Port and Harbour Structures
Professor R. Sundaravadivelu
Department of Ocean Engineering
Indian Institute of Technology Madras
Module No 08
Lecture 38: Coastal Structures And Environmental Management

This particular course is on port and harbour structures. The main important requirement for building a port is environmental management. You cannot build the port wherever you want to build a port.

(Refer Slide Time: 0:38)

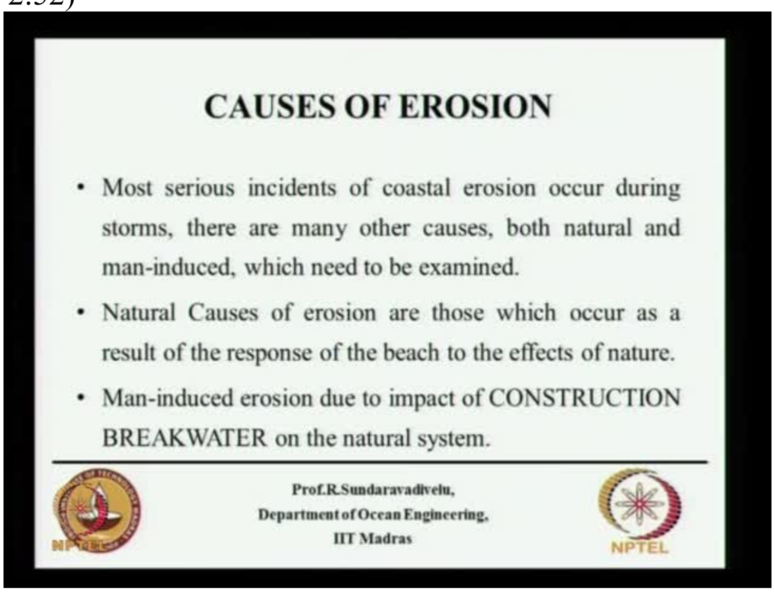
There are certain locations where we can build the port without a breakwater but most of the locations, you have to build a breakwater. So in this particular slide, you are seeing a breakwater here. This is called as the South breakwater and this is a North breakwater. This is for a fishing harbour in Pondicherry. So once you construct the breakwater like this, you have accretion on the southern side of South breakwater and erosion on the northern side of the North breakwater.

But you are not seeing all these things here in this slide because we have done what is known as artificial nourishment. This we will explain. This is one of the method for environmental management. Generally when you build a breakwater like this into the sea, it obstructs the flow of sediments which naturally takes place. This sediment movement is from south to north on the East Coast.

So when the sediment is trying to move from south to north, because of the construction of the breakwater, there is a deposition on the southern side, this is called as accretion. There is erosion on the northern side, that is called as erosion. The original shoreline was somewhere here and we have so much of accretion on the southern side and so much of erosion on the northern side. Okay? This erosion has taken place right up to this end, up to this end somewhere here and about this building also where they have put the stones.

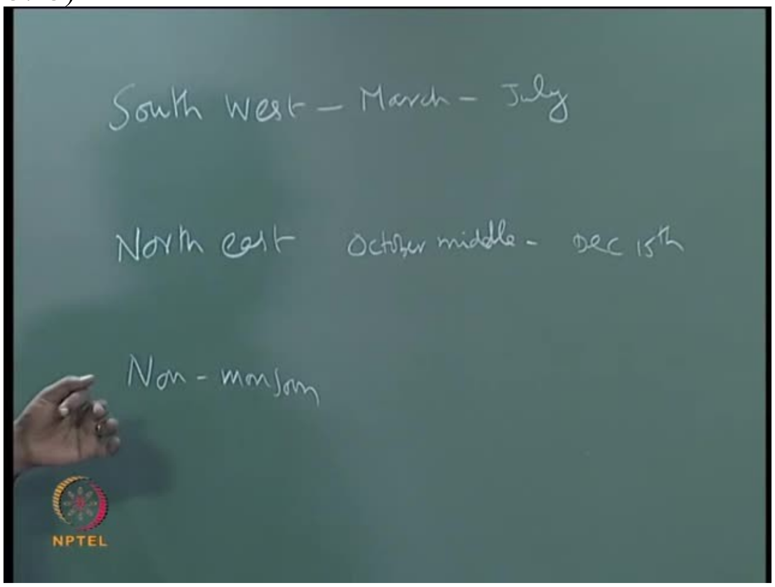
I think you are able to see the stones because the erosion has taken place up to this end. By doing artificial nourishment, by taking the sand from inside the harbour basin, we have advanced the shoreline up to this point. This is one of the methods which can be used for environmental management. So in this lecture, we will discuss what are the causes for erosion and how to manage this erosion.

(Refer Slide Time: 2:52)



What are the causes for erosion? Mostly, these erosions take place during storms. Storms or cyclones, they are experienced in the East Coast, both Southwest and North East monsoon. For Tamil Nadu coast, the Southwest monsoon is not predominant. Only north-east monsoon is predominant.

(Refer Slide Time: 3:23)

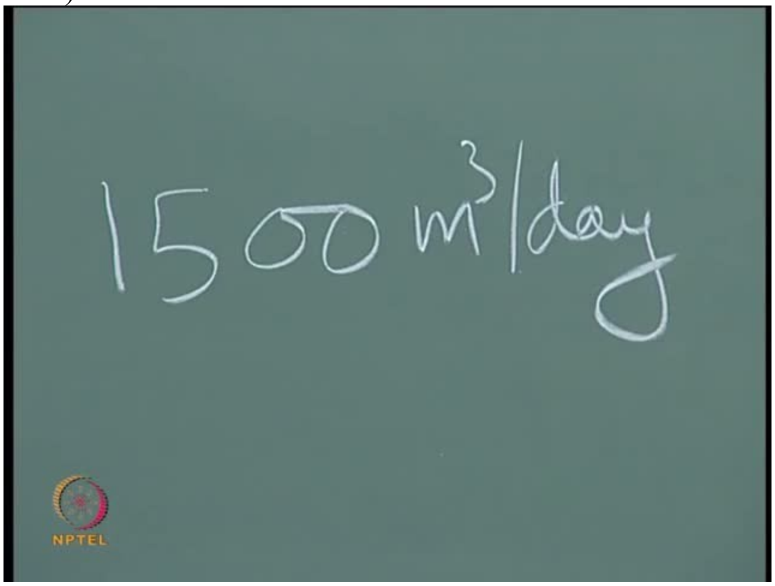


So we have 3 seasons. One is called as Southwest monsoon, another is north-east monsoon, next one is non-monsoon. So the Southwest monsoon we can say from March to July, this one we can start from October middle to December middle, that is December 15th. The other seasons we can classify as non-monsoon.

The littoral current from Southwest monsoon suppose you take this as the North, the movement in the Southwest monsoon is from the South to the North. In the north-east monsoon, it is from North to the South. That means if we build a breakwater in one season there will be the deposition on the southern side, whereas in the other season, the deposition on the northern side. In non monsoon, the deposition will not be very much okay?

