Coastal Engineering
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Module - 3
Coastal Erosion Protection Measures
Lecture - 1
Coastal Erosion Protection Measures – I

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So, we have seen the kind of erosion; these are all just typical pictures you see, cutting-off of the roads, buildings, hotels, valuable properties being dislodged by the waves that create or cause your coastal erosion.

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This is a very short movie or a video clip, which shows the erosion in progress. So, during particularly during a storm and you can see by yourself, what is going on there.

(Audio not clear)

So, we know the devastating effect. So, many times what happens, this erosion can be some kind of short term, only for some time, and it can be either gradual or all of a sudden, understand. So, but one thing you should remember is whenever you plan to have a structure in the coastal area you have to look for this kind of effects on the adjoining shoreline. When you put a structure what happens on the adjoining shoreline.

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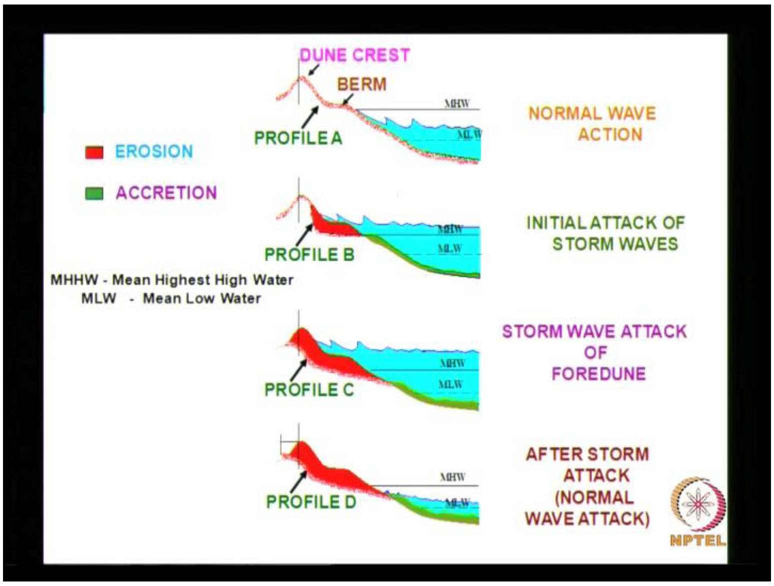

So, now we see the problem. In order to go in for the coastal protection, etcetera, we, first we will try to understand how this erosion takes place, coastal erosion, how it takes place? So, under this I will try to explain this phenomenon with the help of this slide, particularly when there is a storm that attacks a coast.

You know, that the tidal variation, you know about the tidal variation. So, initially you have the mean low water, then you have the mean sea level somewhere here, above which you have the mean high water line. Under the mean sea level, that is, in between the MLW and MHW, you see, the waves will be propagating and breaking and it will be breaking at a location when the wave height is approximately 0.78 times water depth, all of us know, so that 0.78 times water depth may be occurring somewhere here. So, once the wave is breaking here, then you have just the up rush.

The same thing, when there is a high water, when there is a mean high water it will be breaking somewhere here and then after that you have the run up. So, what will happen is, there will be some amount of sand, which will be removed, transported and then it will be brought back.

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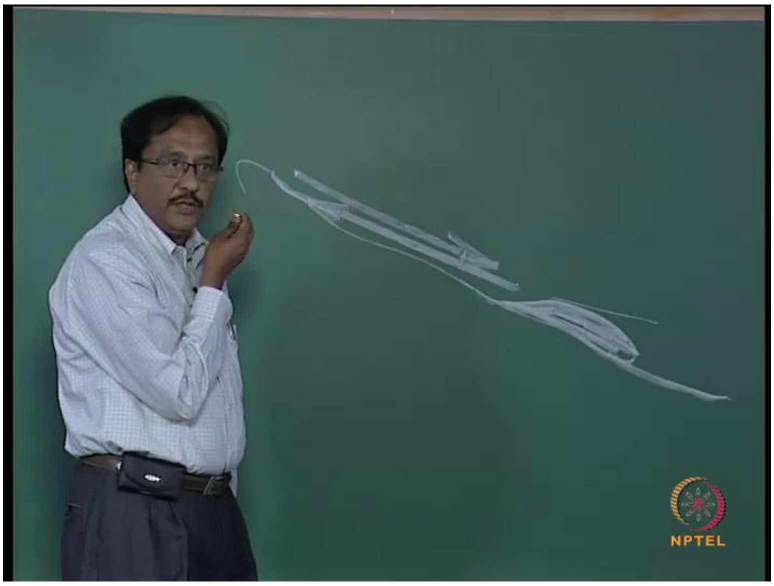

So, you will see, that when the, over the beach there is sand, which is going up and again, which will be coming back, so this kind of oscillation. And during such an oscillation if the material is moving without much of loss of material, then the beach is said to be in stable equilibrium. Even if you see some kind of erosion taking place what will happen is, this will remove the sand and then probably, this sand will settle something like a bar and then again this bar will be removed during low tide and this sand will again redeposit. So, this is one kind of a problem, which you have to be in mind, whether it is a short time kind of erosion or a perennial kind of erosion, etcetera.

