Coastal Engineering
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Module - 2
Sediment Characteristics and Longshore Sediment Transport
Lecture - 4
Radiation Stresses - II

We had a detailed look about the radiation stress in the earlier class. I always use to refer radiation stress as radiation stress. Please look into all the slides. It will all be mentioned as principle radiation stress. I will come back to that again, but before that, we will be having a look at the radiation stress in connection with yet another important topic, which is called as a wave set up which happen in the coastal waters.

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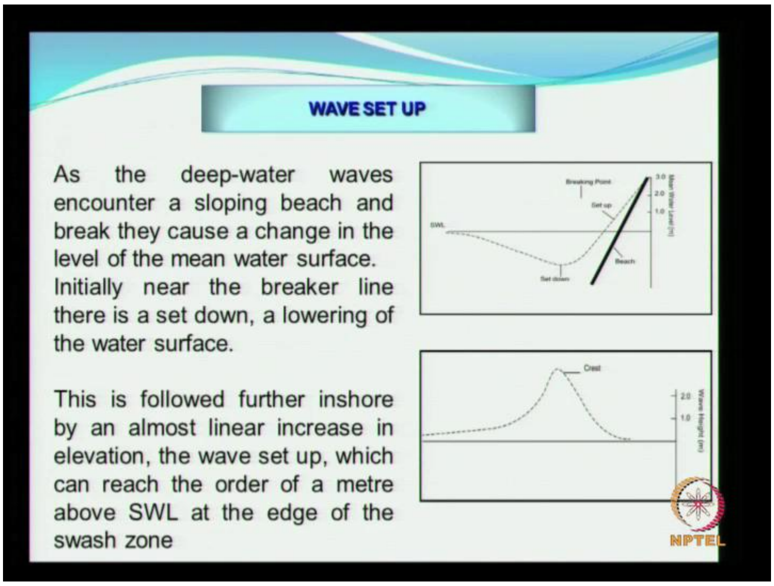

So, you see that there is a beach. Here, this is a beach; and waves are propagating from deep water to the slope. As deep water waves encounter a sloping beach and break, they cause a change in the water level. Initially, near the breaker line, there is a lowering of the mean water line, because of the lowering of the mean water level near the breaker zone. It is something like pumping you know. So, it pumps. So, you see that there is a rise in the water level along the beach. So, this is what is called as wave set up. Run up is different form wave set up.

So, this is wave set up and this is, so you see that it is mainly because of the wave propagating in the direction normal to the shore line. Is that clear? So, lowering the water line somewhere near the breaker line which results in a steep rise in the water level near the beach, on the beach. So, this is called as the wave set up and the wave setups can be often order of about one meter above the steel water at the edge of the coast or edge of the swash zone. Do you know what is mean by swash zone which I have already explained. Is that clear?

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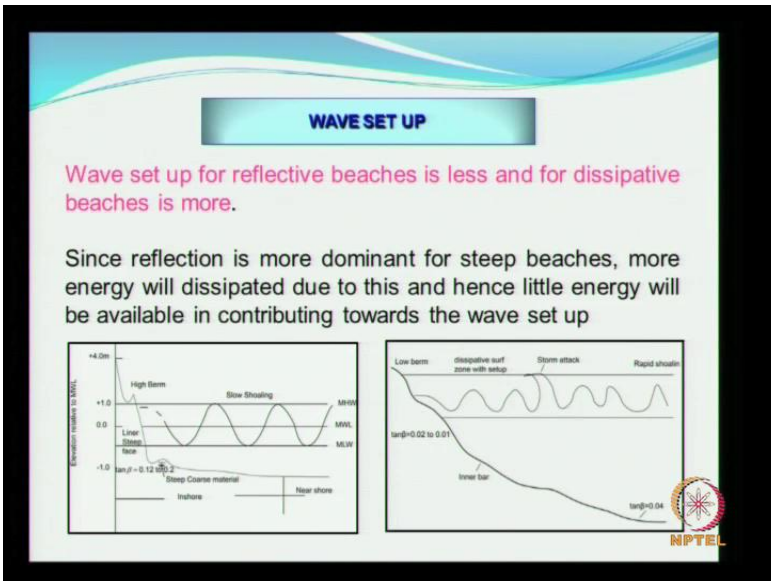

So, let us look into the aspects of the wave set up. Wave set up for reflective beaches is less and for dissipative beaches, it is more. The flatness of the beach plays an important role in the dissipation of the incident wave energy. If you have a flat beach, what will happen is the waves will keep on propagating. This is what happened in the case of a Tsunami. Wherever you have flat beaches, you see the Tsunami moves towards the land. So, Tsunami was in terms of at least one to two kilometers whereas, its locations where you have steep beaches, most of the energy will be reflected back.

So, when most of the energy is reflected back, so you have lesser energy available for creating the set up. So, naturally for a steep beach, the set up is expected to be less, just contrary to the flat beach. Is that clear? So, that is what is explained with the help of this figure.

Now, we will move on to the principle radiation stresses. In order to understand the phenomena of wave set up, we will enter into the aspect of principle radiation stresses and the principle radiation stresses which we had, we have already calculated the principle radiation stresses. What exactly is principle radiation stresses? Principle radiation stress which we have seen so far is nothing, but the radiation stresses in case the waves are approaching normal to the shore line.

What we had considered earlier, the derivation of the radiation stresses are nothing, but refer to as principle radiation stresses, but we simply call it as radiation stresses when we consider normal to the angle that is the waves normal to the angle. Is that clear?

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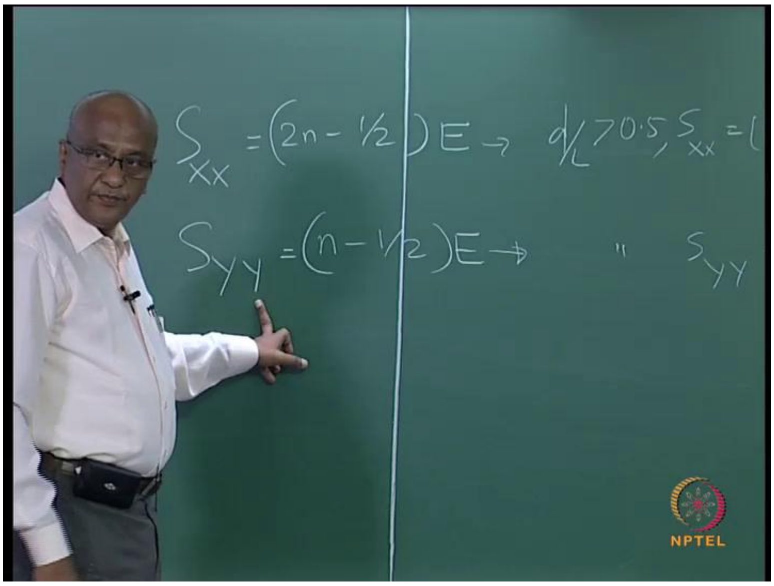

So, when we derived S XX capital X capital Y, which was equal to a function of energy and this radiation stress in the X direction is reduced to half of the wave energy in the case of deep waters, and it is 3 by 2 into energy in the case of shallow waters. Now, S YY in the other direction, this will be n minus half into energy whereas, this is going to be 0 for shallow water conditions.