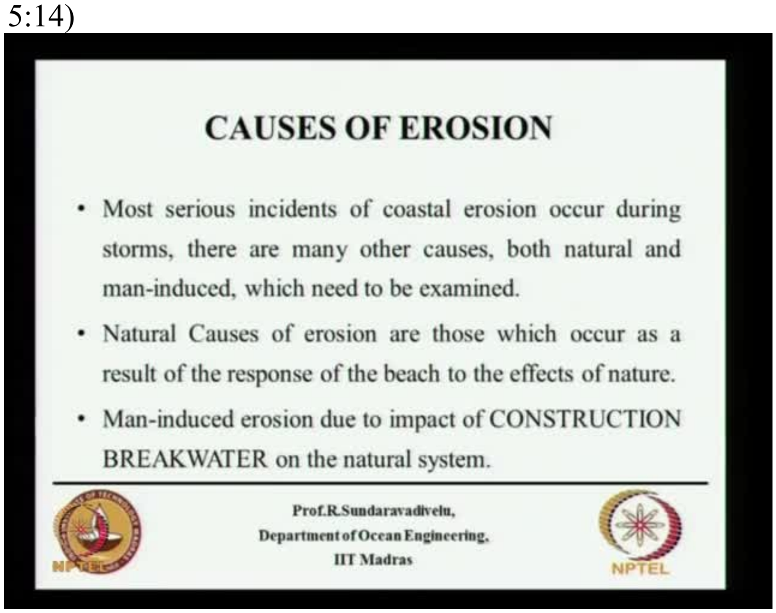
Approximately, the Pondicherry Harbor what I have told, the sand which is moving is about 1500 cubic metre per day on average.

(Refer Slide Time: 5:06)



And it is maximum in Paradip port, there it is about 1.5 million cubic metre per annum.

(Refer Slide Time: 5:14)



This coastal erosion generally takes place during storms and cyclones and there are many other causes both natural and man induced. The man induced is the construction of breakwater. Natural causes are those which occur as a result of response of the beach to the effects of nature. Nature effect may be the concentration of energy in the coastline. That depends on the bathymetry. There can be some headlines. So it is a coastal feature, it is called as a coastal geomarkology.

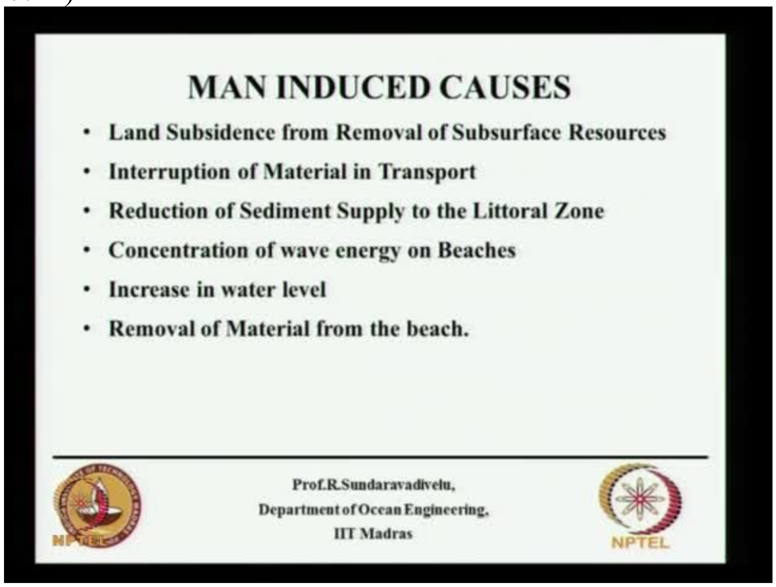
Man induced, many reasons are there. One of the things which we want to discuss is construction of breakwater on the natural system.

(Refer Slide Time: 6:10)

So we will list the various natural causes. One is the sealevel rise. They say the sealevel is rising. It varies from 1 millimetre to 100 millimetre, that is the range they are telling per annum. It is not yet quantified. The variability in sediments apply to the littoral zone. The sediment is coming from the rivers when there is a sediment is there, there are various sources. One of the source is the sediment coming during floods from the river.

Storm waves, so when the wave is higher, that is the wave height is more, what it does is it carries more sediments and then creates erosion. Then we have wave and surge over wash. Surge means when the cyclone is crossing, there is certain amount of water which is going into the land. Then we have other cases like deflation, Longshore sediment transport, sorting of beach sediment, etc.

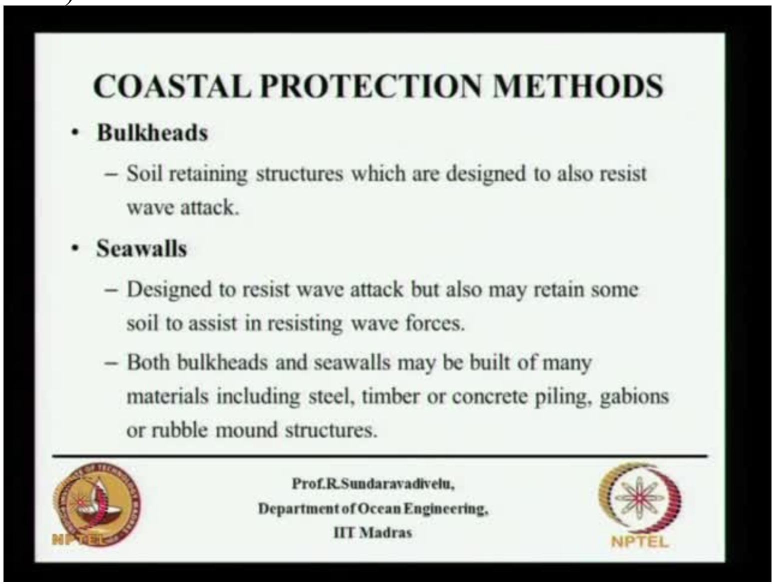
(Refer Slide Time: 7:22)



The man induced causes, this land subsidence from removal of subsurface resources. So we have a this heavy metals concentration on the sea coast , they dredge the sand. Then the interruption of material in transport, that is construction of breakwater. Reduction of sediment supply to the littoral zone. I will explain littoral zone in another slides. So when there is a interruption of transport, one side it get deposited, that means whatever sediment it was carrying, that is the littoral zone, that is deplished on the northern side. So that causes erosion.

There are certain concentration on the wave energy on the beaches. If there is a concentration of energy, the erosion is more. The increase in water level is also a man induced cause because of the temperature increase, global warming and things like that. So we cannot say the increase in water level as natural. It is also man induced. Then removal of material from the beach, that is, this removal of beach means that is the dredge material.

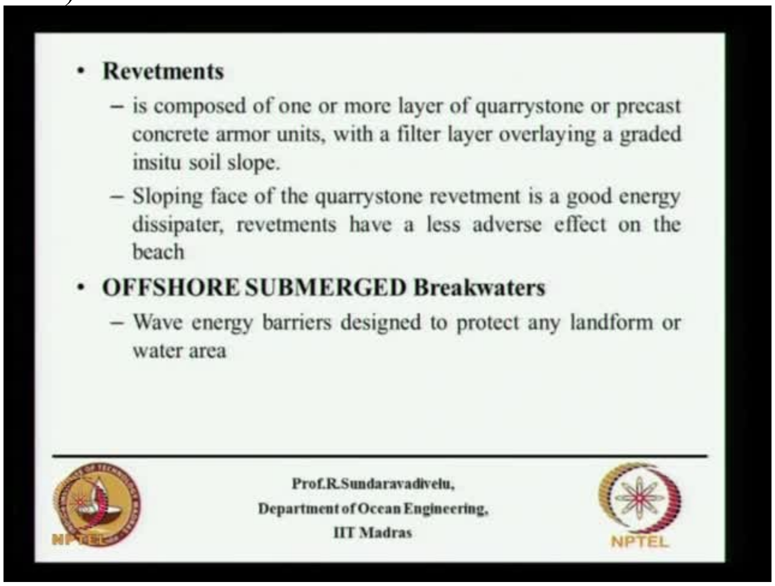
(Refer Slide Time: 8:30)



There are various methods that are used for coastal protection. One is called as the bulkhead, another is a seawall. Both bulkhead and seawalls are constructed parallel to the shoreline. Bulkheads, they are retaining the soil. Whereas seawalls do not retain the soil. They both are designed to resist the wave attack. There are many materials that are used for building the bulkhead and seawall.