Now, in this case, where there is a storm, when there is a storm, the water level in the ocean will go up. When the water level in the ocean goes up, it may go even above the mean water, mean high water. How many high waters you have? In a day you can have either, one high water, or two high waters, depending on the tidal, kind of tidal variation. So, over a year if you take, you will have mean high waters and also, you will have maximum high water that is clear.

Now, when there is a storm, the water level in the ocean can go even above the maximum high water, but definitely it will go, most of the, most of the time it will be higher than the average high water line. Under that situation the water level has risen. In this case, as shown in the second slide, when the water level goes up the waves, which were originally breaking in this particular location, that is governed by 0.78 times water depth, will not happen because at that particular location you have sufficient water depth, so that the criteria of the, depth limited criteria will not satisfy.

So, what will happen? The waves will still propagate with all its energy stored and it will attack the coast and when it is attacking the coast with so much of energy, part of the coast as indicated in, green, red color will be the portion, which is being swallowed, the material will be removed. How much of the material is going to be removed depends on the kind of energy the waves contain and the kind of material that is lying on the beach.

So, the material is removed and when it is removed where does the material go? Naturally, it has to go; it has to go inside the ocean. So, all this material will be removed gradually and then as the storm persist, the cumulative effect of this erosion will be there and you see greater portion of the coast will get eroded, as shown here. So, all this area will be eroded and this sand is likely to be towards the sea bed. So, this is a problem that has occurred all of a sudden. And if you have some kind of structures and these structures, the stability of these structures are rather questionable.

So, now, the storm recedes, it settles down. The original scenario comes into picture. The original scenario is this one, which is corresponding to the first one. Under such a situation what will happen? When the waves are propagating, you know the affects of orbital oceans, you know the affects of mass transfer velocity, so the sand in the sea bed will be removed and the sand will be directed towards the direction of propagation, which will be towards the coast. So, the sand, which has to be removed due to the storm, is now going to get settled back into this eroded area. This process will continue for some time.

So, now, if the quantity of material, that was removed during a storm and deposited here is again redeposited to the eroded area without any loss, then what do we say? The coast is said to be in equilibrium. There is not much of a problem, even during a storm has removed the material, but it has come back. We have a classical example, later when I talk about tsunami. This has happened when we really monitored about the performance of the shoreline.

So, now you see, that if there is no replenishment back after the storm, you see, that the stretch of the coast gets eroded. This is the way it has been explained in the coastal engineering manual very clearly and for benefit, for additional information you can see this book, there is a manual by US army corps of engineers.

So, now we have understood how and why you have the coastal erosion when you have a storm. But then we should also know that how the sand lying in the sea bed comes to the surface along the beach; that is very important. But we have undergone the course on wave mechanics and you know, all of us know, the physical behavior of ocean waves.

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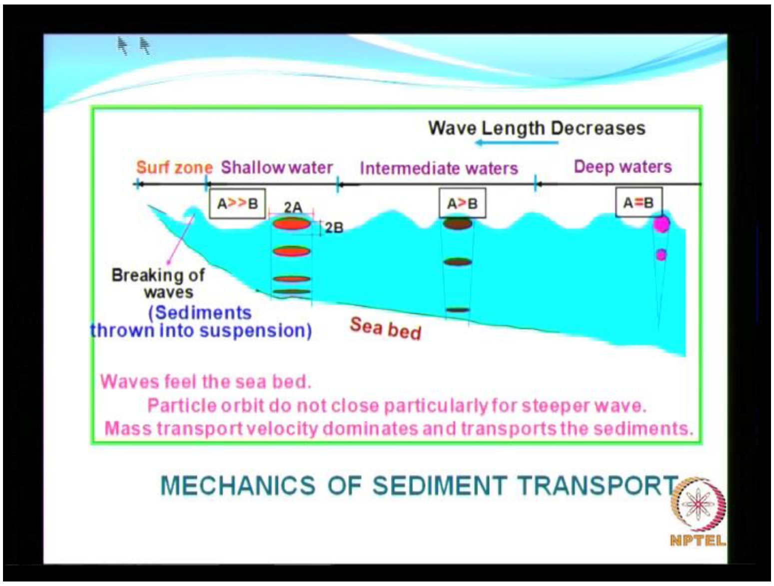

What does that say? That says, in deeper waters you have no effect of the surface waves on the sea bed. So, that means, the sand in the sea bed under this location will be more or less stable. But once the waves leave the deep water situation, once it enters intermediate depth condition, you know, it starts filling the bottom and the horizontal displacement will slowly reduce as it goes towards the sea bed, but still the affects of wave will be felt on the sea bed.

In intermediate water depths and at this, at that point of time you see, the initiation motion coming into picture, which we have seen recently depending on the relationship between the wave characteristics and the size of the (( )) and the size of the sediments. The sediments in the sea bed will get its affect and it will start moving and when it is moving, it is going to now feel the affect of the mass transport velocity. What does the mass transport velocity do? The phenomena of mass transport velocity is some amount of mass is being transferred in the direction of wave propagation. So, the sand, which is picked up from the sea bed is now subjected to motion, gradual motion in the direction towards the coast. So, now you see, the mass transport velocity is now going to be a function of z.