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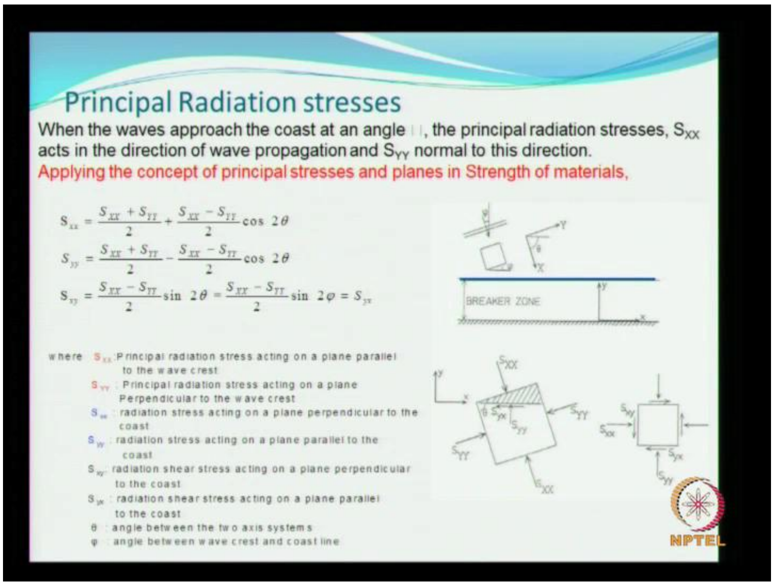

So, this S XX and Y are indicated in this picture. Do you see how we defined the axis? So, now what we have seen so far is within this region that is within the breaker zone or very close to the coast, all these expressions are valid for the normal angle of incidence.

Now, what happens when there is waves approach? The coast at an angle psi is indicated here. The principle’s radiation stresses S XX acts in the direction of the waves here in this area in the direction of waves is nothing, but normal to the shore line. Is that clear, but outside the breaker zone, you have an angle attack. So, the S XX will be in the direction of wave propagation and SYY will be in the transverse direction in this direction. Is that clear? So, this S XY is not parallel to the coast as in the case of this location in this area. This S XX, S YY is going to be parallel to this shore line in this stretch whereas, in this stretch, it is not going to be parallel to shore line. Is that clear?

So, now we are dealing with the two coordinate systems. Now, the coordinate system small x and small y, that is the suffix corresponding to the radiation stress S of small x, small y, small x. Then, s small y small, wherever you have small x and small y in this subscript, these are referred to as radiation stress and wherever you have s, but suffix capital X or capital Y, then these are referred to as, these corresponded to the principle radiation stress. Please have this clear in your mind. You should know that the oblique wave angle attack only generates your currents that are responsible for the sediment transport.

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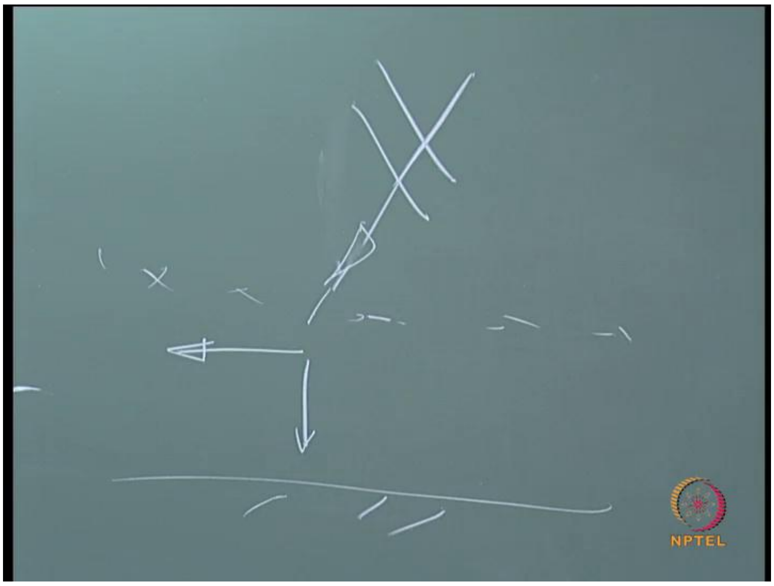

Only when you have a wave approaching, the direction approaching, only when you have a wave approaching the coast at an angle, this will be breaking at certain water depth which is the breaker line. Then, when angle is there, you have a component in the direction and you have a component in the y direction. If this is normal to the coast, then what will happen if it is normal to the coast? What will happen? This component will be 0.

Now, what is wave set up? Wave set up is caused because of the direction of wave propagation normal to the shore. So, only when there is the propagation of waves normal to the shore that only is going to create your wave set up. Is that clear?

Now, there are two aspects. One is the long shore current velocity, and another is long shore. I mean another is the wave set up. All things are caused by the radiation stresses only. So, again I am going back. There are two axis's which we are dealing now. One is this axis small x and small y and whereas, here, we have an axis capital Y and capital X. Do not get confused. So, I am sure you would have studied the strength of materials under which you consider the concept of principle stress and planes applying that we can extract all these things, that is the radiation stress in this direction, in this direction as well as in this direction as well as in that angle.

So, all these three kinds of stresses are defined here, where S X is a principle radiation stress acting on a plane parallel to the wave crest parallel to the wave crest. Is that clear? Parallel to the wave crest. Is that parallel to the wave crest?

Now, SYY is the principle radiation stress on a plane perpendicular to the wave crest. Similarly, the radiation stress very close to the coast and here acting plane, that is S YY is the radiation stress acting on a plane parallel to the coast. So, what we have is you have the principle radiation stress acting somewhere here and the radiation stress very close in the breaker zone. Is that clear?

Now, if you take an element here, if you an element here, this element, what will happen is you will have S capital XX and this will be countered by capital S X. That is clear and similarly, you have S capital Y and capital X capital S YY. Now, since there is what we call is the stresses which are responsible for the wave set up, the stress which are acting normal to the coast.

