Wave Hydro Dynamics.

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Module No. # 03

Wave Deformation

Lecture No. # 01

Wave Deformation I

Ok after having seen some of the aspects about the behavior of ocean waves particularly, with it is about it is characteristics, and also having seen some of the worked out examples. We now move on to understand how this ocean waves behave as they propagate from deep to shallow waters. So, they undergo a number of, kinds of a few types of deformation, which we will look into it. Before that here is a slide which shows the zonation based on the behaviour of ocean waves.

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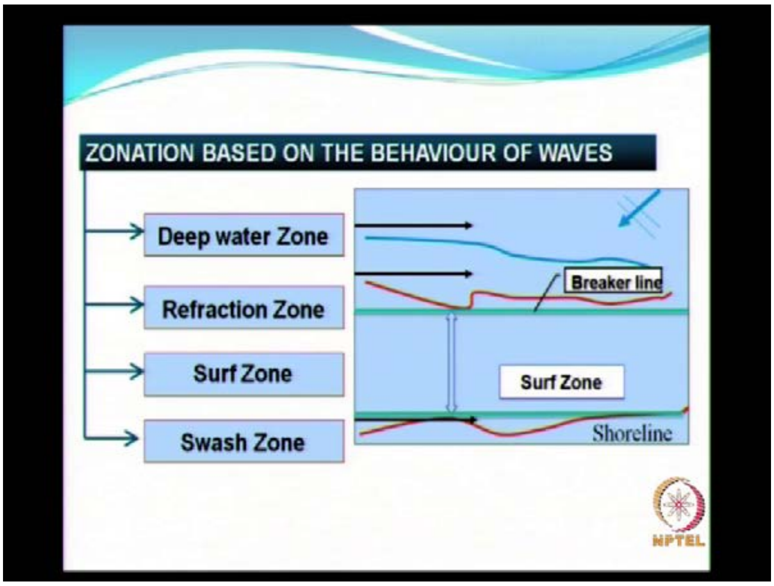

The first zone is the deep water zone, wherein the wave crests are parallel to each other. Some of the books or some researchers they call it as wave fronts. So, that is implant in elevation you represent waves like this, which when you see from plan it will look like this and then this is the wave length.

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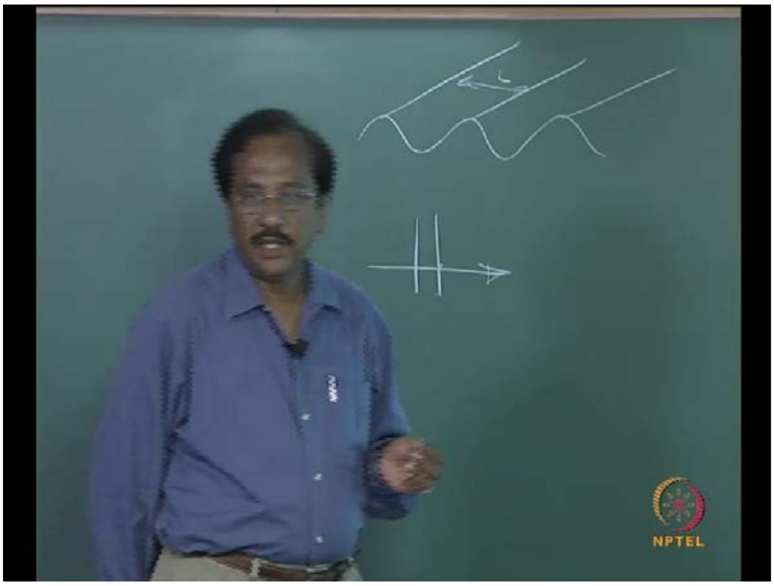

And normally when you want to represent the waves, you represent like this. So, this shows that it is a direction of wave propagation and these are the wave fronts or the wave crests. So, in deep waters the wave crests are parallel to each other. Why it is parallel to each other? Because it is not a function the speed with which the waves are moving in deep water is not a function of water depth. So, you have a very well defined deep water, I mean direction, very well defined direction when the waves are moving in deep waters. So, then comes, the refraction zone. What is the phenomena of refraction zone? So, we had in basic physics you know refraction in physics lab we have a, an experiment to conduct the refractive index, to measure the refractive index.

The other way of simple explanation is, have a bucket of water then insert a stick and look at the stick from top you will see as if the stick is bend. This is because from the air, air is one medium and the water is another medium. So, you have that bending of the stick, it appears as if the stick is bend. So, the most important phenomena takes place in the refraction zone. The waves start feeling the bottom as they propagate. The speed becomes a function of water depth and this phenomena is extremely important and also controls, the stability of the shoreline. So, here the refraction zone the wave start bending, a simple definition is wave start bending and this phenomena is called refraction. That is the simple explanation, but we see in the details later.

Now, once a wave undergo refraction, although I have written it as a breaker line. This actually a zone where you see the waves are breaking. As I said earlier, the waves start feeling the bottom, attenuation is being offered and then the waves start steepening, somewhere close to the breaker zone and the waves break. So, when you stand on the shore you see the wave's breaking so, that is called as a breaker zone. And the from this deep water zone that is d by L greater than 0.5, that is called as the deep water zone. So, this zone is approximately d by L equal to 0.5, that line or the region. So, this is the region where the waves are breaking and this zone is the refraction zone.