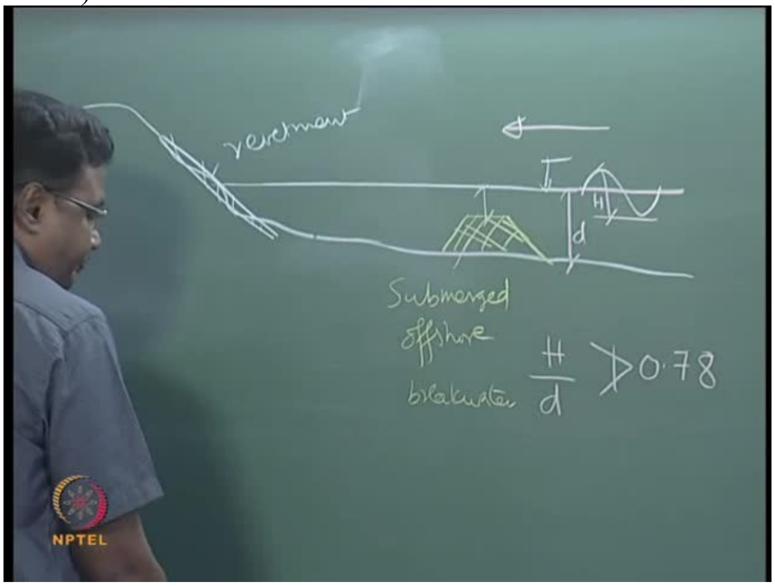
They can be made of steel, timber, concrete piling, gabion boxes or rubble mound structures. So we will be discussing about the various types of seawalls but we will concentrate on this rubble mound seawall with gabion boxes as to protection in detail.

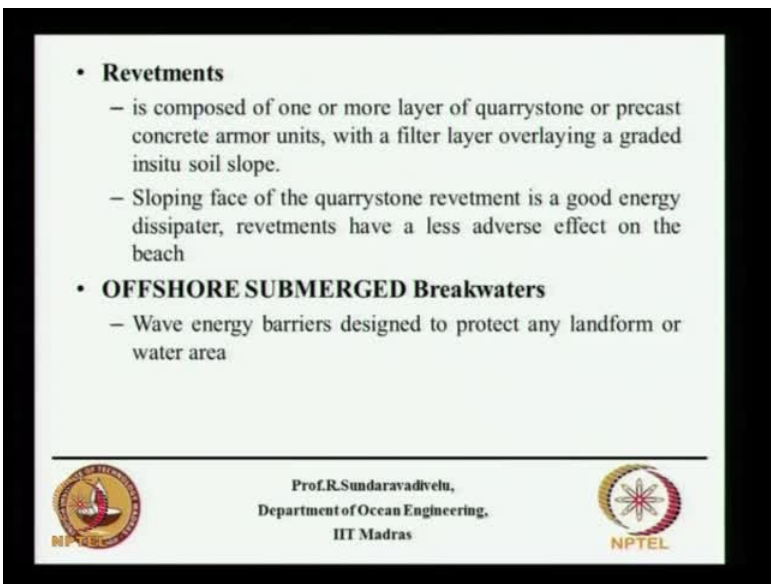
(Refer Slide Time: 9:25)



Revetments, this on the beach itself you put some filter layer and then put some armour units. This is called as a revetment. So this revetments also is a energy dissipator. They have less adverse effect on the beach. We have one more concept that is called as offshore submerged breakwater. These offshore submerged breakwaters are built in the sea and they act as a wave energy barriers and protect the landform or water area. So let us see by sketch all the different types.

(Refer Slide Time: 10:18)



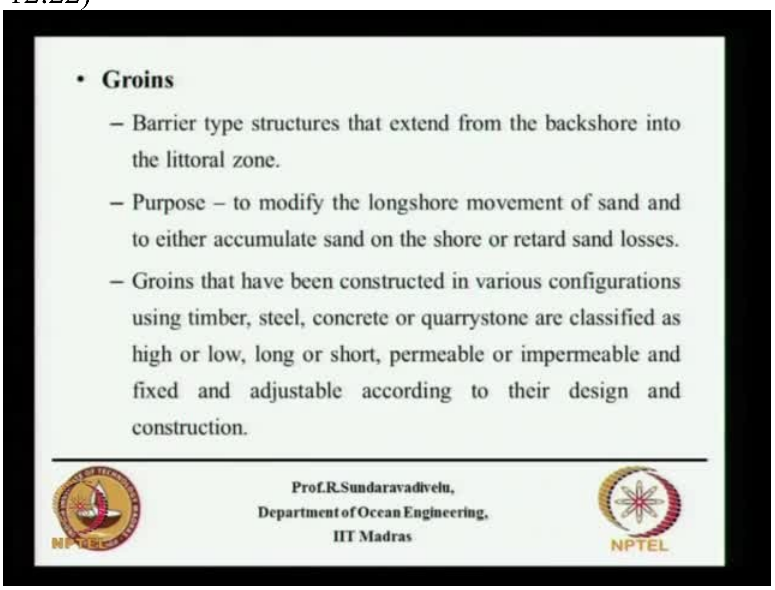


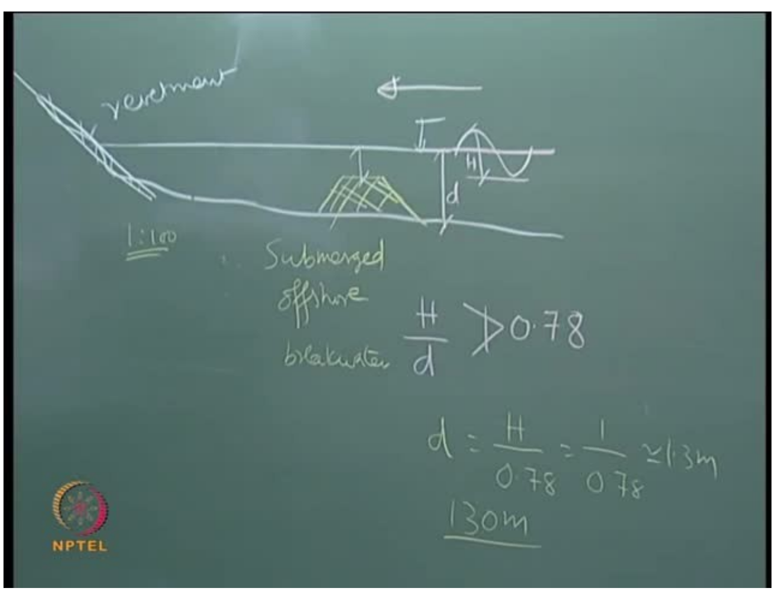
Suppose you have a shoreline going like this, then this is your water level. Revetment means you put some structure on the slope. This is called as the revetment. And when you talk about the offshore submerged breakwater, this is some kind of a structure which we built below the water level. So whenever the wave is travelling from Seaside to the land side when it comes over here, the wave will break here.

So breaking wave height is suppose this is your wave height H and if this is your water depth D, H by D cannot be greater than 0.78. So instead of the wave breaking somewhere here, since we have reduced the water depth here, the wave will break here. That means, the wave beyond this point will not have any energy. So it cannot create any erosion.