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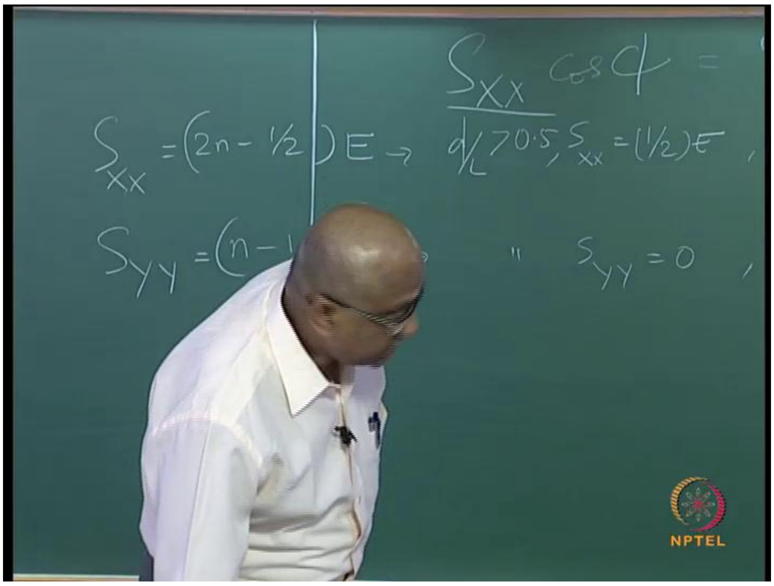

So, in this case, the stress which is acting normal to the coast is SX. Now, that SX is acting at an angle psi. What is that which is normal to the coast? Normal to the coast will be SX into cos of psi. Am I right? You are resolving, when you resolve that will be countered by, what that will be countered by? S small y y because in this, within this coordinate SY is normal to the coast. Is that clear? Which we have already derived as here, we have already derived.

So, now so that is so, but this one which is normal to along the shore will get cancelled because it is not going to create any, it is not going to be responsible for creating the wave set up. So, along the shore that component we neglect because it is not going to have any effect. So, when you have this, only this will be compensated by the small xx, small yy.

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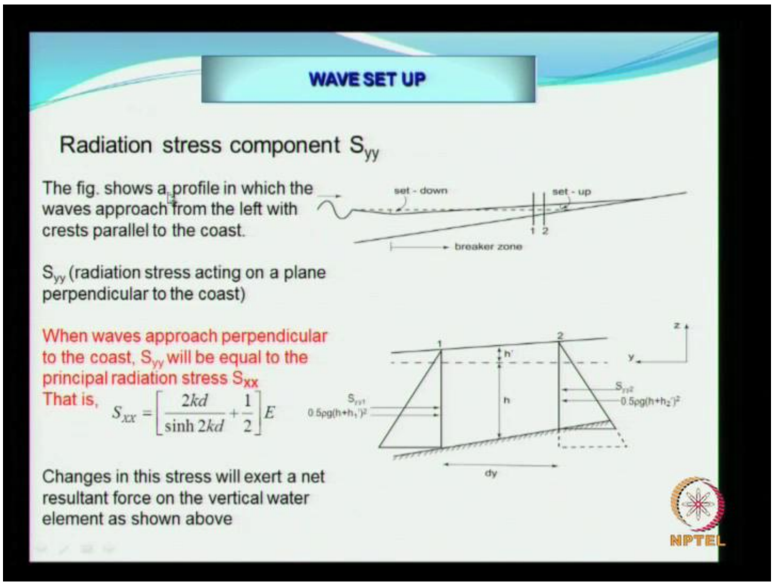

Now, since that is what I am trying to say here. So, radiation stress acting on a plane perpendicular to the coast, that is y y when suppose if you consider the propagation of the waves over a beach. Now, there is a certain degree of set down as I have explained earlier somewhere close to the breaker zone which is going to result in some kind of up. I mean set up near the, on the beach. This is what I explained.

Now, S YY is the radiation stress acting on a plane perpendicular to the force as explained earlier. Is that clear? Now, when the waves approach perpendicular the coast, then SYY will be equal to the principle radiation stress. Principle radiation stress is what we have already obtained earlier. So, a principle radiation stress will be this, the general expression which we have seen in the last class. Yes or no?

So, now you take any two cross sections; one cross section here, another cross section here. Look at the various components acting on this water column or water medium. So, on this plane, you will have S YY enacting in the plane number one and also, this component due to the hydrostatic pressure. The hydrostatic head will be the main water level plus the rise in the water level which is h dash. So, similarly, let me have here. So, this will be h plus h 1 dash whereas, here it will be h h plus h 2 dash. So, there are two planes. Similarly, there will be a stress which will be acting in the other direction. So, you have difference in the stresses on both the sides, both the planes and that is going to be countered by the pressure gradient. The pressure gradient is given by this, the hydro static gradient. So, changes in this stress will exert a net resultant force on the vertical element as shown above.

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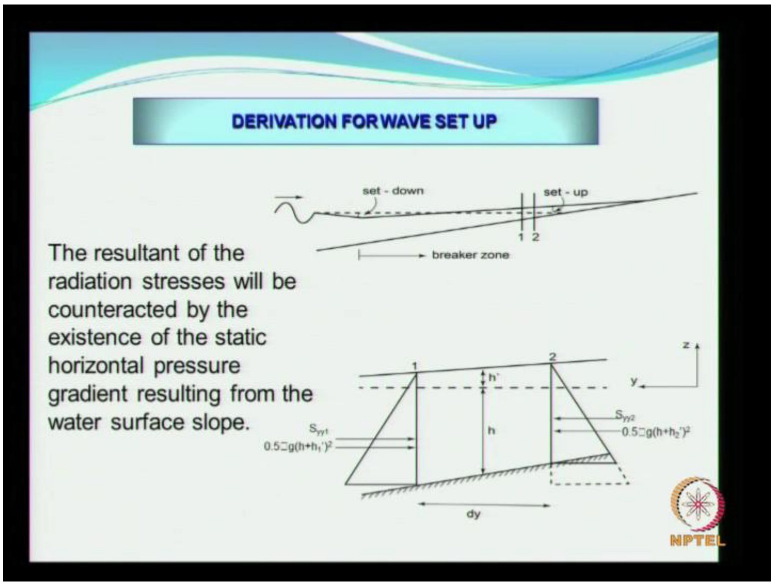

Now, the resultant radiation stresses will be countered by the existence of the hydrostatic pressure gradient resulting from the water surface. So, these two will be, this is the resultant. There will be a resultant from these two radiation stresses and this is going to be countered by the horizontal pressure gradient because of the difference in the water level. You understood? So, this is the basic phenomena which have been considered and the equilibrium between the radiation changes radiation stress.

