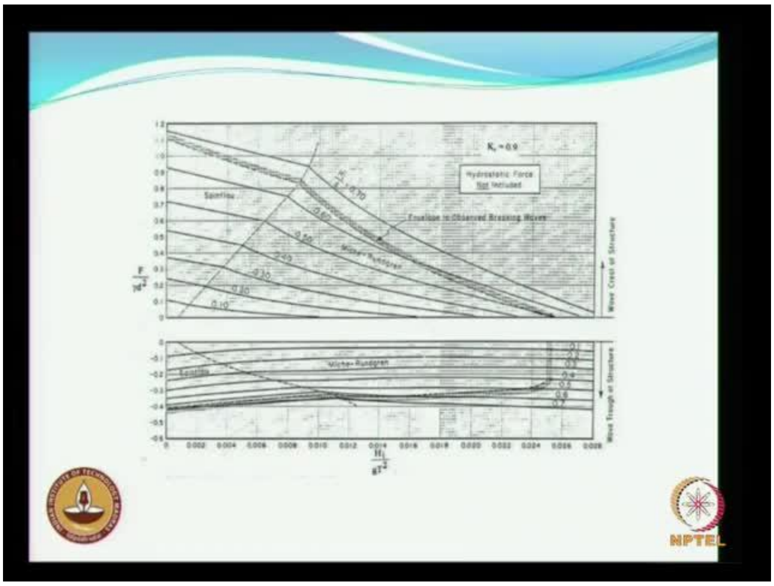

So, this is for K r equal to 0.9 and that is for the force and this is for the moments.

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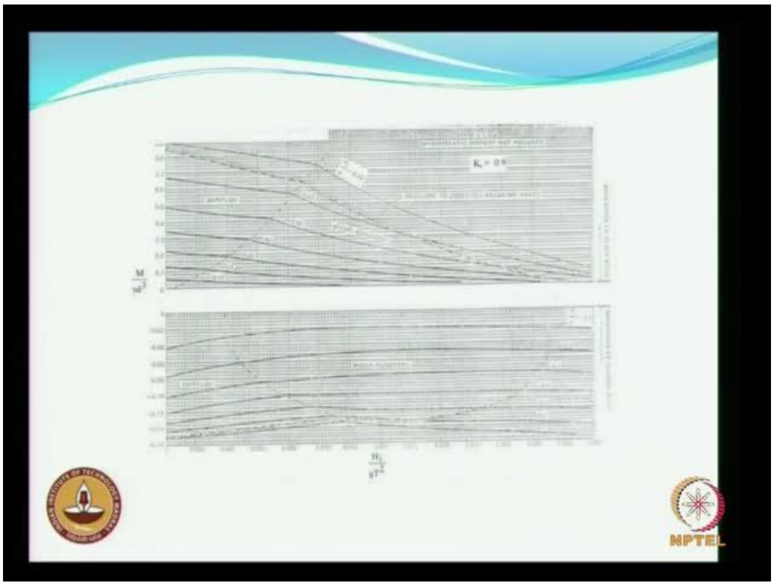

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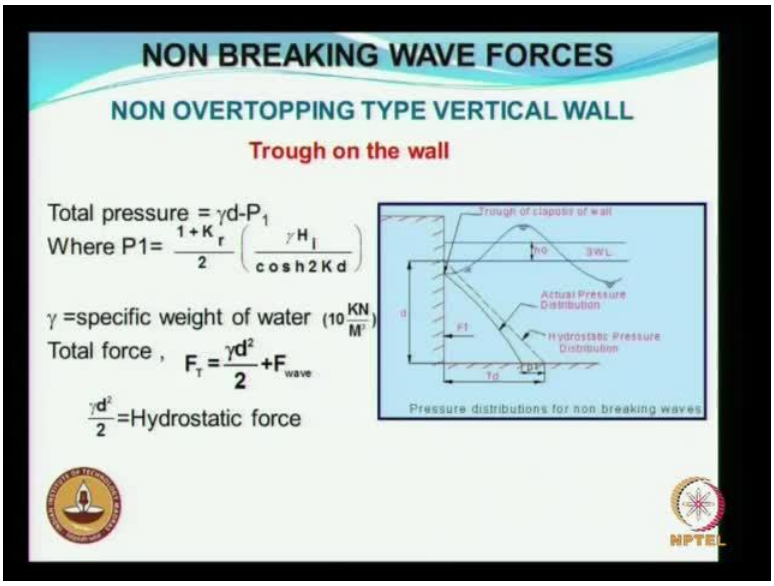

We have seen the force exerted on the wall when a crest is acting on it. When a trough is on the wall the distribution of the pressure would be as shown here. So, this is the actual pressure distribution and this will be your hydrostatic pressure distribution. The total pressure in this case will be gamma d divided by minus P or P 1, where P 1 is given as similar to what we have seen earlier when the crest is acting on the wall.