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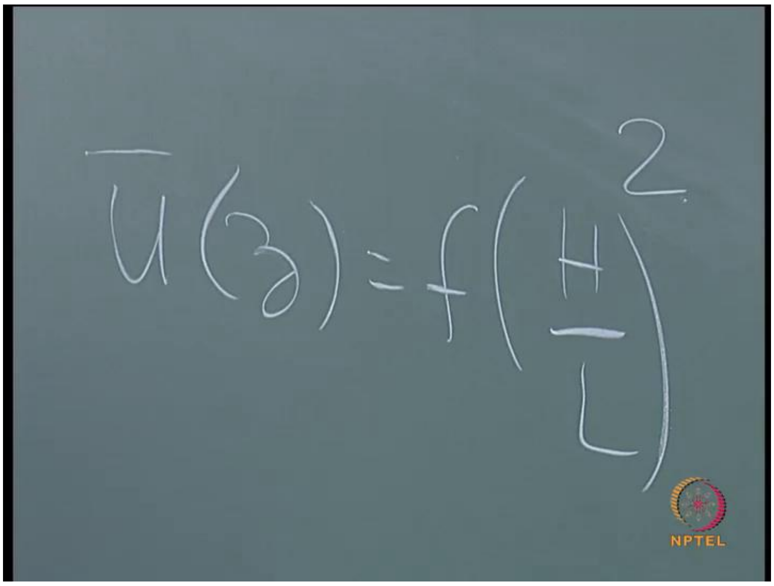

Recollect expression for mass transport velocity. If you recollect, we have seen, that mass transport velocity will be a function of z and it will be a function of H L square, function of H L square, that means, when does, when do you expect steepness to be higher? When you have storms, cyclones, etcetera. Steep, the steepness of the wave is expected to be higher, at that time you see, you can see, expect more amount of sand being propagated towards the coast. Now, so there will be motion in this direction and there is a velocity gradient also. So, you see, the motion will be taking place and all this things will reach your breaker zone.

So, now you see, the sand, which was in the sea bed is picked up by the particle displacements of the wave being transmitted in the direction of wave propagation by the phenomena of mass transport velocity and the sand will reach you breaker zone, somewhere near the breaker zone. And at the breaker zone what happens, the wave will break. Depending on the breaking criteria, when it breaks, the sand is now set in a motion, it undergoes a churning motion because of the wave is going to break. So, the sand will get sorted out, the sand will get sorted out. So, you have both, fine sand, as well as, the coarse sand. It will have a kind of a mixing. So, the sand is now coming to the surface and now it is being transmitted. So, it is being transmitted to the coast, to the shore line.

So, now you see, there is a region where the sand is going to move and what is that region? That region is nothing but the surf zone. The distance between the shore line and the movement of the sand along the shore will start somewhere near the breaker zone. That is why it is really brought to the surface. When it is brought to the surface, then you have this area, sand in suspension and sand moving as bed load. Also, sand will be moving as bed load, as well as, as in suspension. So, most of the sand is now within the surf zone.

Now, this is, as far as, with the help of an elevation. Now, we will look at the (( )). Now, what we have understood right now is how the sand from the sea bed has come to the surface somewhere near the breaker zone; that is very clear.

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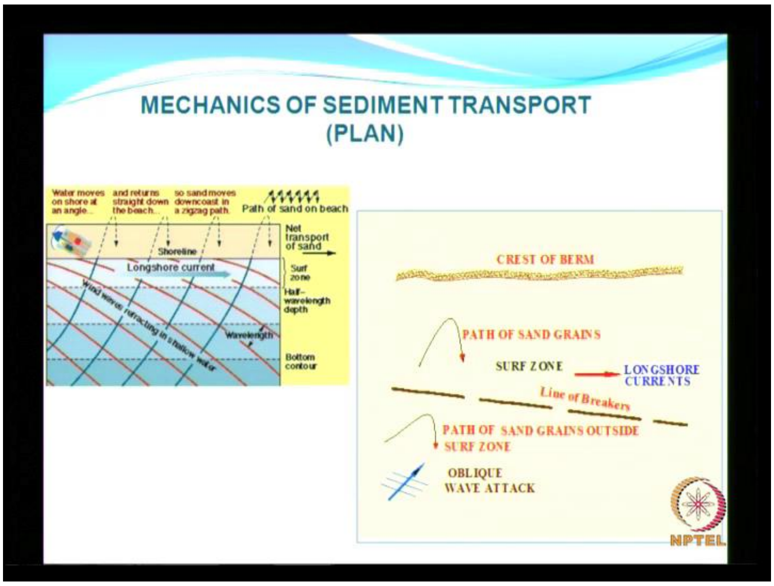

Then, what happens? How the sand moves? So, this is in plan, this is in plan wherein you have the, when you look into the ocean there will be locations where the waves will be coming either this direction, or in this direction. For a certain location it will come directly to you, directly normal to the shore line.