Then from the refraction zone, from the breaker zone up to the shoreline we call it as surf zone. And this surf zone varies with a wave climate, every; I mean even daily it may vary. And the surf width that is width of this zone varies with season or with months and it is not a constant width and this zone is also very important. Because it is the area where all the sand you see on the beach is being transported, which is not covered in this subject. So, the surf zone is from the shore line up to the breaker zone, I think that is clear. Now, in addition to surf zone there is another zone which is called as swash zone.

What is swash zone? I have an explanation, written explanation later in the next slide probably, but I will explain the physical meaning. So, when you go the beach some of them they do not like to wet their feet, they stand at a distance. So, most of the time the water will be coming may be few feet or few meters away from him. Occasionally, all of a sudden you see that the water line, water will run up to higher plain that is it will run beyond the, and then you start running because you do not want to wet your feet. So, the distance between the point or the region up to which normally the waves run and the distance; and the point up to which the maximum run up takes place is called as the swash zone.

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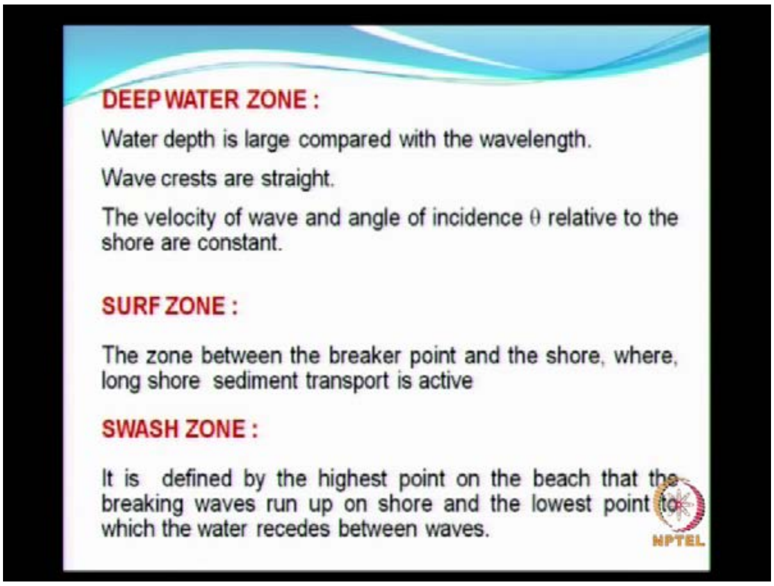

So, these are the important zonation of the waves. And this is what is shown in this slide, as I have already explained all this things surf zone, swash zone. Of course, breaker zone is defined by just one line that is the zone of wave breaking.

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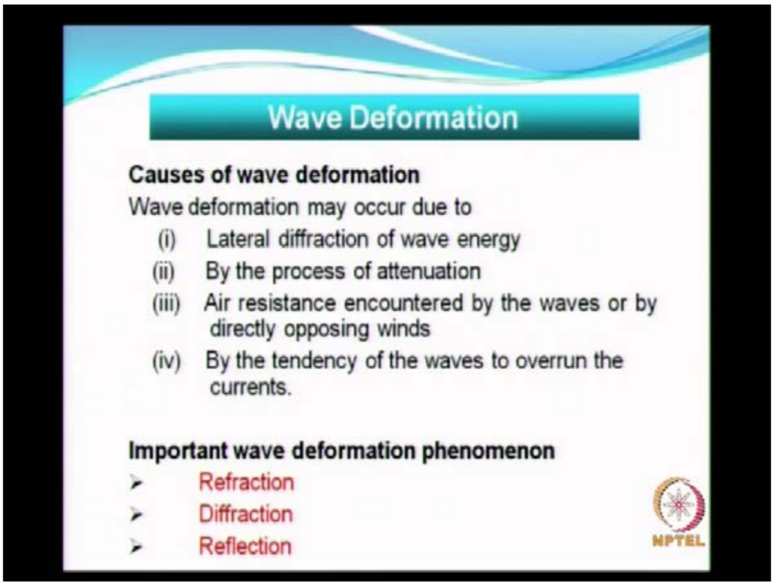

What is meant by wave deformation? Any kind of deformation of the wave surface we call it as wave deformation. What are the main causes for the wave to deform? Although there are several causes, the most important causes for the wave deformation to take place are the lateral diffraction of wave energy. What is meant by lateral diffraction of wave energy? So, you expect if the waves are moving in this direction, as per the definition of average power. What is the definition of average wave power? You see in the first earlier classes, this is the rate at which the energy is transmitted in the direction of wave propagation that is wave power.