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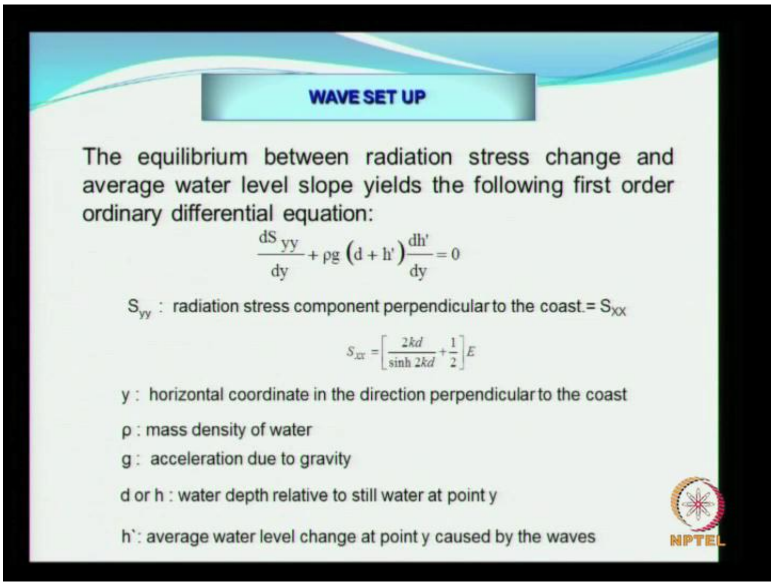

The average water level slope that would yield an expression or an equation that is just a ordinary differential equation as shown here, which is the stress which is normal to the coast. Normal to the coast is S YY. Am I right, but that we have already proved that S YY is going to be equal to S XX. So, now this will be S XX. So, you can substitute in this and then, all other variables are defined. Here, rho is mass density, d r h are the water depth relative to the still water line at any point y, then h h dash is the average water level change at any point y.

So, when you integrate by integrating this equation and also, using the initial boundary condition that the wave setup in deep waters is going to be 0, so the phenomena of wave setup is going to take place only in the coast, along the coast in the deep waters. Since, the wave setup is 0, I use that condition h dash equal to 0, the resultant of which when you use this equation substitute.

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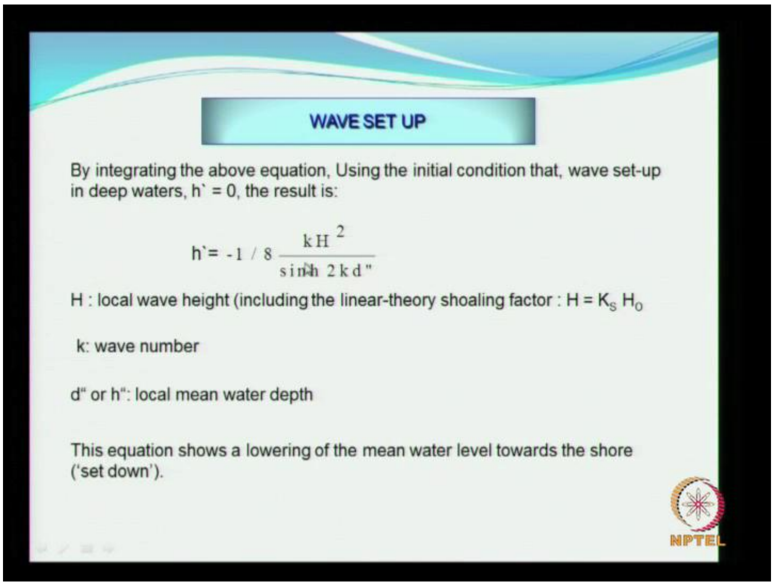

All these things solve the equation for h dash. H dash will result in terms of wave height. That is the local wave height including the linear theory, that is shoaling coefficient in terms of deep water wave height which we already seen, wave number and then, h d dash, d double dash or h double dash are the local mean water depth. So, you have two depths. So, you take the average water depth in order to arrive at the wave setup. This equation shows a lowering of mean water towards the shore and that is going to be set down. Since, we have this sin h 2 k d, you know the hyperbolic limitations hyperbolic function limitation depending on its argument.

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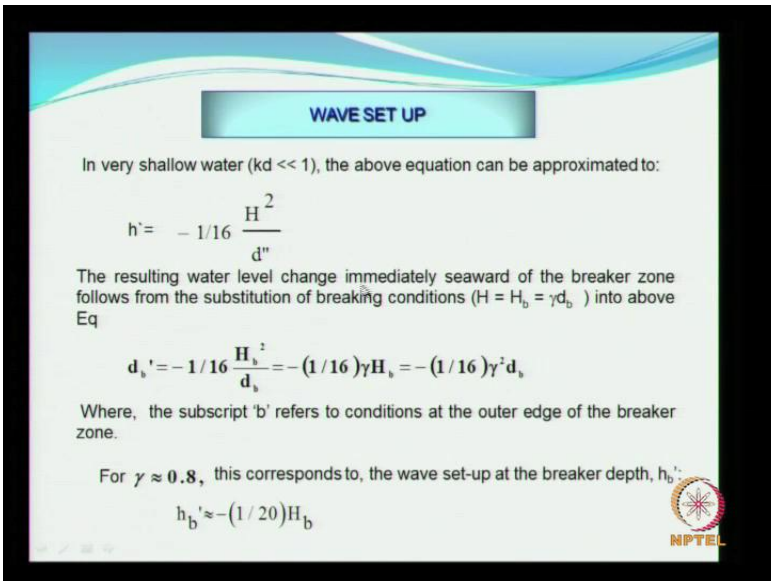

So, when you do that in very shallow water, when k d d k d is very less than, much less than 1, then this can be easily proved to be h dash equal to so much. The resulting water level changes immediately seaward to the breaker zone. Immediately after the breaker zone or at the breaker zone, you can replace h by h b that is the breaker wave height and d d by d b. You understood?

So, the final expression d dash will be as shown here, where suffix subscript b refers to the conditions at the slightly out of the edge of the breaker zone. So, if you use gamma is 0.78 to 0.8 that is breaker index, in case you use it as a 0.8, this will correspond to approximately the breaker wave setup at the breaker depth. Approximately so much I mean in terms of h b. So, you have a breaker index either. You see this can easily be solved.

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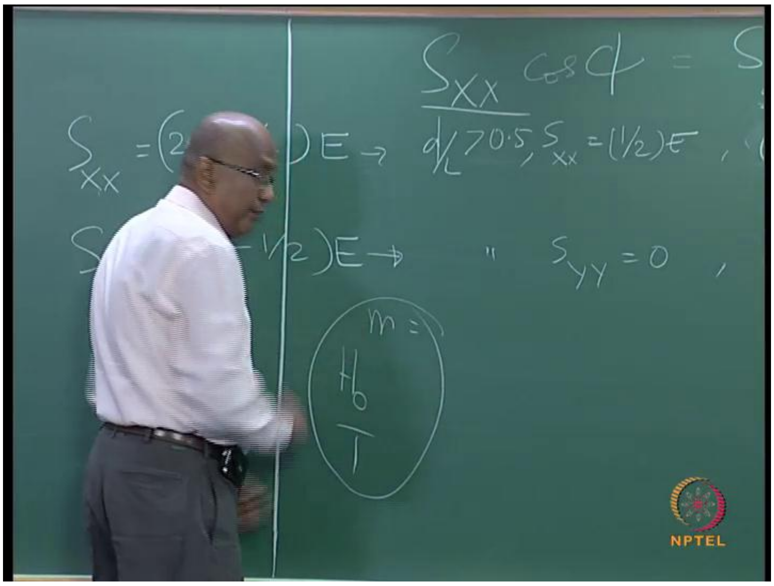

For example, if you have a slope, b slope, wave height is deep water, wave height is given, wave period is given, so you use the breaker formula to calculate the breaker depth or the breaking wave height and then, go into this equation to arrive at your wave setup what is the lightly wave set up. Is that clear?