When you have an oblique attack of the wave and when it reaches somewhere near the line of breakers, what will happen? At the line of breakers when the waves break and when the waves are in direction, it will have two components; naturally, when it is inclined it will have two components. Since it is inclined, since it is inclined, this will have a component along the shore and normal to the shore. When the waves break, because of the waves breaking we have currents set in. Current is nothing but the movement of mass of water that is going to be created because of the waves breaking in the breaker zone. And this current is nothing but the wave induced current, that will start somewhere near the breaker zone and it will be directed along the shore, as well as, normal to the shore, because of the oblique wave attack, is that clear.

So, the flow field or the move, the speed with which the water moves along the shore is called as the long shore currents and the one, which is moving normal to the shore is called, normal to the shore is called as what, cross shore currents or it is also called as, onshore-offshore currents. So, you see that we have a system of currents in the near shore. I have already explained about the ripped currents, that is also going to take place near the, in the, in the near shore zone. Now, we have the long shore currents and the onshore-offshore currents and these two currents will act as the driving force in moving the sediments.

So, hence, the sand within the surf zone will be moving along the shore, as well as, normal to the shore, but along the shore is much more, usually it is much more compared to the onshore-offshore currents. So, now, you see, that there is continuous propagation of ocean waves, a continuous system of breaking of waves and continuous generation of long shore currents, hence there is a continuous motion of sand along the shore, is that clear.

Now, through this, this slide it is clear how the sand is picked up and how it is transported. We understand clearly, that the sand is going to move along the shore.

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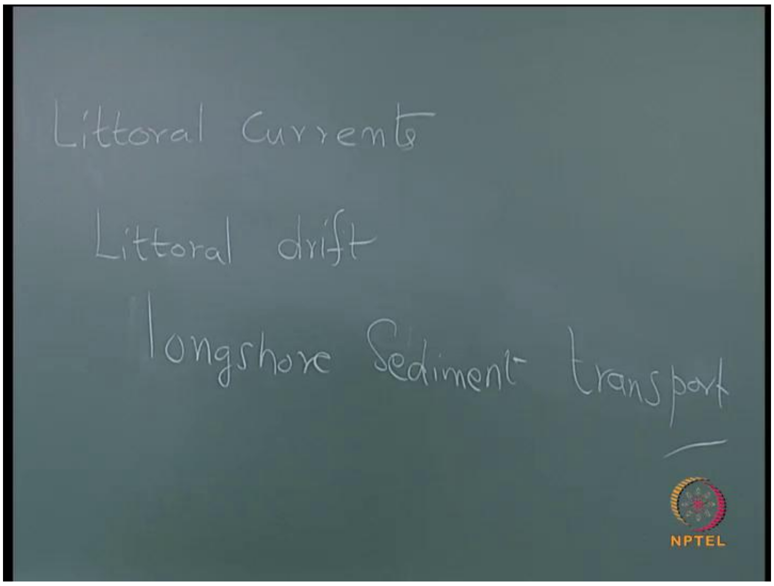

With this background where we have understood what is the mechanics of sediment transport. This long shore sediment transport, long shore currents are also termed as littoral currents.

And the movement of sand along the shore, along the coast is called as we refer this as littoral drift or long shore, long shore sediment transport. So, the movement of sand along the shore is called as long shore sediment transport and the movement, the currents are called as littoral currents or long shore currents and it is also referred to, this is also referred to as littoral…

So, later we will try to work out some few examples, how to estimate the littoral drift quantities, etcetera, direction, quantity of sediment, transport, etcetera.

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So, what the sand is moving, so what when the sand is moving? Naturally, it is going to dictate the coastal geomorphology, the orientation of your coast, the changes that can take place along the coast. So, coast, coastal geomorphology, coastal morphology is extremely important and that is what we will try to understand.

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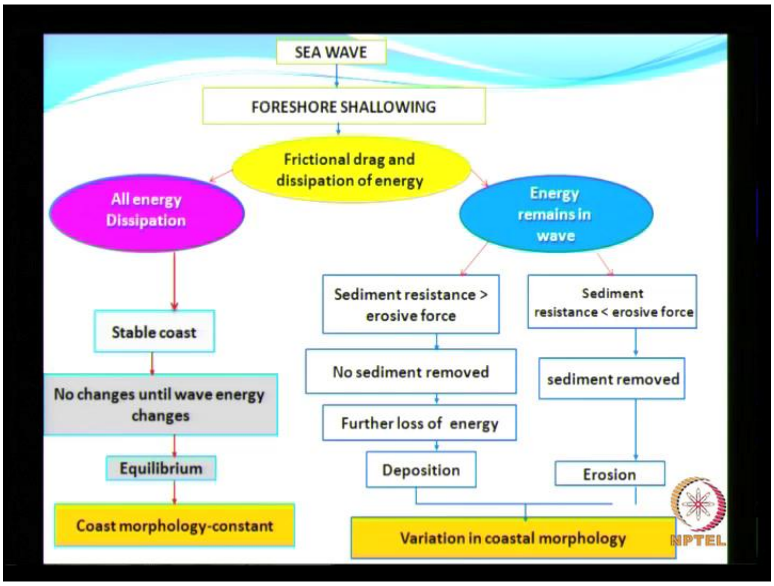

This is in brief about coastal morphology, the physics behind the whole thing. Sea waves, when they propagate, they have the shallowing effect over the, when they propagate over the foreshore, the definitions of the foreshore, backshore, etcetera, we have already seen earlier, this foreshore shallowing. You can have frictional depth because of the bottom depth contours and also a certain amount of energy can be dissipated.