Why but, for some reasons there is certain amount of an energy, which is transmitted in the lateral direction then we call it as, lateral diffraction of wave energy. We will see about this later. By process of attenuation, this attenuation can be due to anything. The presence of outcrops, sub merged outcrops are reefs. So, you have the waves moving so you have some kind of a outcrop or reef or a ridge for that matter. So, that is going to offer some kind of an effect either it is, mostly it is attenuation. Attenuation is reduction, the energy will get reduced this is what, this is natural Attenuation. That is naturally there are outcrops, reefs etcetera that gives some kind of reduction in the wave height or there can be artificial means.

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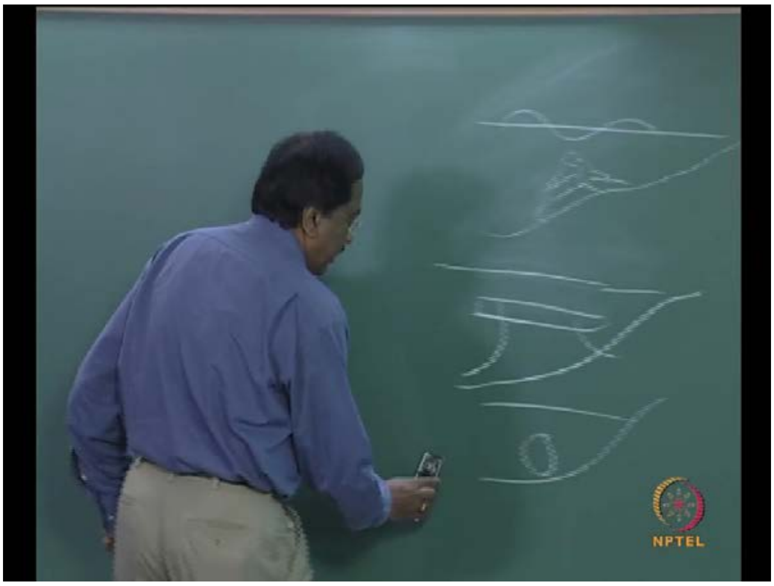

How? For example, you may have some kind of a structure, which is floating. This will also deform the waves, this structure can be at the surface or it can be also at the bottom or it may be even a pipeline. So, these are all artificial kinds of attenuation, which can alter the waves, the shape of the waves. Air resistance encountered by waves or by directly opposing winds. So, you have the wind blowing against the waves then there can be some amount of air resistance. Then by the tendency of the waves to, run over the currents.

So, you can have a situation in the ocean where the waves can be in this direction moving with a following current. So, the current will be here and then the waves are also moving in this direction. That is this is called as the following currents or you can have a current in the opposite direction. So, this is current and these are waves or you can have waves, but the current is in; it may be a following, but it may be at an angle, all these kinds of situations are possible. Each one of the scenario will have it is own effect on the change of the shape of the wave. And this change of the wave shape is called as the deformation. The important wave deformation are Refraction, Diffraction and Reflection.

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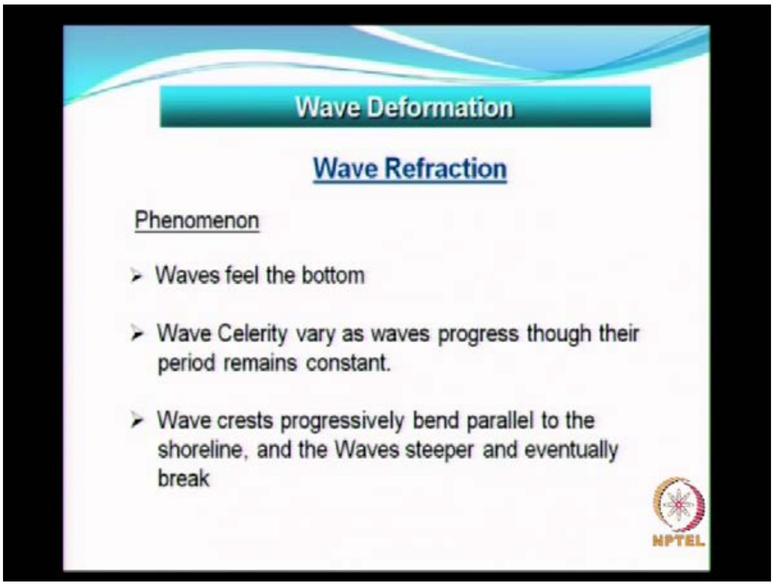

Of course, shoaling is always there. So, we will just see one by one, what are these phenomena and how this can be accounted for in the calculations? But the basically you should know, why you need all these information. Why do you need the, why do you account for the refraction of waves, diffractions of waves? Only then you can represent correctly the behavior of waves in the ocean. So, let us look at wave refraction. Waves feel the bottom that is what I said. Waves sea, feel the sea bed, surface of the sea bed. The speed of the wave varies as waves propagate, through their period remaining, although the period is going to remain constant. Wave crests progressively bend parallel to shore line and the waves steepen and eventually break this is the phenomena which I am trying to explain.