And about the seawall, there is a separate sketch that I will discuss. Now this is only for revetment as well as for submerged breakwater. This called as submerged offshore breakwater because you want to protect some land area here, you build this breakwater. It can run into about a kilometre or depending on where you want to build. It can be detached also. It need not have to be continuous.

(Refer Slide Time: 12:22)





Then we have the groynes. These groynes are barrier type structures. They extend from the back showed into the littoral zone. The littoral zone is the zone in which you will have the what is called as sediment transport taking place. So it depends on the point where the waves break. Normally when you talk about the waves, the waves will be different. During storm, you will have very high waves. During normal period, the waves will not be so high as a storm or cyclonic wave.

But 90 percent or 95 percent of the time, what is a wave that is going to be attacking a shoreline, that you can find out statistically. Suppose that wave is about 1 metre then the water depth it breaks will be water depth in which the wave of 1 metre will break can be calculated, that is 1 divided by 0.78. So this will be approximately about 1.3 meter. So the distance from the shoreline to where the water depth of 1.3 meter occurs, that is the zone where the littoral drift will be more.

You find out that width of the distance, you take twice the width, that is called as the surf width. It is clear no? Where the water depth is about 1.3 meter from the shoreline, it can be generally the slope of the beach will be about 1 is to 100. That means, 1.3 meter water depth will be available at a distance of 130 metre. The beach slope is 1 is to 100. So you take 260 meter is the zone where the littoral drift will be very critical.

Suppose 90 percent of the times, the wave height is 2 meter, then 2 divided by0.78, it becomes 2.6 meter and the slope is very flat, 1 is to 200 then you have to multiply by that and correspondingly your littoral zone will vary. So purpose is to modify the longshore movement of sand to either accumulate sand on the shore or retard sand losses. This is the purpose of the groynes.

This has to be done very systematically. Systematically means we have to carry out analysis and then design. Groyne is not built alone, we have what is called as the groyne field. Number of groynes are built with sufficient gap. There are mathematical formulations for that. Maybe about 10 to 12 groynes will be filled, will be constructed and this. And this construction methodology is also important.

If there are 12 groynes means you cannot start constructing the 1st groyne, then 2nd, then 3rd like that. Preferably you have to construct all the 12 groynes, you have to start at the same time. Sometimes it is not possible but at least 4 or 5 groynes, you have to start together. And the season in which you start the groyne also is important, whether you need to start with the south-west monsoon or Northeast monsoon or non-monsoon, that is also important.

Professor-Student conversation starts

Professor: Which is better? Which season it is better to build the groyne? Hmm?

Student: (())(16:14)

Professor: I have listed 3 monsoon periods.

Student: Non-monsoon.

Student: Non-monsoon.

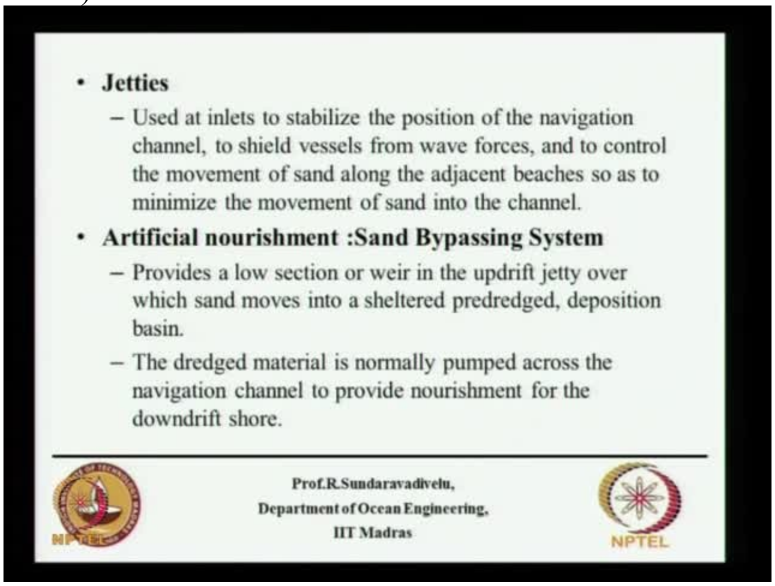
Professor: Non-monsoon is the best because there is no littoral drift.

Professor-Student conversation ends.

So it is better to start in the non-monsoon. Non-monsoon, I have written about 2 months. So it is preferable to finish in 2 months time. And these groynes have various configurations. These are also built using timber, steel, concrete or quarry stone. And they can also be classified as high groyne on low groyne depending on the top-level of the groyne. Long groyne or short groyne depending on the length of the groyne. Permeable or impermeable depending whether if it is quarry stone, it is a permeable.

If it is a solid concrete block,(())(16:58) type of a thing, it is permeable. And fixed or adjustable. We can half floating groynes also. Floating platforms can also be used as a groyne. Then it is adjustable.

(Refer Slide Time: 17:10)



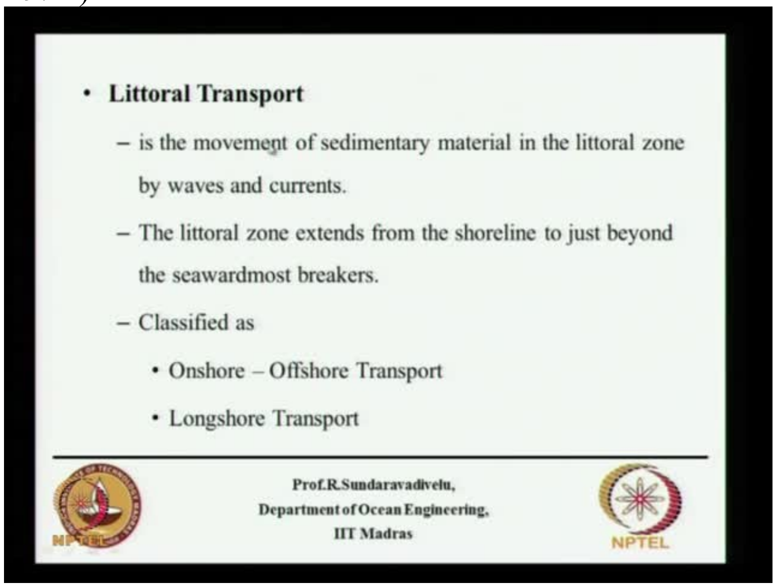
Then we have jetties. These are used as inlets to stabilise the position of the navigation channel. They are used to shield vessels from wave forces and control the movement of sand along adjacent beaches so as to minimise the movement of sand into the channel. Jetties are built mainly at the inlets. Then we have artificial nourishment. This artificial nourishment is done by the sand bypassing system.