So, are there any questions? So, what I suggest is you again go through the notes carefully and in order not to get too much of confusion, particularly the difference between the principle radiation stresses and the radiation stresses, there are two axis, coordinate axis which you are dealing with. So, make sure that you do not get confused yourself. So, you have a thorough reading of the material and then, make yourself clear. Now, you have the breaker formulas, right. Now, all of you have the breaker formulas.

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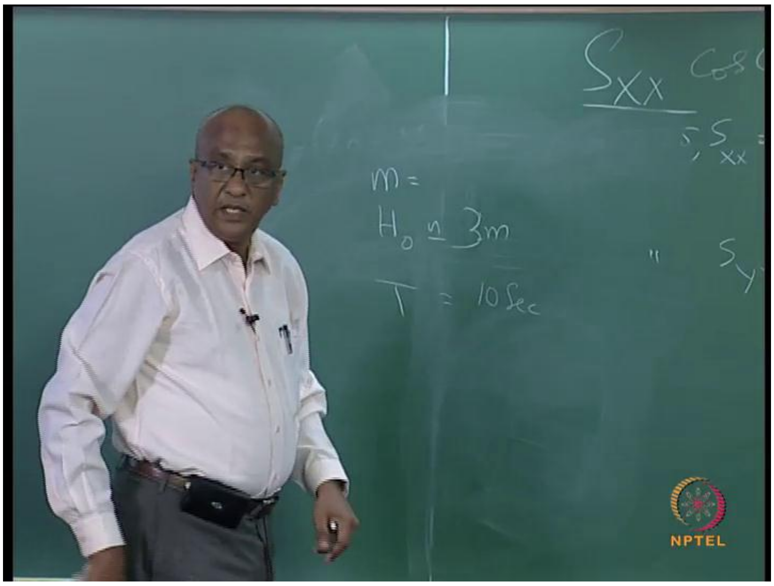

So, I want you to assume a beach slope wave height, say deep water wave height, say 2 meters or you can take it as 3 meters. What other parameter you need to calculate your setup, wave setup? Look at the formulas, look at the general formula, generalized formula. Is this ok?

So, anything else you need? Wave period unit, right. Take it as 10 seconds from which you can calculate all these things and try to get your local wave height and may be the water depth, local mean water depth and try to calculate your wave set up later, not now. Ok? So, may be in terms of breaker depth, you can calculate your breaker depth and then, try to arrive at your h b, the wave set up at the breaker depth you can easily obtain. Can you not obtain this wave set up at the breaker depth? So, calculate your h b. That is the easiest way of doing, solving the problem. Although, you can calculate your wave set up. You understood? Try to recollect what we have studied under wave deformation.

With this, we are done with the radiation stresses and the topic related to radiation stress that is the wave set up. So, the radiation stresses are the main driving forces for the near shore field. Is that clear? Easy in order to keep your stable coast as stable as possible. The calculation or the evaluation or the estimation of your longshore sediment transport is very important.

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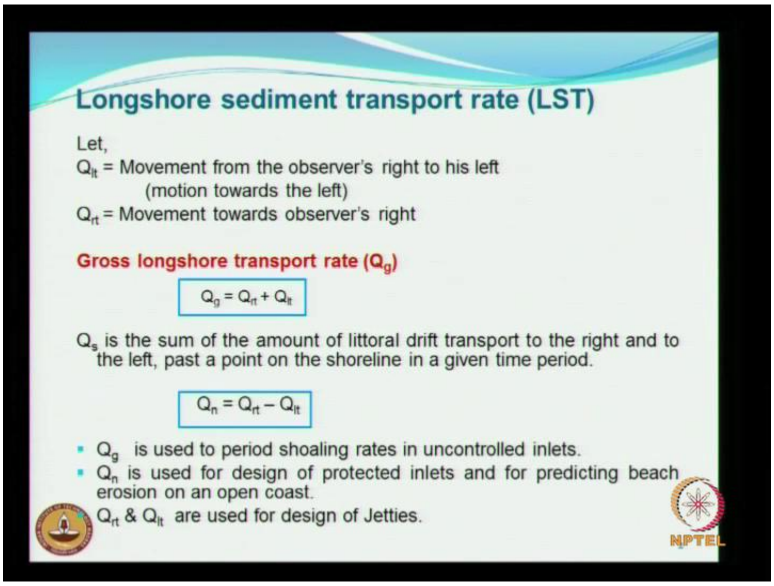

So now, we will try to in this lecture, I will try to cover the aspect of longshore sediment transport.

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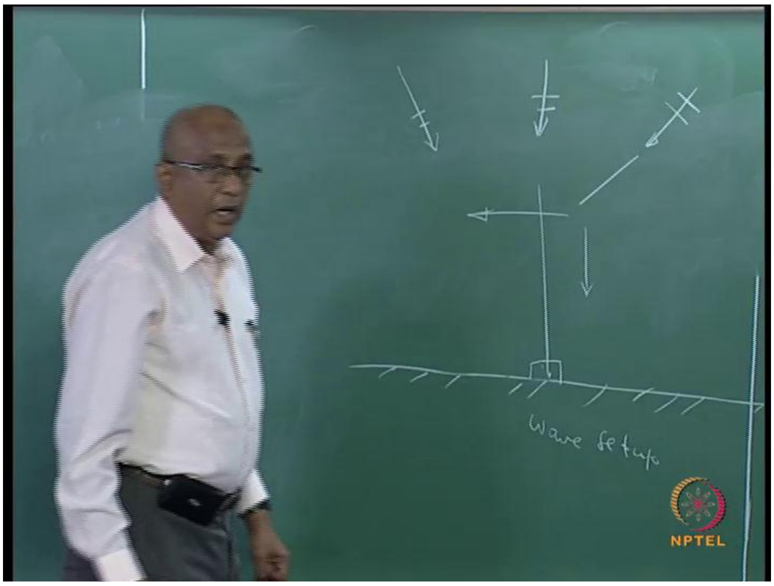

So, when this is the beach, you know that the waves can come from any direction. As of now, you have just completed understanding the radiation stresses. So, the radiation stresses which are progressing towards the coast are responsible for the wave set up and this is mainly because of the normal angle of incidence, and when there is a movement of waves in other directions, for example, oblique wave attack as shown here. So, this will generate a current in this direction and there will be a current in this direction. This is the normal to the shore.