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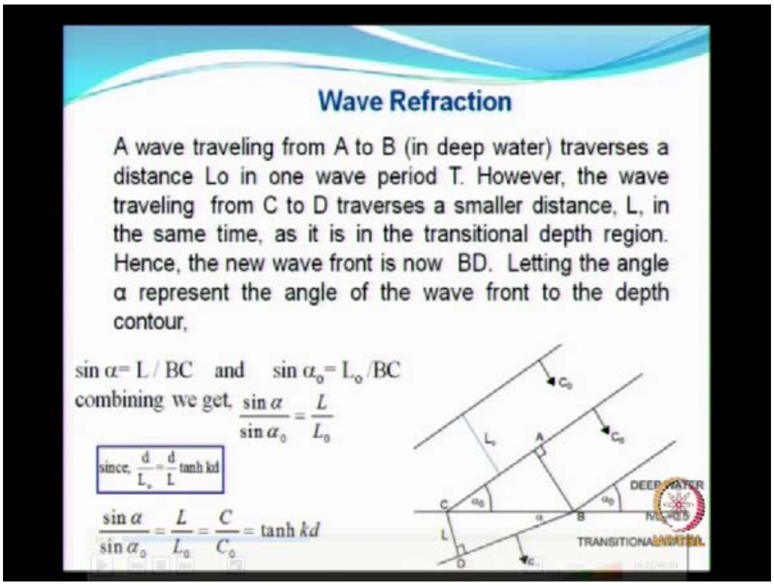

So, try to recollect deep water celerity is L Naught by T which is just 1.56 into T only a function. It is not a function of water depth, which we have already seen. The same thing only wherein in shallow waters, it will be L by T and it will be function of water depth and the T. So, as a wave travels, we now consider a wave crest which is entirely in deep water. And we also consider a wave crest, which is a part of the wave is in deeper waters and part is in transitional waters are intermediate one’s.

When you take two wave crests in deeper waters so, these are the two wave crest, this one and this one, the distance is separated by L naught L suffix naught because it is deep water condition. When this waves is crossing the line which is indicated as deep L naught equal to 0.5, then you see that the wave is going to bend as shown here. This would mean that the wave length is going to decrease, compared to the deep water wave length. So, if this also had been deep water then you would expect that this line would be straight. So, let me say that this is the water depth and then the angle that is made by the wave crest by the water depth contour is alpha naught.

Which becomes alpha with this, when the wave front is in transitional waters. Now, look at this picture this is what conveys the phenomena of wave refraction. Now, sin alpha that is this angle is given by L divided by B C. And alpha naught is again, what is that?

That is this distance which is going to be L naught divided by B C. So, I can equate this and get a expression for the sin of angle of the wave which makes with the shallow water wave contour. And the sin of deep water wave angle equal to the ratio of the wave length in shallow waters to the deep water wave length. Now, we have already seen from the dispersion relationship that d by L naught equal to d by L into tan h k d.

So, because of which, now you can get an expression which relates the angle celerity and which will be equal to tan h k d, tan (( )). I hope this is clear. So, what exactly is happening? This is bending of the wave crest. I will come back to this again. Now, herein in this picture, what is this? This is nothing but the wave direction. You see that this is the wave direction, you extend this has to be perpendicular to the wave front. So, this will be in the wave direction and it is also refer to as wave ray or wave orthogonal. So, different books they use different terminology, but everything pretends to be wave direction. So, now if I want to draw the wave direction at this location so, this will be like this. So, this line like this. So, this will be perpendicular to the wave crest.

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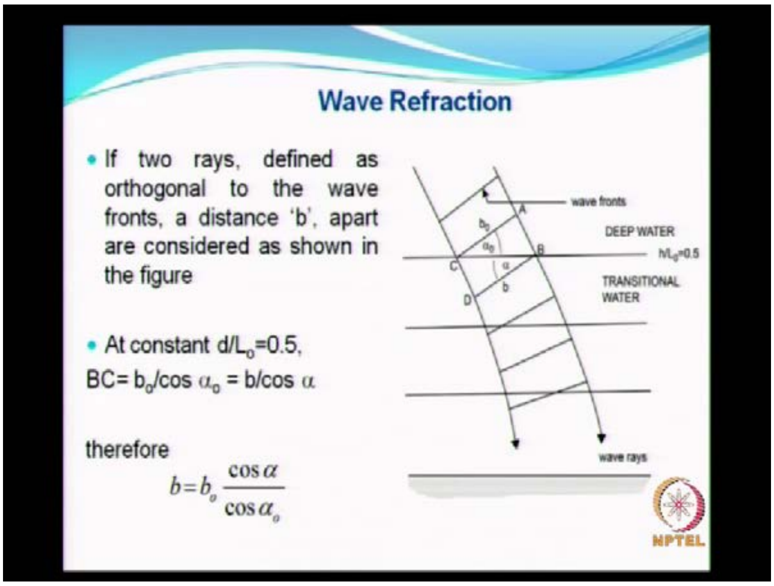

This is what is represented here; I am taking only 1 step I mean I am taking two wave direction, I mean single wave direction, but two different points. So, I am taking a wave crest here and then trying to locate one point here, one point here. And I am trying to traverse, how this waves will go. When I try to do that and that is what I get it get as the wave ray or the direction of the wave. So, I can extend this for a complete reason, running for 100 kilometers. And this distance, what I am trying to say is? We can assume this distance, where the distance between the orthogonals in deep waters. May be if you want you can assume a 2 meters or 3 meters or 50 meters or 100 meters and try to see how it is going to keep changing as the waves are going to bend.