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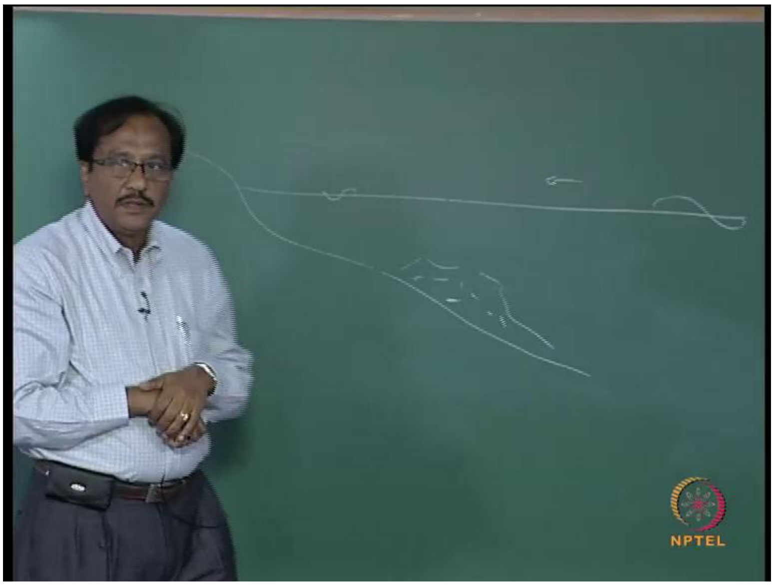

So, if you have energy dissipation taking place before the waves reaches the coast, for example, if you have a coast and you have some kind of artificial reef, sorry, not artificial, some kind of natural reef, some kind of natural reef and now, you have the waves propagating, what will happen in this case? If there is no reef, the wave is supposed to break somewhere here and that is going to create erosion.

Now, because of this existence of a natural reef, the energy can get dissipated. So, when the energy gets dissipated, higher energy to lower energy, so the sand will automatically get deposited here. When such a situation happens, you have a beautiful beach, so herein we talk about dissipation, dissipaters, we think of dissipaters. So, that is one area, one, one kind of area where you should think you, when, want to plan for coastal protection, how can I reduce the energy before it reaches the coast.

So, when you see, that if you are able to see, that all the energy is dissipated, then the coast is said to be more or less stable, no changes until the wave energy changes equilibrium. So, the coastal morphology is going to be constant. So, we do not have coastal engineering, does not have any role to play here.

So, using this there are some attempts where you can think of having a structure. These are called as submerged breakwaters, which we will be seeing under the topic when I cover on breakwaters. So, you can think of having submerged artificial structures in order to dissipate the energy, so as to combat coastal erosion by dissipating the waves. On the other hand, energy remains in the wave, then it is a problem.

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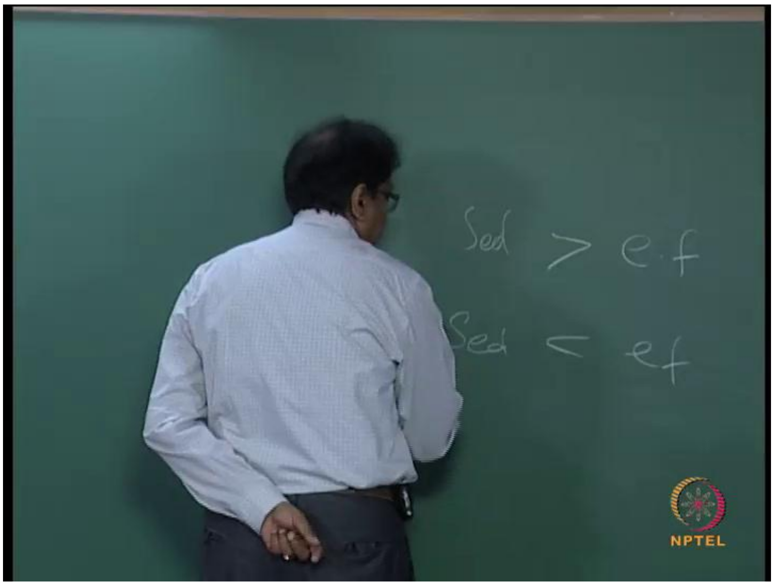

So, when you have energy remaining in the waves, then sediments, there are two situations that can arise. Sediment resistance is greater than, sediment resistance is greater than erosive force and sediment is less than erosive force. If sediment resistance is greater than erosive force, then no sediment is removed, further loss of energy. So, because of this it will result in deposition and just a vice versa will happen. When the, if you have the sediment resistance less than erosive force, your sediment will get automatically be removed because the resistance is less and when it is removed, then naturally you are supposed to have erosion taking. So, erosion or deposition will naturally result in changes in the coastal morphology.