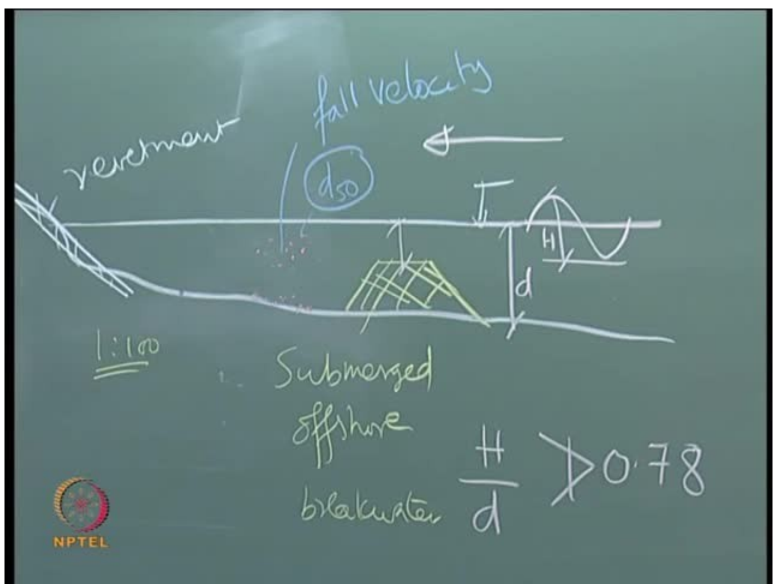
I told, one side there is accumulation, another side there is a erosion. So take where it has accumulated, deposited and put it on the place where it is eroding. Very simple principle but it is costly. So you have to do that. If it is 1 million cubic metre, you are considering 1 million cubic metres of sand is to be deposited after dredging from the southern side and put it on the northern side. So this sand is sheltered predeposition basin it is the sand moves.

The dredged material is normally pumped across the navigation channel to provide nourishment for the downdrift show. Normally, artificial nourishment, what we do is, we call a sand trap that is built. Especially on the East Coast, the sand trap is on the southern side where it gets deposited and from the sand trap, that is you dredge the area more so that the all the sand is collected at a particular place. Normal it is about 1000 meter by 1000 meter for a depth of about 10 meter.

So 1000 metre by 1000 meter for a depth of 10 meter means it will be about 10 power 7 cubic metre. Now you dredge from that and put it on the northern side.

(Refer Slide Time: 19:11)





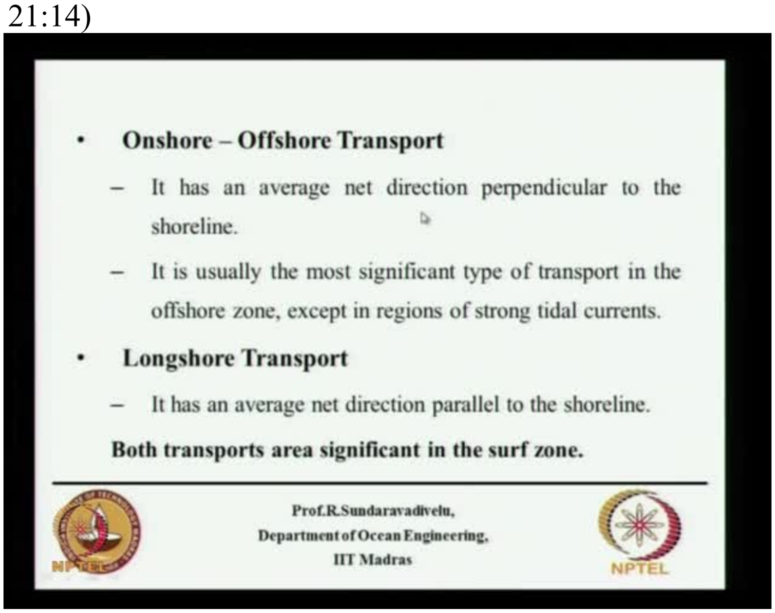
So the littoral transport is by waves and currents. These are movement of sedimentary material. So we have what is known as fall velocity. That is, in this zone where there is sand movement, there are some sand particles which are suspended like this. And these particles, we define by the fall velocity. It depends on the crane size, we called as the D 50 size. That is the size of the sand particle. Due to wave and current, if the velocity is more than the fall velocity, this will be suspended.

If the wave and current velocity is less than the fall velocity, this sediment will get deposited. Clear no? Due to wave and current, you have a velocity. If that velocity is more, the sediments will be suspended or it will pick up some sediments from the shore causing erosion. If the wave and current velocity is less than the fall velocity, then the sediments will settle down. So the littoral zone extends from the shoreline to just beyond the Seawardmost breakers.

I said already the breaker is that H by D is equal to 0.78. And we have different type of transport. One is called as onshore offshore transport. That is from the offshore to the onshore. Another is long shore transport that it is along the shoreline. This along the shoreline only is obstructed by breakwater. So we have the transport. There are 3 directions. One direction is along the shore, another is perpendicular to the shore, 3rd one is the water depth.

So these are the 3 directions. So you can have onshore to offshore transport just as shown in this sketch, onshore to offshoot or we can have a long shore transport.

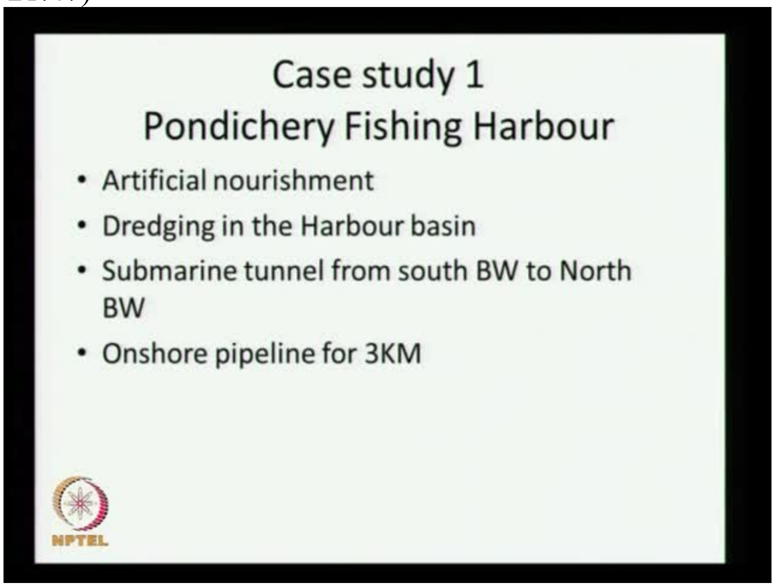
(Refer Slide Time: 21:14)



So this onshore offshore transport has an average in a direction perpendicular to the shoreline. It is usually the most significant type of transport in the offshore zone except in regions of strong tidal currents. And the long shore transport, average in a direction parallel to the shoreline. So parallel means, it need not be exactly parallel. It can be slightly inclined also. Both transports a significant in the surf zone.

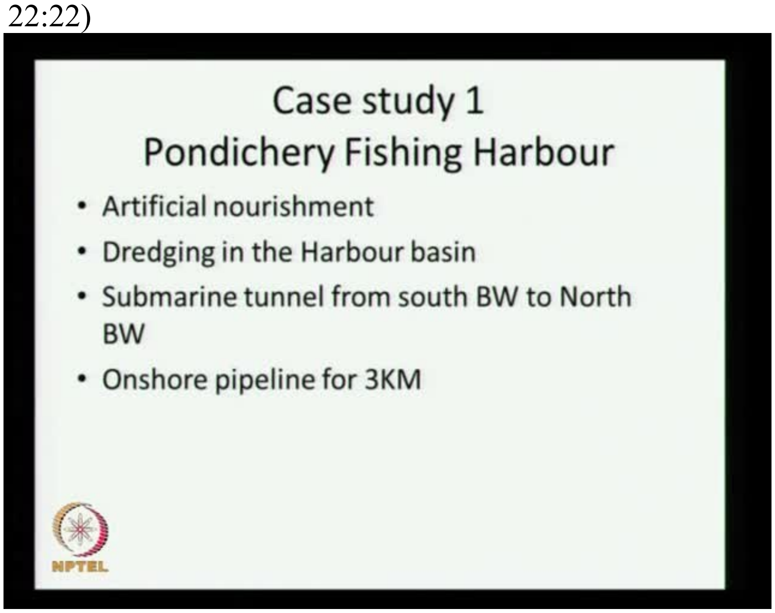
Surf zone means twice the width of the breaker zone. That is what I discussed earlier. There it will be very significant.