So, here we are trying to see that we are having some water depth contours and this waves are trying to bend. So, in the deep water we are assuming that distance between this equal to b naught. And the same distance in the transitional waters, if you assume it to be small b then I can get a relationship at constant h v L naught, B C equal to in terms of L naught, I mean alpha naught and b naught and in terms of b and Cos alpha. You understand. So, this without suffix 0 potent to transitional waters, the parameters of the wave in transitional waters.

So, earlier we have an expression in terms of, we have the expressions for L wave length. As a function of wave length or celerity as a function of deep water wave characteristic of like the deep water celerity or the and deep water angle. And here we are having a relationship between, the distance between the orthogonals in the deep waters to that of the distance between the orthogonals in the transitional water. Does it convey something? Yes it conveys a lot. So, this is one of the basic phenomena which is extremely important. And let us try to understand this.

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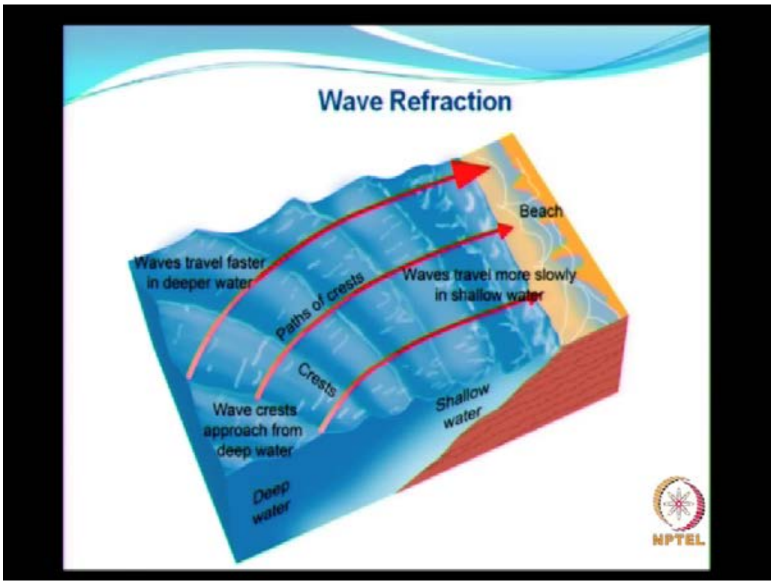

What it defines is. The portion if you take a wave crest, as long as it is in deep waters there is absolutely no problem. But when it is moving into the transitional waters, you take a single wave crest, the portion of the wave crest in deeper water. I am talking about a single wave crest. The portion of the wave crest in deeper water will move faster compare to the portion of the wave portion of the same wave in transitional waters. For the simple reason, the speed of the wave is going to be higher when it is in deeper waters. So, you will see that the bending takes place.

What is it trying to do? When the waves are trying to move, it tries to move faster and try to align parallel to the depth contours. For example, if this is the and then you have the waves moving in deep water. So, look at my hand so when the wave is moving then it will move and then it will try to move like this. So, you look at this portion of the hand. What it is trying to do is? It is trying to align itself parallel to the bottom that contour, these are all the sea bed contours.

Remember that the sea bed contours is more or less parallel to the shore line, when you are talking in terms of, when it is close to the shore. And this is one of the reason when you go and stand near the beach you see that the waves are almost more or less coming parallel to the I mean approaching normal to you. That the wave crest are parallel to the bottom depth contours. So, there are certain locations were the waves may be coming at an angle. But that small angle also even if the angle is very small it does make some amount of difference, in terms of the stability of the shore line.

So, this is what I have covered here and this picture clearly shows you, how the bending of the waves takes place, the path of the wave crests etcetera. The path of the wave crest is perpendicular to your wave crests or wave fronts. So, this kind of a picture, when you have, when you draw it, for a given stretch of coast that gives you how the wave energy is getting distributed. So, you want to plan for some kind of a structure or development of a harbor etcetera. Along the coast you need to know, how the wave is going to behave even if before, you are going to construct something there. For a given deep water wave height, deep water direction, how this transformations takes place?

And in between the; we assume that the energy is being propagated only in the direction of wave propagation and the energy is conserve in between any 2 orthogonals. What does that mean? There is no lateral spread of energy, wave energy. So, this phenomena of propagation of energy only in the direction of wave propagation, being conserved is called as your wave refraction. And now we do not assume that there is no transfer of lateral wave energy. So, this is very important. And then what kind of information, you can get? As I said earlier, if you try to draw such kind of a plot which you are suppose to do, in the planning process of any kind of a project be it a coast engineering project or port project.