So, this beautiful slide clearly explains for us what are the problems or what are the main causes where you should look for if you see a coast is getting eroded. This is, this gives overall picture.

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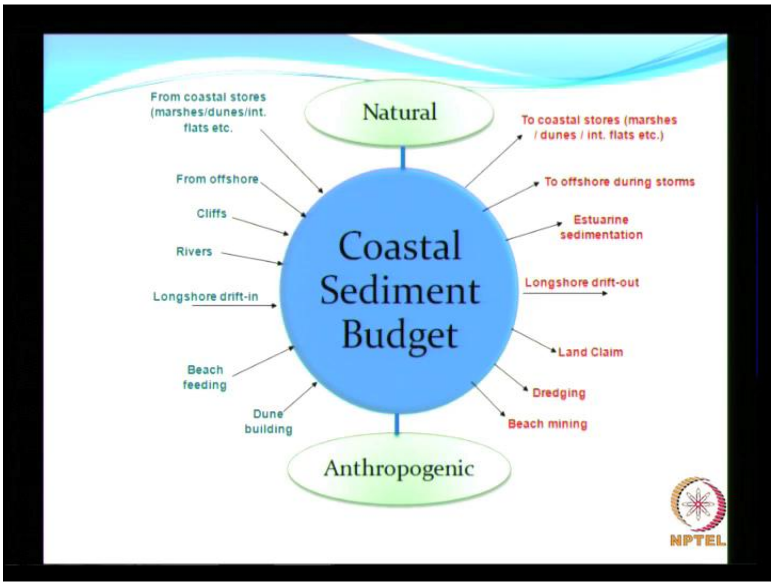

Now, we move on to coastal budget coastal sediment budget. First I am trying to explain to you all the terminologies and all the physical parameters and physical phenomena that are involved in the coastal zone and in the area of coastal erosion. First we will understand that and then we will go in for the mathematical aspects of estimating all these things, and how do you use all this calculation, etcetera.

When you talk about sediment budget, see, like we have our own budget, right, what is in and what is out and what is that you have, that is a simple budget. So, here also we have natural and anthropogenic; you look at the arrows, one is sink and one is source.

So, now what are all the things, that are going to come inside the sediment budget from coastal dunes, tidal, flats, marshals, etcetera. You can have some amount of sand coming inside the coastal area, then from the, from the offshore, if you have cliffs, from the cliffs there can be some sand and also some amount of sediment supply. Then longshore sediment transport or the long shore drift, you are going to have some amount of sand coming into the pool, then through beach feeding and also through dune building. All these things are adding on to the sand, that is incoming, inside the system.

The outgoing can be during storms to the offshore or to the coastal. There can be some movement of the sand away from the source. Then estuarine sediment, sedimentation, there can be some amount of sand, which are moved from the ocean transported through the estuarine and that sand does not come inside, inside the ocean.

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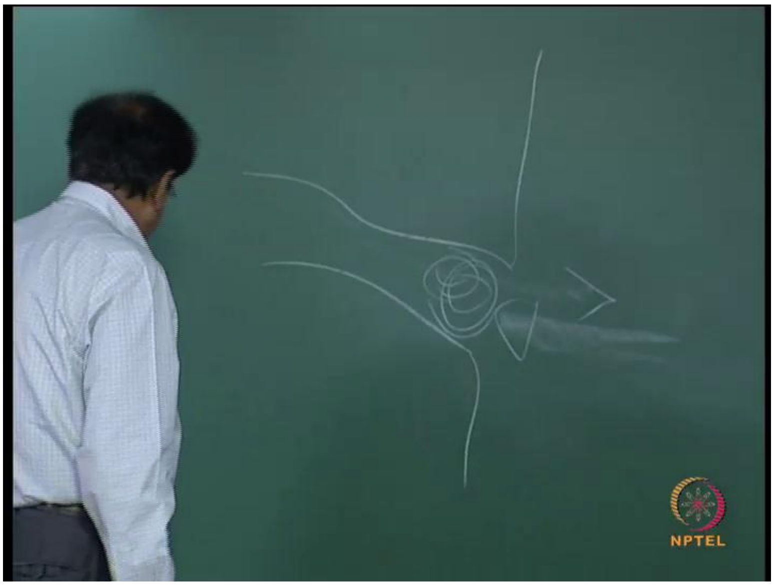

So, that creates another major problem, that is, when you have an estuarine open to an ocean, so there is a supply from the ocean during high tide, it brings in lot of sediments. But during the low tide, it is returning back, it does not take away all the sand, it leaves the sand here. And we, you, if you allow this to continuously happen, what will happen? There will be lot of sand accumulating here and ultimately, it will lead to closure of river mouth. That is going to create another kind, another headache, another problem. So, you see, some, that to offshore, during, so this is estuarine, so again littoral drift out. Although you have some sand coming in, all the sand are not going to remain in one location, it can go away or land claim.