(Refer Slide Time: 21:47)



So we are going to study some case studies, we are going to study 6 locations. All of them are on the east coast because West Coast the littoral drift is not from south to north. Some places, it is south to north and most of the places, it is from North to south. This is because of the topography, because of the bathymetry and the direction of the waves.

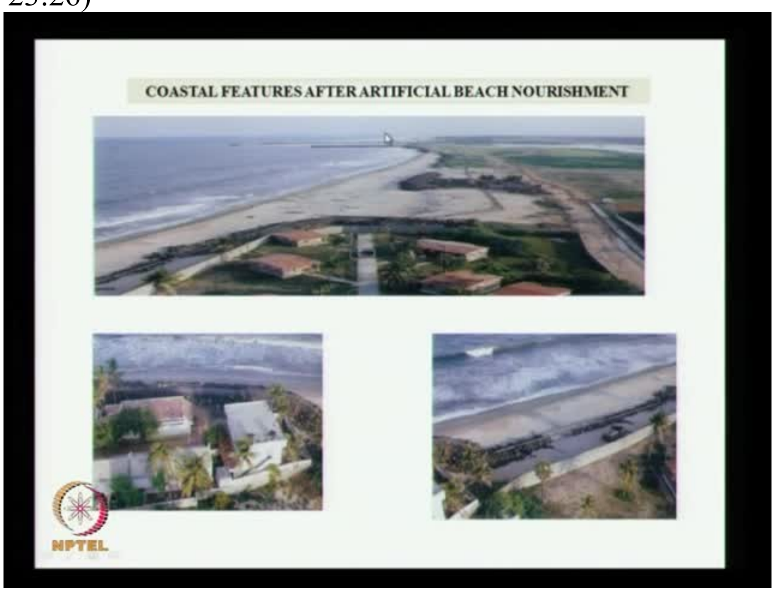
(Refer Slide Time: 22:22)



In Pondicherry Fishing Harbour, this shoreline is protected by various means. By sea walls, but what we have such study artificial nourishment, this artificial nourishment is a continuous process. You have to carry out every year. As I told, it should be done preferably in the non-monsoon season starting from December 15 and completed before March 15. They are not getting out every year because of funds constraints.

But when they have done it, this artificial nourishment, they have seen that it is making the shoreline stable on the northern side preventing it from erosion. So for this artificial nourishment, we dredge in the Harbor basin and there is a submarine tunnel from the southern side to the northern side. That means you pump the sand below the seabed using a submarine tunnel and you lay a pipeline on onshore for about 3 kilometre and dispose the dredge material.

(Refer Slide Time: 23:26)



So here you are seeing this photograph again. This is your south breakwater and this is your north breakwater and between them, you have a submarine tunnel. You dredge it here and then through the submarine tunnel, it comes. See, able to see the pipeline here. Through the pipeline, it comes and it deposits. What you are seeing here as rubble mound seawall, it is also seen here, rubble mound seawall, these are all the places up to which the shoreline was there.

Once we start pumping the sand inside the Harbor basin and brought it here, the sand has deposited here and advanced the shoreline. And this rubble mound seawall is not required for any shore protection. The advantage is, we have a very nice beach, the fishermen can beach their crabs here, people can also go over here.

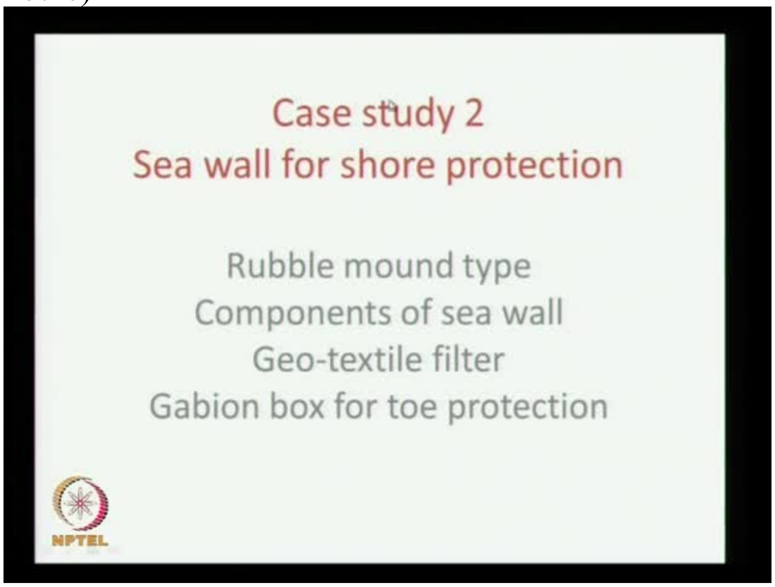
Here also you are seeing the 2 photographs where earlier all along the compound wall, they have put a seawall. The compound wall collapsed also 1 or 2 times but now this is not required.

(Refer Slide Time: 24:35)

This is a famous Gandhi statue in Pondicherry beach where they have put the seawall to protect and the waves were breaking on the seawall but now after we did the artificial nourishment, we can see the beach formation here. People are enjoying thebeach here. And another stretch where the seawall rubble mound seawall was subjected to wave attack. After we have done the nourishment, we can see the beach which has formed.

The unfortunate thing is that they have discontinued this artificial nourishment. Now we are seeing like this only, not like this. No beach in Pondicherry. This is very advantageous, this type of beach nourishment.

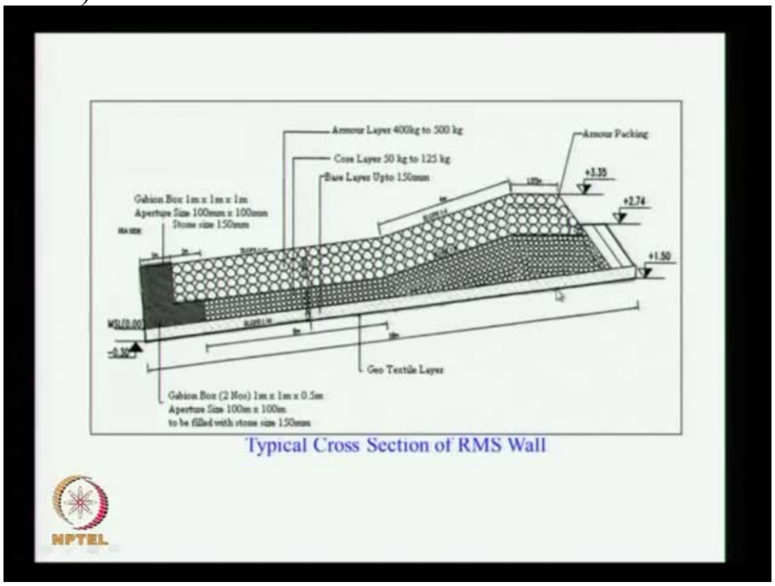
(Refer Slide Time: 25:26)



The 2nd is, the seawall this is for shore protection. This is one-time construction cost. Only marginal cost is required for maintenance. We have what is known as the rubble mound type seawall. We have different components of the seawall like core layer and normal layer. In Kerala most of the places, they have done this rubble mound type seawall. In 2000 when this seawall is to be built in Kanyakumari district and Tuticorin and other places, we have introduced this geotextile filter and gabion box for toe protection.