And this and also in order to understand the stability of your shore line, you might have to do this for may be 100 kilometers or 50 kilometers or just for 3 kilometers. So, in that case you have to one has to use his own judgment and experience in selecting the distance between the orthogonals which you assume initially that is b naught. If you want to have more accuracy you have to use smaller value for that e naught, is that clear. Once you get that so, you can prepare a refraction diagram. What does a refraction diagram gives you? The refraction diagram gives you the bathymetry of the area; it also gives you the wave rays.

What is this wave ray? For example, this distance conveys us something. Depending on the water depth contours, the orthogonals can converge or can diverge. This depends on the sea bed topography and your wave characters. So, when once you try to get a refraction diagram, you can easily understand what a refraction diagram can convey. For instance, if you draw a a refraction diagram, a simple explanation is here. Whenever you have the convergence of the orthogonals, that means the energy is getting converge. I mean converge the energy is going to get concentrated.

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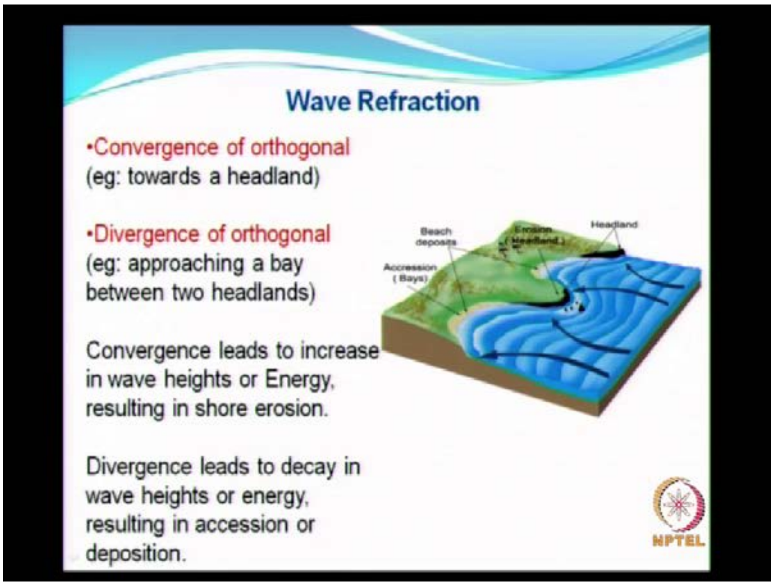

So, within these 2 orthogonals, the energy at the converging point is going to be higher. and when the energy is going to be higher it will automatically lift, the sand material around that location. On the contrary, if the orthogonals are diverging you will see that the energy getting diverge. So, there is a question of deposition taking place. So, here that is what is explained here. These are all the bottom depth contours and assume that this drawing is already available to us. So, this only a illustration to understand the physics. So, you see that you have a bay here. And when you have a bay like formation that is the location, that is the stretch of the coast where you can anticipate the divergence of orthogonals, leading to deposition of material.

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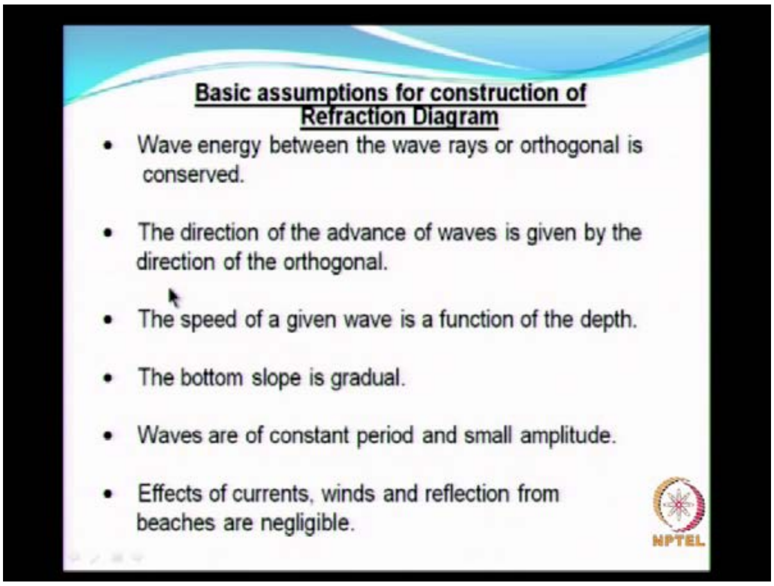

And herein you see that convergence taking place, energy gets concentrated, removal of material takes place. So, such kind of a diagram refraction diagram needs to be constructed before you take up any work. So, earlier this refraction diagram it used to be very difficult to draw. When you did not have this fast computers, we used to have what is called as a template method. But now, it is all forgotten and there are so many kind of user friendly software available in the public domain, to draw a refraction diagram.

So, you should visit some of the sites for the programs available in the public domain and they have some kind of demos. And some of these programs are also user friendly. So, you can try to give your own data and try to see how all these, physics really takes place. So, why you construct the basic, I mean the construct the refraction diagram there are some basic assumptions, which I have already told to some of these things. The first one is already mentioned. The second one is the direction of advance is of the wave is given by the direction of orthogonal that because that is the wave ray.