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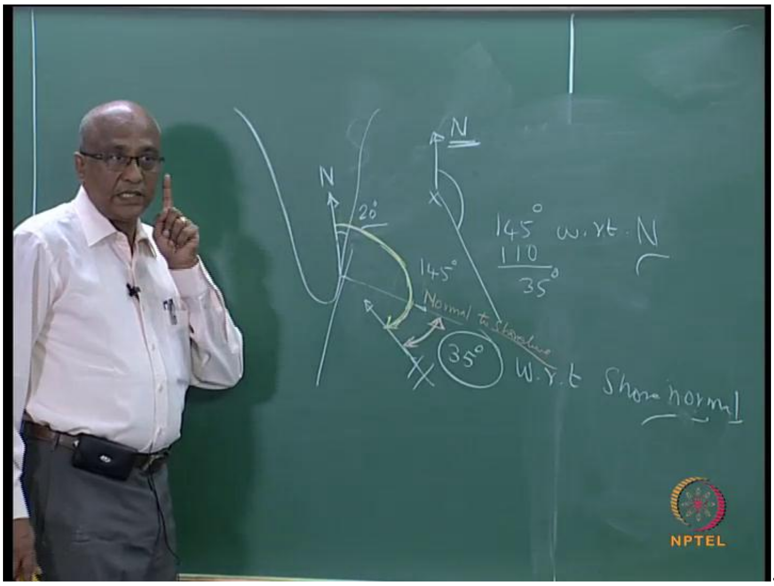

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All wave directions are referred to the geographic north when you refer or when you want to have the wave direction somewhere in deep oceans or even along the coast, it will always be referred to as geographic north, but when you come to the coast, for example, you need to convert this angle. For example, 145 degrees with respect to north and when we are taking about this coast, may be this coast is inclined from by an angle of about say 20 degrees. So, how do you get this? You have to work with angles normal to the coast. Normal to the coast is this.

So, what is a wave angle with respect to the north, with respect to the shore line? So, this is your wave direction. In this case, this is 140 degree, 45 degrees as given. So, you have to subtract how much? 90 minus 90 plus 90 plus 20, hundred and 10, 90 plus 100 and 10. So, what is this 35 degree with respect to shore normal? Is that clear?

This is a very important aspect which you should always remember. What very frequently happens? This will be your wave angle, this is your normal to shore. Then, I have seen many people making major mistakes in assigning the angle or fixing the angle and this is the very serious mistake. Whenever we ask what the angle is and they give 145 degrees. Then, when we ask with respect to what they fumble and this may happen even in your case when you are facing any of the interviews or may be viabilities, etcetera. So, better be clear. So, the orientation of the coast is extremely important when you are estimating the sediment transport rates. Shall I rub this?

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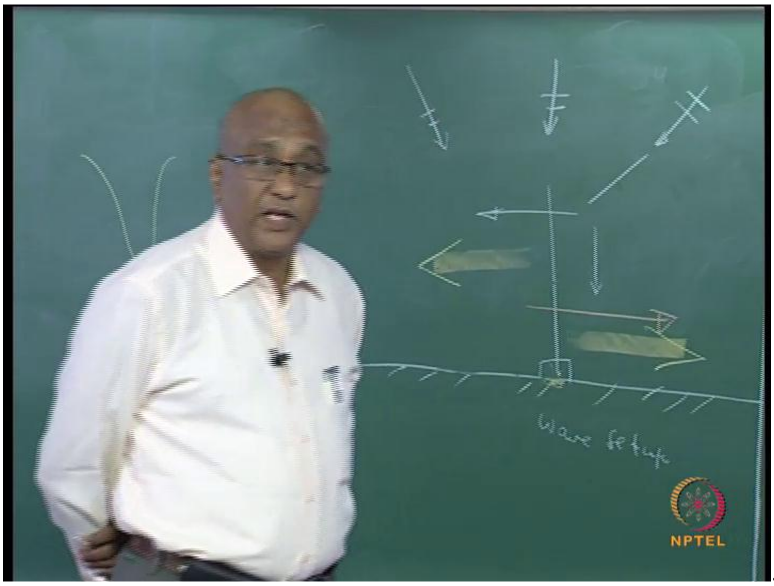

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So, now you see that you can have movement of sand in this direction and when there is an angle, the wave direction in this side, from this side, then you see that the current will be directed in this direction so as the long shore sediment transport. So, you will have the transport in this direction as well as in this direction. So, this direction varies from coast to coast and many of the coasts are seasonal. I mean the monsoons are seasonal; for example, our own country, you have the north east monsoon and the south west monsoon which I have already told you. When we looked at some of the case studies, we have already seen how this moves. I mean in which direction the sand moves.

So, if a person is standing along a coast and looking in to the sea, whatever is moving from a right. When it is moving in this direction, so I am looking in to the ocean and now movement from a right to left; so in this direction, let me call it as q l t and when it moves in this direction, let me call it as q r t. There is a quantity of sand moving in both the directions. If these two are added together irrespective to the direction, then we call it as the gross sediment transport. So, we say so much of the gross sediment transport.

What is the gross sediment transport? So, it does not consider the direction, it considers only the magnitude, but what is this? What is the necessity of q g? Q g is when you have an inlet moving into the ocean.

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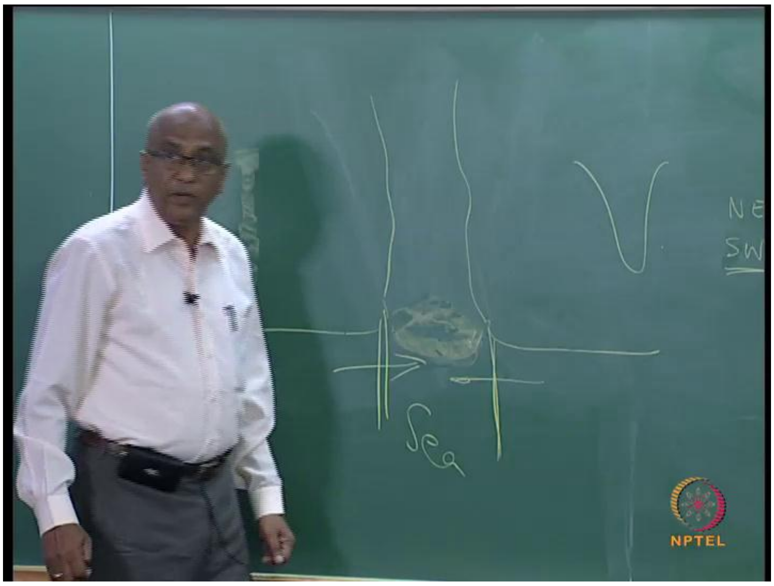

How do you assess the quantity of sediment, whether the sand moves in this direction or in this direction? It is bound to settle here. So, if you want to have some kind of training walls, for example, you want to do only the maintenance dredging. So, when you want to do only maintenance dredging, what is the quantity of sand likely to come across for dredging? You need to ignore the directions, whether it is moving in this direction or in this direction. It is bound to set layer, but not all that which is going to move is going to settle there. No, that is where your fall velocity, the grain size, all those things come into picture, that is you have two types of sand sediment load. One is the suspended and then, one is the dead load, I mean the bed load. Do you understand?