So, same procedure we need to use for calculating the force when the trough is there, so you have the static component plus the dynamic component F wave.

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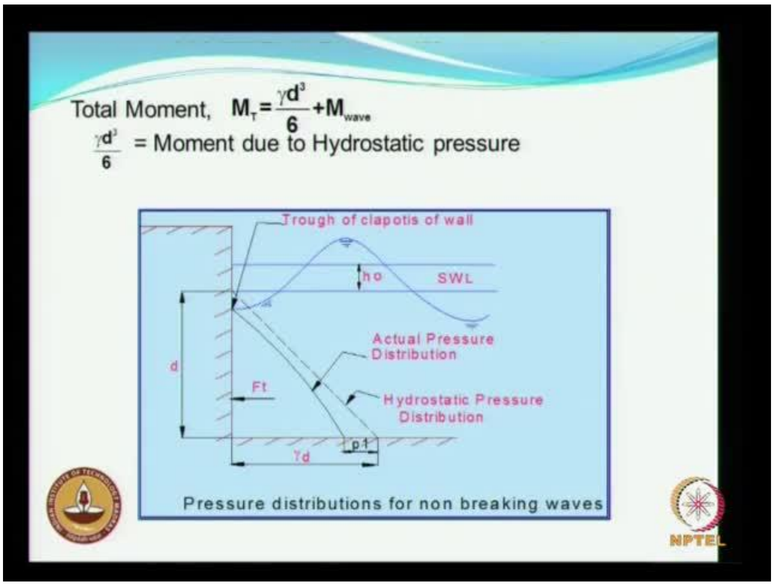

And similarly, you have the moment due to the static head and due to the wave.

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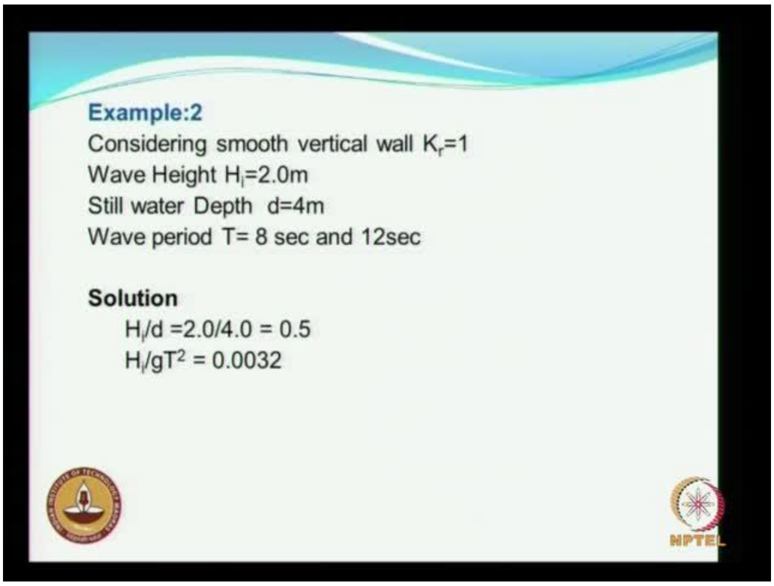

The smooth vertical wall the same values are given, we have calculated your H i by d and H i by g t square.