The speed of a given wave is a function of water depth. We assumed that the bottom depth, contours, the bottom depth, bottom slope is gradual. Why gradual? So, if you have very huge obstruction, then there is other phenomena which is called as diffraction, coming to picture. Waves are of constant by a period and small amplitude. And here in when we are trying to construct a basic refraction diagram, we neglect the effect of currents, winds and reflection from beaches.

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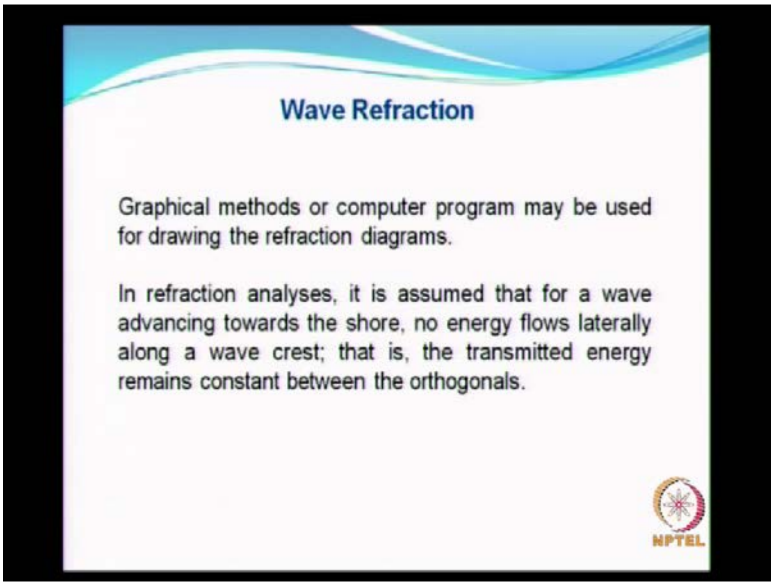

As I said earlier, graphical methods or computer program may be used for drawing the refraction diagram. And all the other points also have been discussed, no energy flows laterally along the wave crest. That is the transmitted energy remains constant between the orthogonals, all these points are extremely important.

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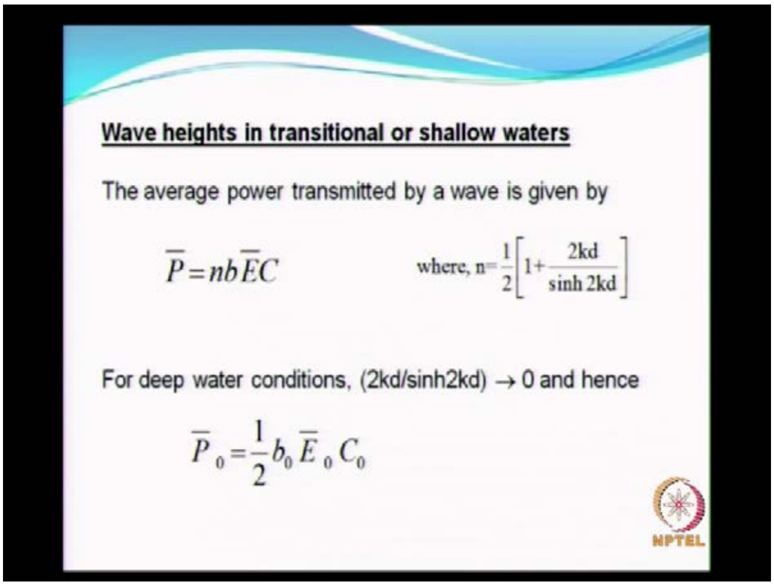

How do we relate? Remember I hope you can recollect the shoaling coefficient. What did we do in the case of shoaling coefficient? We equated the power in the deep waters to the power in the shallow waters. And the assumption that is parallel water depth contours so, you do not have the refraction taking place and only shoaling is occurring. Now, the same thing is being extended this is nothing but, already we have seen under power, n into that is, what is power? Power is energy into group celerity. I am retaining that group celerity here, n into c is still the same, group celerity into energy. But I have introduced b because I am assuming that the power is, I am considering an area in between only 2 orthogonals, in order to obtain an expression.

When I do that the power between any 2 orthogonals in a transition waters, will be n into b into so, only b will come into picture. So, you know about this that in deep waters what happens to 2 sine h k d and because you know n is given by this. And in deep waters the power p naught will become half into b naught into e naught into c naught. Deep water energy, deep water celerity and the distance between the orthogonals in deep waters. Now, we know that the energy according to energy conservation or power conservation, the power in deep water and the power in the shallow water are to be equated. So, when we equate that what happens?