Then, beach mining or dredging, these are removal from the sand, from the location. So, you see that when you are talking about sediment budget for a coast you have to identify all these problems, how much is expected to come in to this area, how much sand is going to go from this area, etcetera. So, this needs proper planning.

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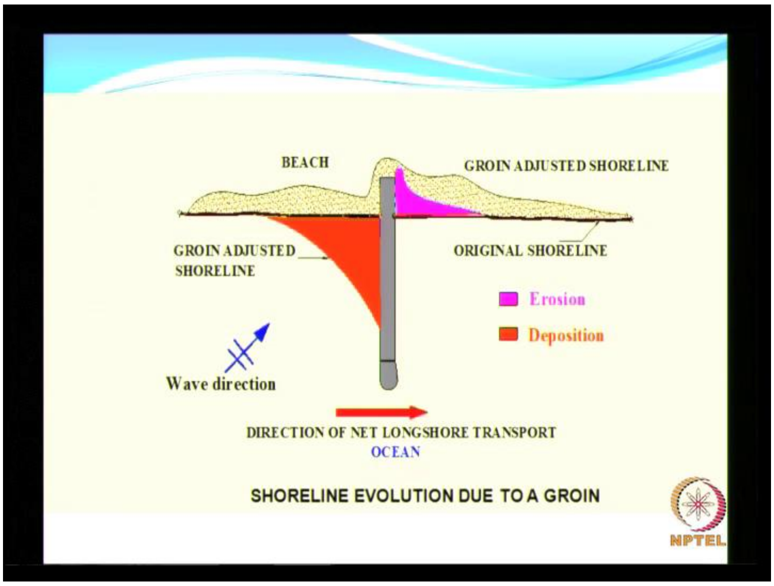

Now, we, again we will start with what happens. When you have sand moving along the coast, here is a slide, which shows for some reasons you have structures penetrating into the ocean and this structures can be normal to the shore, harbor breakwaters, groins or you need a structure to support a pipeline for continuous (( )) of sea water, may be for aquaculture or power plants. So, there are many industries, etcetera, which may need a continuous sea water and they will be mounted on structures, as shown here.

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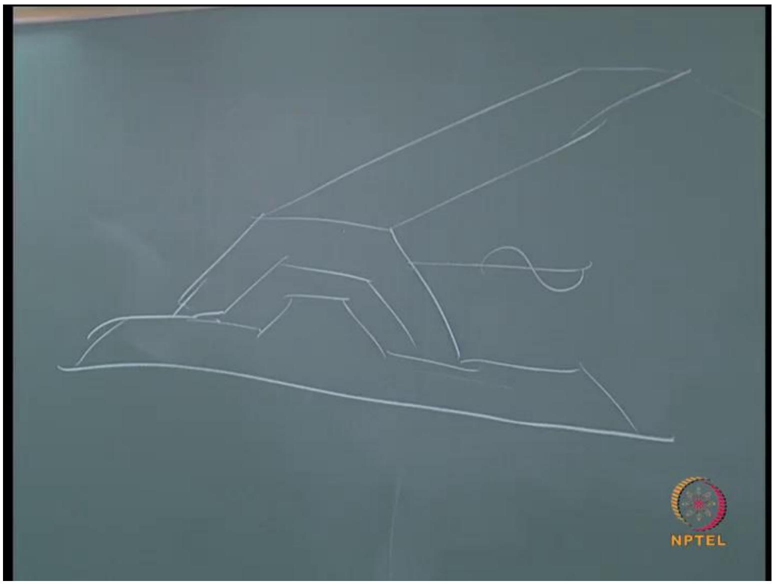

These structures can be some kind of the designer section; it can be some kind of a trapezoidal section checked into the ocean. And if this structure is either impermeable or slightly permeable what will happen to the shore line? As we have seen earlier, there is a continuous movement of sand along the shore. When it is moving along the shore you have put a, if there is a structure normal to the shore what will happen? This structure is not going to allow the sand to move and hence, you will have the advancement of the shoreline and you have the beach advance, so you have nice beach here. This process will keep on continuing until it reaches a stage. When you have, when it reaches this location, then you have automatic bypassing, is it advantageous or disadvantageous? So, putting the construction you see that you have a beach on the updrift side. So, we call this as updrift side and this side we call it as downdrift side. So, this is very, very clear.

On the other side, on the down drift side what is going to happen? You know the phenomena of diffraction, what is, what is meant by phenomena of diffraction? When the waves move it penetrates into the sheltered area, it penetrates into the sheltered area and because of the energy contained the waves, this will remove the sand. When the removal of sand takes place, the sand is available for the long shore currents to drive it because at this location also the waves are going to break. At that location also you have the long currents and that is going to move the sand along the shore. So, you see, the phenomena of diffraction permits the wave to propagate to the sheltered area, remove the sand and then comes to shore and then comes to the surf zone and then the long shore currents keeps driving the sediments.