Because most of the places when we do not use the geotextile filter and gabion box for toe protection, the seawall fails during cyclonic conditions. So this is an improvement which has been built into the design of the rubble mound seawall. We will see the construction procedure of this double mound seawall. There is a design procedure. I will not be discussing it here but it can also be designed just like a breakwater.

(Refer Slide Time: 26:50)



This shows the typical cross-section of the rubble mound seawall. We are given mean sealevel as 0.0. This is not a normal convention. In short data means given as 0.00 but here we have used mean sealevel as 0.00. So we can take about 30 centimetre below the mean sealevel you have to take. Typically, the seawall width is about 18 metres, that is from this point to this point is about 18 meter and we give a slope of 1 is to 10.

So if we give a slope of 1 is to 10 and 18 meter, the vertical elevation difference will be 18 divided by 10, that is 1.8 meter. So here we have minus 0.3 meter. That means here we will have plus 1.5 meter. Right? So if tidal difference is larger, then the width has to be increased so that this level is above the highest high water level. Here, mean sealevel is 00.

In Kanyakumari district and other places, the water level variation is tidal variation is about 0.6 meter. Right? That means this will be approximately your low tide level and 0.3 meter above mean sealevel will be your high tide level. So 0.6 meter is the tidal level. That means part of the breakwater will be submerged during high tide level but during low tide level, there will not be any water.

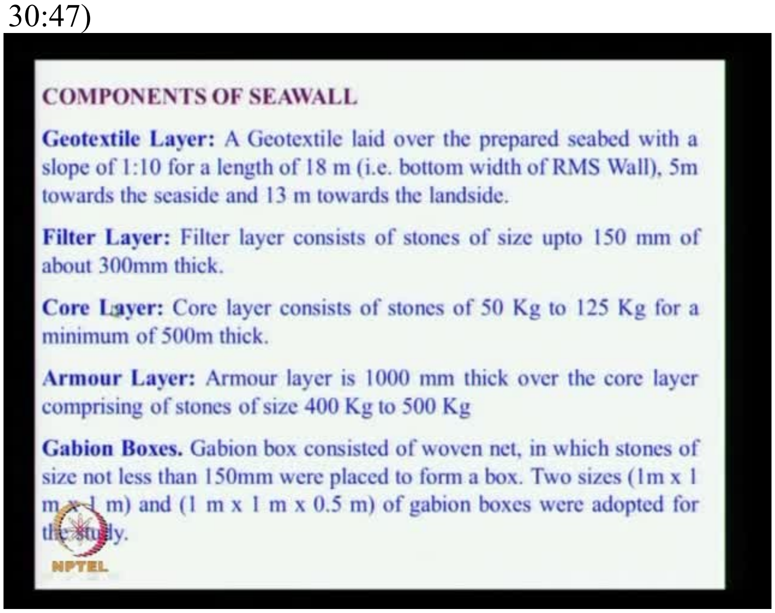
So it can facilitate construction. Point is clear no? From the shoreline, when you want build up to the low water level, you have certain duration in a day where it is without water, so you can do. We put a geotextile filter. This is to separate the seabed material with the base layer. Generally this base layer is a filter layer using sand. Then we have a core layer. This core layer consists of stones, 50 kilogram to 125 kilogram.

Then we have the armor layer which is 400 to 500 kg. This weight of individual stones 400 to 500 kg can be calculated based on the wave height prevailing at the particular location using Adson's formula. Here we have 2 slopes. One slope is 1 is to 10, another slope is 1 is to 4 so that we go at plus 3.35. So even in a very big waves come, the wave will not overtop and come down. That is why we provide here steeper slope.

If you provide the same slope, the top-level will be much lower. So we provide a larger slope. And this is called as a gabion box provided at the toe. This is the toe of the breakwater. Here we put 1 metre by 1 metre by 1 metre box gabions. These are filled with stones of size more than 150 mm. because the opening size for the gabion box is 100 millimetre by 100 millimetre.

These gabion boxes are tied together, adjacent box it is tied together and if there is a based gabion box, 2 boxes are provided, so with this we will be trying this and geotextile filter is provided like this. We will see the advantages of geotextile filter as well as the gabion box in the coming slides. The bottom we are providing 2 boxes, 2 numbers, 1 by 1 by 0.5, the height is 0.5. The aperture size and the stone size is same. And aperture size, because size also you can provide, 150 by 150 also depending on the wave height.

(Refer Slide Time: 30:47)



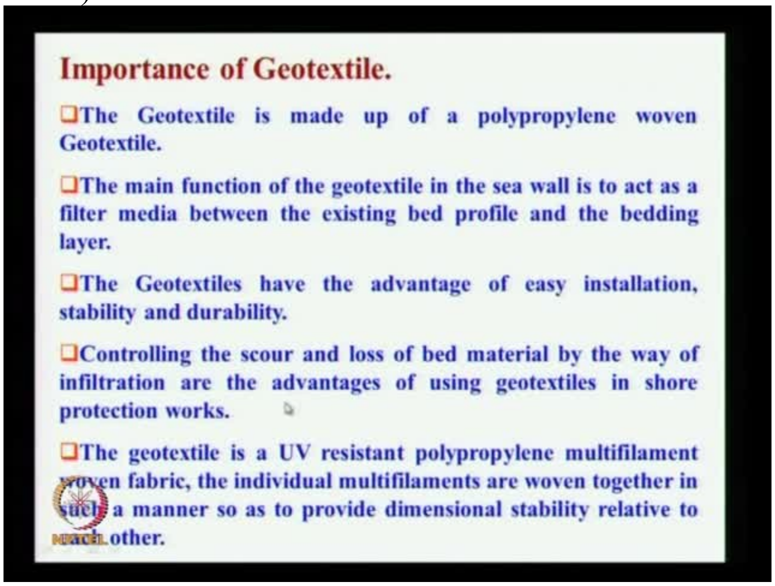
So these of the components of a seawall. One is a geotextile filter, the other is a filter layer, 3rd one is a core layer, a normal layer and gabion boxes. So this is in a slope of 1 is to 10 and about 5 meter towards the seaside and 13 meter towards the land side. The 5 meter towards the sea side is from the high tide level to the toe that is about 5 meters. The filter layer consists of stones up to 150 mm of about 300 mm thick.

I said this base layer or filter layer can be sand. It can be stone also up to 150 mm size because at this location, the base material itself is sand. Suppose you have a clay, then after putting a geotextile filter, it is better to put a sand and then put a stone. Depending on the subsoil condition, the filter layer varies. Then we have a core layer. So this is the size of the stone and this is the thickness of the core layer.

Normally, if we use size of Stone 150 mm, twice the size of the stone, we have to put the thickness of the filter layer. At least twice the thickness of individual material should be there. Here if we are putting 500 mm above thickness, the average size of this 50 kg to 125 kg stone will be 250 millimetre. The normal layer is 1000 mm. This is over a core layer of Stone 400 kg to 500 kg, approximate size will be about 400 millimetre or so.

So twice the size we have to provide this. Then we have provided gabion boxes. 2 sizes, 1 by 1 by 1 on top and 1 by 1 by 0.5 mm at the bottom. You can put 1 by 1 by 1 also at the bottom but since the core layer is 500 thick, we have used 500 mm gabion box to retain the core layer and since the armour layer is 1 metre thick, we have used 1 metre thick gabion box to protect the armour layer right? Suppose the core layer thickness is more, you can go in for a bigger size also. What is the importance of geotextile?