If this area is concentrated by only suspended load, then there is a possibility that most of a load is going to go away. So, in that case, what will happen to the inlet? It will be more or less, it will not be having much of a problem concerning these sand bar formation because in such a case, it will be only the minor amount of the bed load. If tall it is there, which is likely to get settled in form of a ripples or so, but if the entire stretch both suspended as well as bed load is phenomenal or if the bed load is quite high, then it is bound to deposit here and that is going to increase your quantity of dredging, the quantity of the material that has to be dredged near in order to maintain the channel.

So, that is why you see that certain locations, the most experience huge deposition and sometimes, it becomes very difficult to maintain a mouth and then, they go in for draining walls. When they have a draining wall, the quantity change; quantity of sand to be deposited to be dredged, definitely it will change. Suddenly it will change, it will definitely change.

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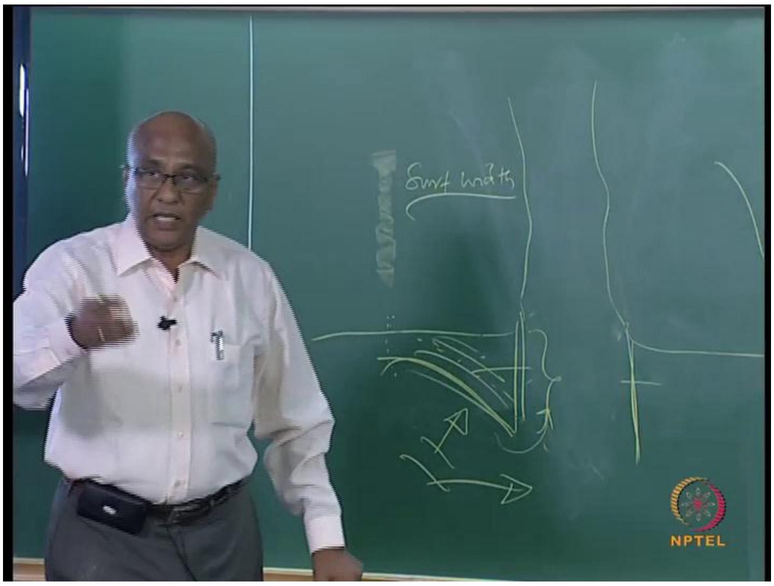

Minimize what are the lightly chances. Suppose, if there is a movement of sand in this direction that is why we call it the net transport. If the net transport is phenomenal in this direction, what will happen is most of the sand will be trapped and then, you will have the advancement of the shore line.

Suppose, in this the amount of sand is so high in which case, suppose in case the length of the training wall is also less, what will happen? It will start by passing. So, again we will come to square one. So, this distribution will definitely be more than the surf width. As we have seen the radiation stresses start at the breaker zone, the sediment movement starts at the breaker zone and the sediments are dominant in the, sediment movement is dominant in the surf zone. So, naturally when you want to draw stop all these things, your training wall has to be extended beyond the surf zone. You understood?

So, when you want to plan for training walls in order to maintain the mouth of a tidal inlet, then you need to know the net sediment transport, but if you do not want to have this, but if you want to keep drenching under maintenance dredging, then you need to have the gross. Is that clear?

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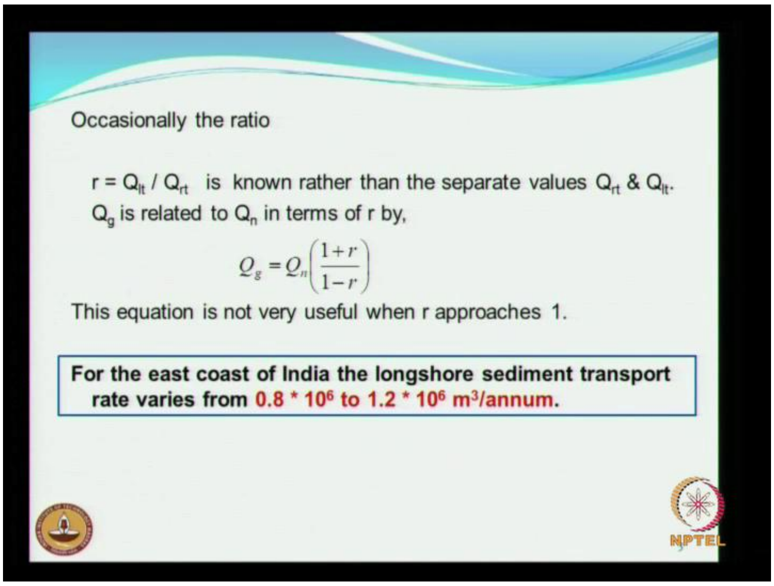

So, this is what has been discussed, explained here. Occasionally, the ratio that is q l t divided by q r t is known rather than separate values of q r t and q l t, but as far as our coast is concerned, normally we do not use this ratio. We normally use the net transport and sometimes, we also use the gross sediment transport, but since there is no problem because every month you can calculate your sediment transport based on the wave characteristics. It is quiet straight forward. There are very simple expressions which you can calculate your sediment transport every month. Depending on the direction of wave, your direction of sediment transport is going to automatically change month wise.

So, add all the monthly transport, you are going to get the gross sediment transport and include the direction. You are going to get the net sediment transport; quite straight forward. Then, q g is related to q n as shown here in this expression. This also is not that much used by us, although there are some information available in the literature, this literature whatever.