So, now you see, by having a single groin you have the advancement of shore line on the updrift side and erosion on the downdrift side. This is the universal problem. Wherever you have, you construct, this is what is going to happen. But can we stop construction of a structure? For some reasons (( )) we might need the structures, which is the one, which is really governing the direction of littoral currents or littoral sediment transport, littoral transport or the sediment transport.

So, when you are dealing with the sediment transport it is not only the magnitude, which matters, it also, it is also the direction, which is very important. Of course, the direction is going to be governed by your basic Snell's law; it, it comes only from your refraction. So, this point is very clear now.

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So, even natural promontories, natural (( )), you may have a nice coast, but you see this is along the Vishakhapatnam coast. So, if you, if you have a straight beach, then there may not be any problem.

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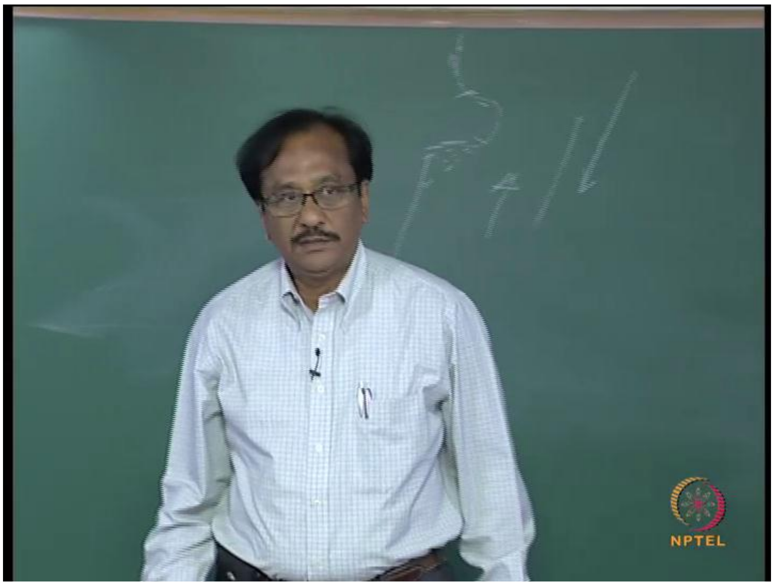

Suppose if you have the coast itself is moving like this, you have large promontory, in this case you will see (( )) along the sandy coast, then you will see, that, that the sand, this area is expected to be associated with formation of beach. And on the other side, they might be having some protection measures or trying to fight with the coastal erosion, that is, if in this case the sand is moving in this direction, if you, if the sand is moving in this direction, you see, that an opposite trend will occur.

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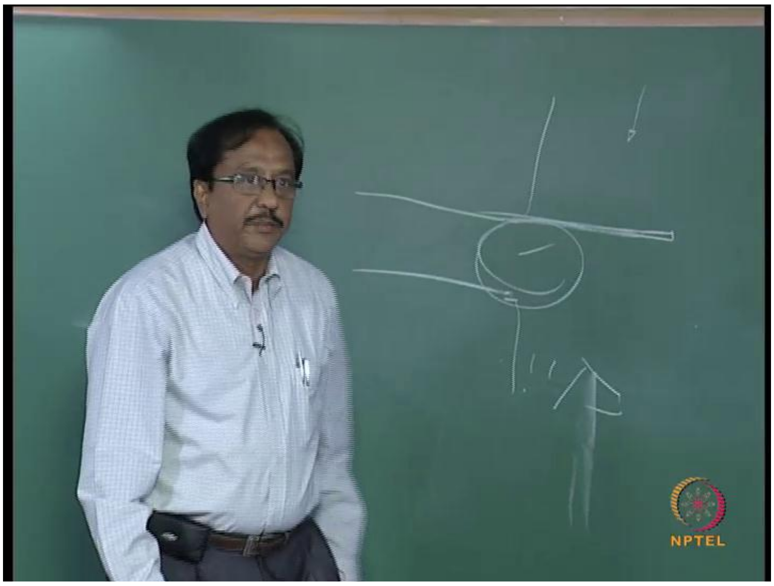

So, now, imagine if you have a river and you have the ocean and if the sand is coming under the, depositing here, closing the river mouth, naturally you will see some kind of obstruction. And if you are very sure, that the sand is mostly 100 percent, that is, moving in this direction, then what will you do? What is the kind of protection measure you can take? You can construct a training wall here.

So, what do you do? You prevent the sand coming and depositing here. And you will have the beach here. But if it is seasonal, during the other season there can be sand moving in this direction, what will happen to that sand? It will come and deposit here. So, you try to put another wall here. If the direction, you, both the directions are of almost the same kind of amplitude, then you have same lengths of training walls, you understand. So, here this is what we need.

Suppose, if you do not know about the direction and by chance, in the location where the direction of sediment transport predominant in this direction and there is only very little transport in this direction and you have raised a training wall in this way in order to serve as a protection measure for this river mouth, that is not going to happen. It is going to your solution is going to aggravate the problem. So, you are going to have more sand deposit here. So, although the solution is quiet not so difficult, but it is bit tricky because you need to have most important the knowledge on this sediment transport, particularly its direction apart from your quantity, is that clear.