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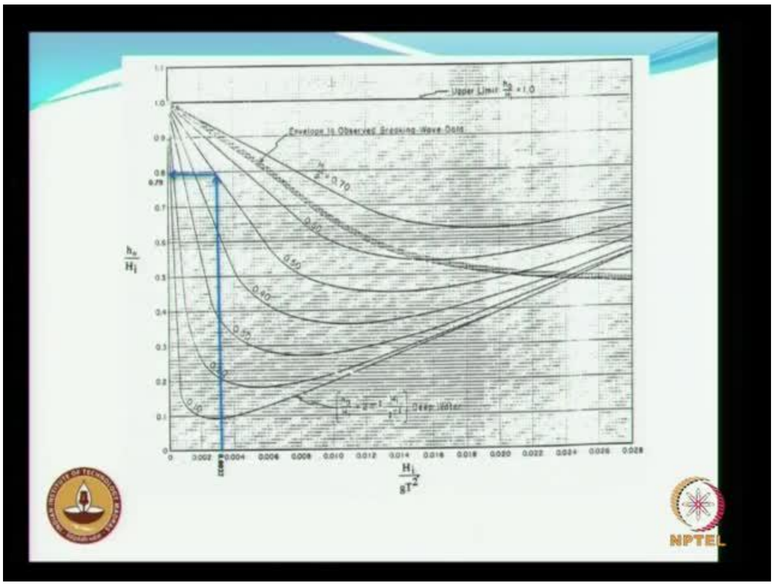

This is already explained.

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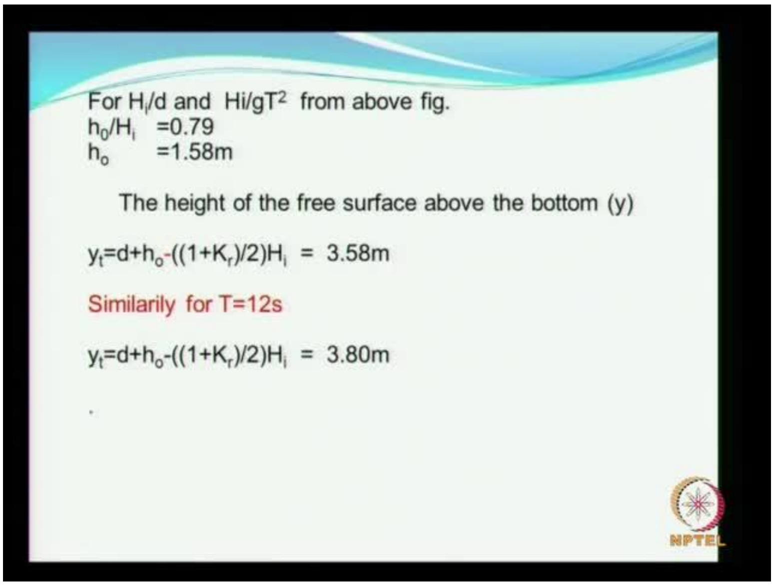

So, all these things have been calculated here. Now what are we up to we are up to calculating your y t.

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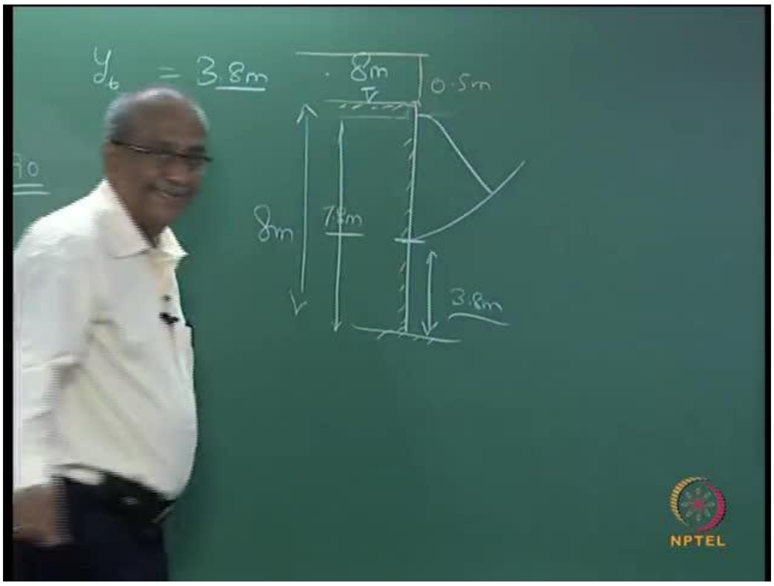

So, the same way you have to calculate your y t, so in the case of y t the only difference will be instead of this plus, it would be minus. And here y t works out to 3.8 meters, so what does that indicate? So, you have a wall, this level considering it as considering that the maximum wave period is going to be 12 seconds, then I can fix the wall height as 8 meters that is, this is 8 meters. What will be the extremes, extremes will be the crest of the wave at a distance of, at a height of how much? 7.8 meters. And what is the portion of the trough? This will be 3.8 meters. Is that clear?