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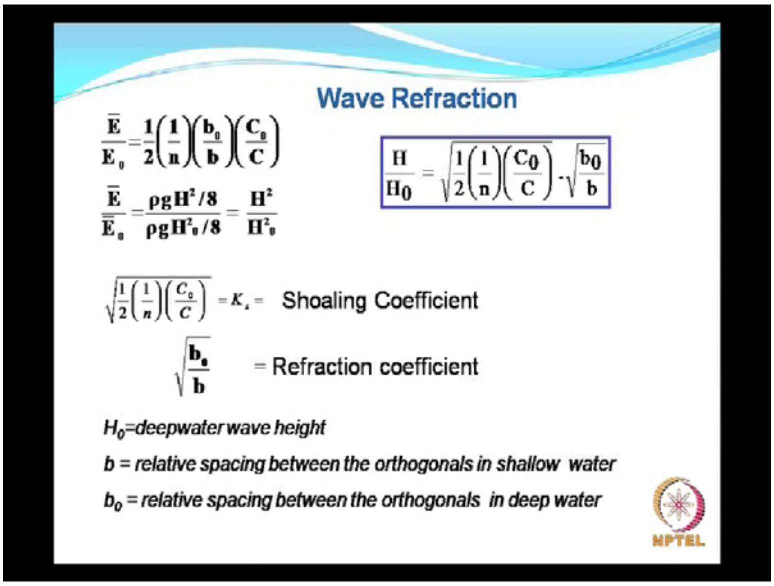

So, this is what happens when we equate, we can get a relationship between the height in the transitional water as you can see here. Wave height in a given water depth 2 wave height in deep water as a function of C naught and C. What is this? This is nothing but the shoaling coefficient. What is a extra coefficient we are having now? We have included that b and b naught that is all we have done. In fact, we have rederived the equation by introducing b and b naught. And now, you have the refraction wave, refraction coefficient as like this. Can refraction coefficient be greater than 1 or less than 1 or equal to 1? What happens if b naught by if the shoaling, if the refraction coefficient is equal to 1.

(( )).

Pardon you will not have refraction, but what nature of a sea bed it would be it should be

Like a (( )).

Like a (( )). So, it would be something like the only the water depth contours will be parallel to each other. What happens if the refraction coefficient is greater than 1?

(( )).

So, what will happen if the refraction coefficient is greater than 1? Look at the refraction coefficient.

(( )).

Refraction coefficient is b naught, if refraction coefficient is greater than 1, b naught is higher than the that is the distance between the orthogonals in deep waters is higher. So, that means the orthogonals are converging and hence the wave height will be higher. So, you should not be surprised whether or you should not be thinking whether the shoaling the refraction coefficient can be greater than 1 or less than 1, it can be anything.

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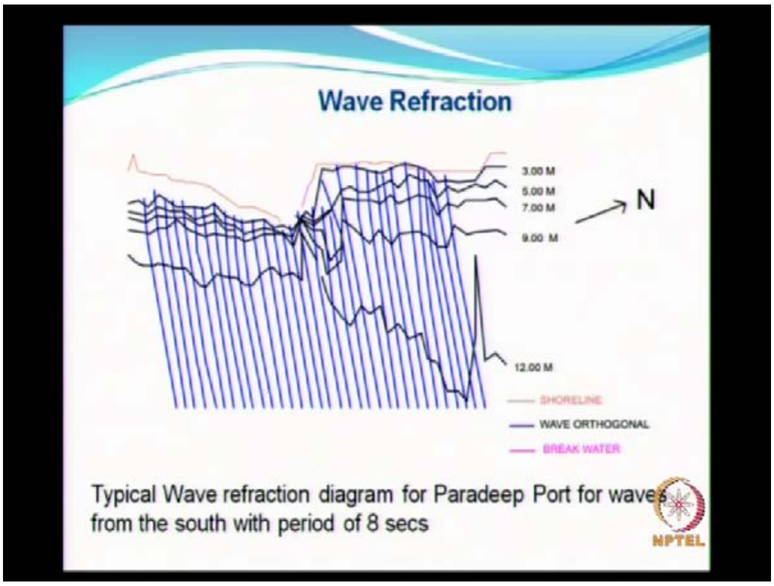

So, this is a typical refraction diagram. And this refraction diagram has been drawn ages back that is as early as early 80s. Wherein these are plotted by using the plotter, wherein see I can show the break waters here this was done for a for the paradip port. And these are all the bathymetry the 12 meters contour is quite haphazard irregular. And for a given wave period, what we do is? How do we construct the refraction diagram? You can construct the refraction diagram for a given month, for a month for a mean wave direction or a particular season. For example, non monsoon season or north east monsoon season or south west monsoon season, you can take an average wave direction and then draw the wave diffraction, wave refraction diagram.

Or you can also take the most frequently occurring wave direction for which you can draw the wave refraction diagram. So, when it is a very important project, you need to study or obtain the wave diffraction details for different wave directions, for the waves approaching from different directions, for that particular coast for the deep water. So, you normally have the deep water wave characteristics, allow the deep water waves are to propagate over a given bathymetry and then you get the details. And from which depending on a there are ways and means to calculate not only with this you can arrive at the zones of if it is converging. So, you can try to find out whether there are zones of the ocean, when it is convergence you have erosion.

So, you may find out the zones of erosion and deposition along the coast. And you can also find out there are some basic calculations that need to be done. Through which you can also calculate, how much of sand is removed, how much of sand is being deposited, is that clear. So, with this, I will today’s lecture, I will, we will close. And then from tomorrow we will, from the next class we will just look into the other types of the wave deformation, starting from wave refraction. And also wave reflection and then the combined effects.