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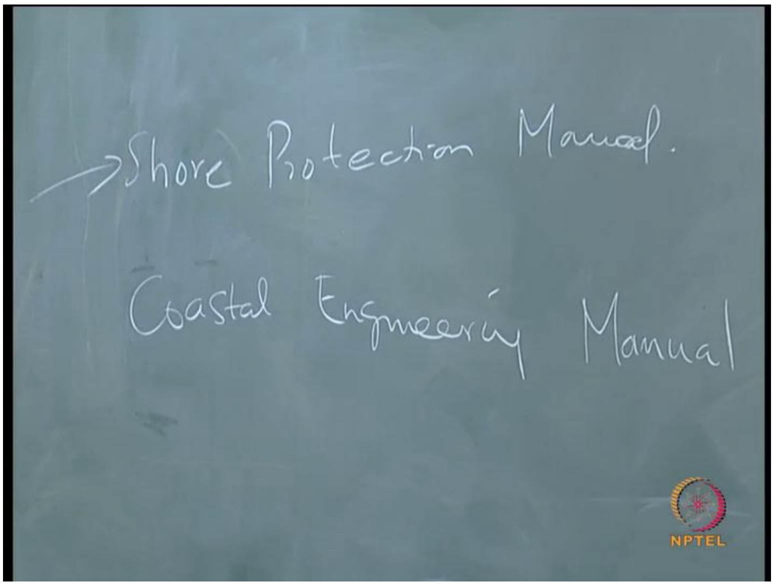

I am going to discuss is mostly from (()) as shore protection manual, now which is referred to us coastal engineering manual. For the benefit of the students, you can very easily download this and this. These two manuals are very useful. It does not take much time to download. Also, earlier we found it very difficult to get these copies. Now, it is quiet easily available. So, I strongly suggest, I very strongly suggest that you download these two manuals and keep it and have it as reference for the lectures which you are undergoing. I mean, this one is not enough. I am just trying to give you just overview. It is a quiet a vast subject.

So, for the east coast of India, the long shore sediment transport varies from about 0.8 to 1.2 million meter cube per year and that is directed towards north. This is the net sediment transport which I am discussing about and this is along the east coast. Along the west coast, there are locations where there is not much of long shore sediment transport at all. There are locations where it is around 0.5 into 0.5 may be 0.1 to 0.5 millimeter cube per year or even less and certain locations, it is almost like nil transport. There is not much of it gets adjusted, although there are some direction variations in the direction, it gets adjusted, nullified. Do you understand?

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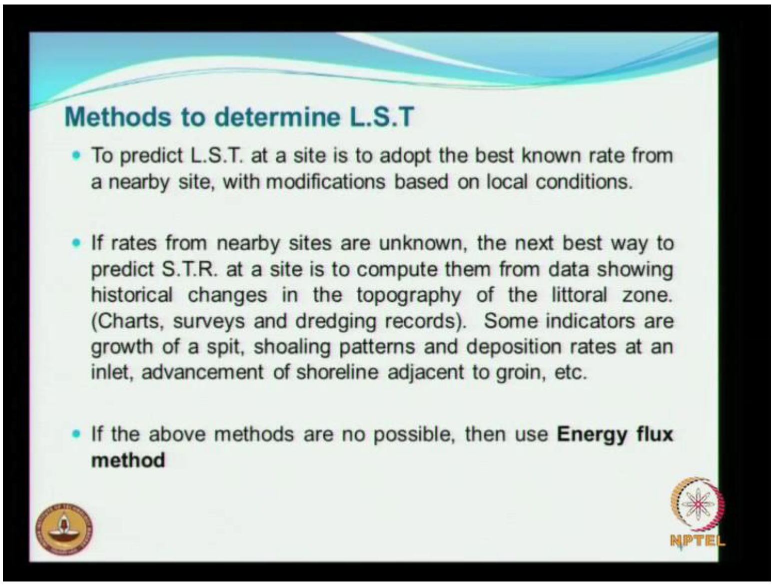

To predict the long shore sediment transport at a site is to best way is to adopt their known rate from a nearby site with the modification based on the local conditions.

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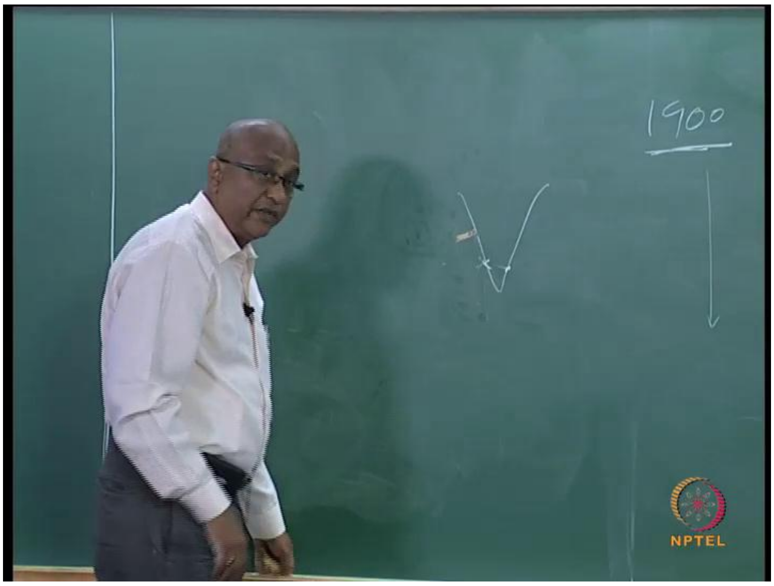

See for that matter if you are say, for example, you are asked to find out the sediment transport around this location. Look for some information like may be published literatures or the information available by the local ports or some local authorities and try to get some information in terms of wave climate or sediment transport itself. May be there are some organizations, they would have measured and that serves as a basic information which can help you to assess the sediment transport rate, if rates from the nearby sites are not known.

The next best way is to predict sediment transport rate at a site is to compute from the data from historical changes. For example, the Chennai port which I was telling, there are historical changes or the shore line. I mean all the shore line has changed from I guess early 90s or even early much earlier and all the way till today. So, there are some shore line changes. So, now that you have the satellite imageries, it has become much more handy all over. Anywhere you can just get the satellite imageries. Try to establish the ground truth and then, superpose all these pictures and then, that will give you the shore line changes. This is this is a very important work which is being done for our country by different agencies.

This is one important area which we need, a lot of work needs to be done here, but just because satellite imageries are available, just simply do not superpose and come out with some conclusions. Make sure that the basics are being referred to whether the basics enough information are reflected in your satellite imageries and when they superposes, try to see if you can give justifications and you can easily understand the basic physics behind the sediment transport and also the sediment transport. This kind of satellite imageries also can help what all I mean manmade barriers which have created, which has intercepted the moment of the free passage of the sediments and created some kind of erosion on one side and deposition on other side; so based on that also you can get.

For example, there is small grain here, somewhere along the coast and when you see the satellite imagery; you can also get information on the satellite. There is a possibility to find out how much of sand has deposited or how much of beach has advance. So, from that there is a possibility for you to assess the sediment transport rate. If some of these things are not available, then we do have some kind of close form solution to estimate the sediment transport based on what is called as the energy fluctuation. There are other methods which I may not be covering under this subject, but there are some other methods and I will try to cover the energy flux method in the next class.