So, we when we talk about the top level or the crest level of any structure, this helps you in in fixing the top level, but always you should think of some kind of a a free bird. Although your calculations shows that, here the maximum difference will be only 20 centimeters, but 20 centimeters may not be enough, because occasionally there can still be some amount of overtopping. It depends on the importance of the structure. Then maybe you go in for a free bird of say 0.5 meters.

So, this is the kind of situation, now you know the height of the wall where the crest is going to come, where the trough is going to come.

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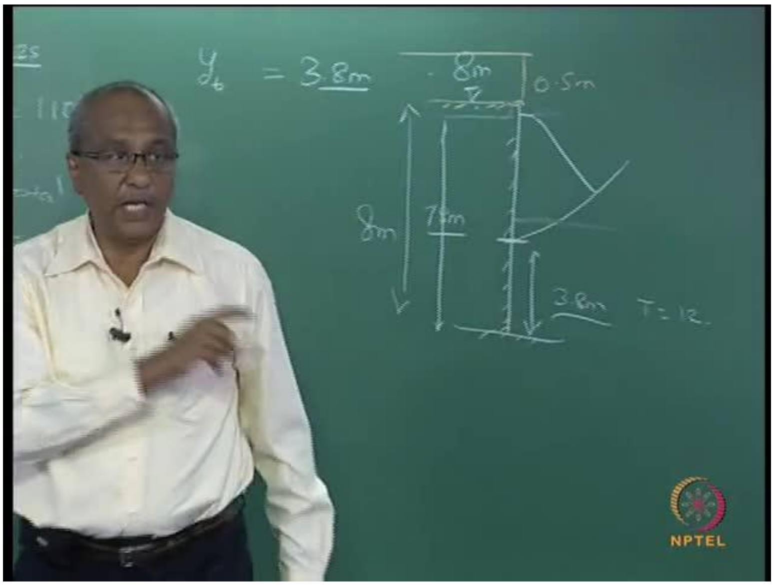

Now, similarly when you do for for 12 seconds, the y t is going to be this much this is for T equal to 12 seconds, but in the case of your, this this sorry y t is 3.58, the other case it is 3.58 for 12 it will be 3.8.

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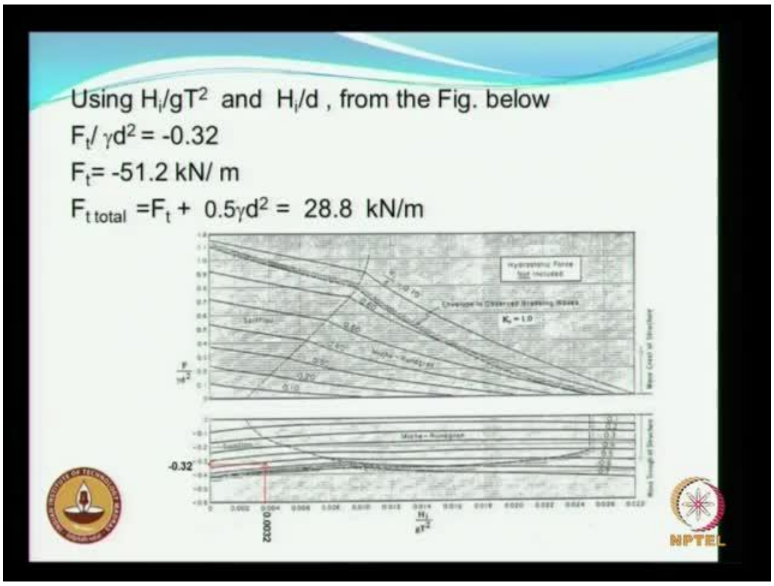

So, using this nomogram the bottom one for the trough, F t by gamma d square will now follow the same procedure as I have said for F c. Now you will get F t as equal to minus 51.2 kilo Newton per meter. The total F t total will be 28.8, so 28.8 what was the F c total? F c total was this much and when the trough is there you have a value 28.8. Is that clear? So, using the same thing bottom feature for the for the, I think I will stop here.