(Refer Slide Time: 33:17)



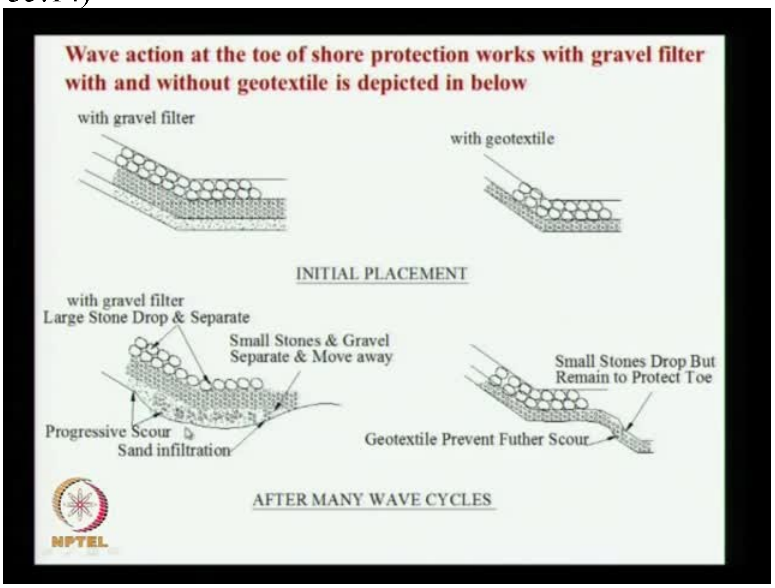
This geotextile is made up of polypropylene woven geotextile. Main function is to act as a filter media. Filter media means like our coffee filter only. Between the existing bed profile and the bedding layer. Bedding layer is nothing but the filter layer. It allows water to percolate but it does not allow the seabed material to get into the bedding material. Bedding material is a filter material, either a sand or a stone of size up to 150 mm. So these 2 things should not come in contact.

That means there is a permeability of the geotextile filter. It should be such a way that the pore size is smaller than the particle size of existing seabed material. Seabed material is 40 microns, the pore size should be 35 microns or 30 micron so that this bed material will not go through that. This controls the scour and loss of bed material by the way of infiltration. These are the advantages of using geotextiles in shore protection works.

One of the important parameter for the geotextile life is UV protection, UV resistant. These are woven together in such a manner so as to provide dimensional stability relative to each other. These geotextiles are normally coming in rolls maybe in 3 metre width. So you lay one 3 metre width and put another 3 metre width with a overlap of about 300 millimetres so that it can be stitched together.

You cannot have, suppose you want to build a breakwater for 1 kilometre long, you cannot have 1 kilometre long geotextile. So 18 meter is the width of the rubble mound seawall. So the roll can be of about 100 meter or something like that. So 3 metre, you lay it, then cut it, then put another 3 metre with a overlap.

(Refer Slide Time: 35:14)



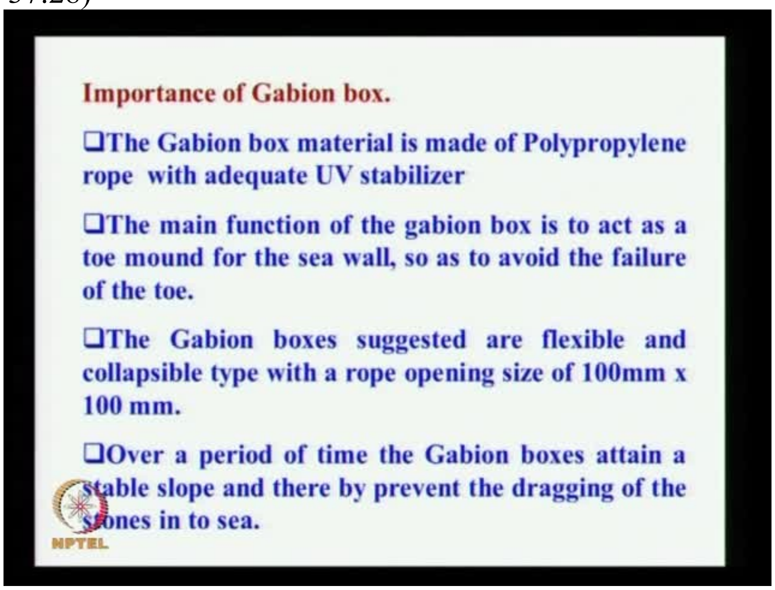
There are 4 sketches shown here. The left side is the one without geotextile, top and bottom figure. The right side is with geotextile, top and bottom. The top figure is initial placement, both look alike. Only thing is here we have a geotextile filter. The bottom after its many wave cycles, so what you are seeing is this bed material is mixed with the stones which are coming here whereas here you are seeing the bed material.

Here we have not shown the bed material but bed material exists here. But there is a filter fabric here. Below that we have the seabed material. So this is the seabed material, this is the core material, this is the armour stone. So the seabed material and core material, there is no filter fabric. So this material can go down, this material can go in go out. So whole thing get mixed here.

The small stones and gravels separate and move away and the large stone drop. These stones also will drop and they also will separate. Then they will have a progressive scour and sand filtration also will take place. These are the disadvantage and over a period of time, you see we have 2 layers of Stone. Some of the stones are not here, missing. It might have taken away by the waves or it could have gone inside.

So here we have a geotextile filter. It does not allow the seabed material to go inside. This does not allow the scour to take place. These small stones may, it is not like this. It is down but it remains there to protect the toe. But this alone is not sufficient. As you see here, here there is a potential failure at the toe. So here only we have provided the gabion boxes to further strengthen that as a toe protection.

(Refer Slide Time: 37:28)

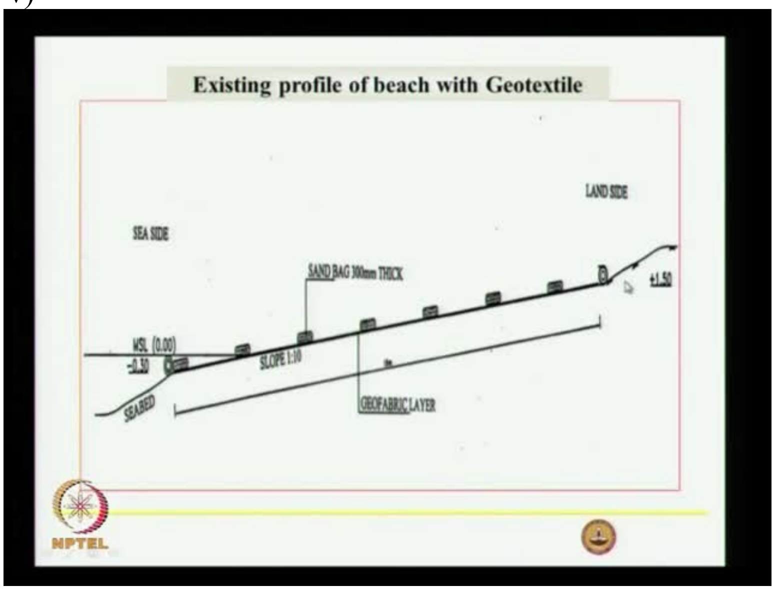


So the gabion boxes these are also made of polypropylene rope, they are having adequate UV stabilisation. UV stabilisation means they will provide some colouring is there, some black colour, some dark coating or something like that they will do. But there are different type of gabion boxes, one is made of metallic wires, another is made of rope. We prefer rope because it is flexible and adjust to the seabed.

This acts as a toe mount of the seawall so as to avoid failure of the toe. The gabion boxes suggested are flexible. They are not rigid. The metallic gabion boxes are rigid. Whereas these gabion boxes are flexible. They are collapsible type with a rope offering size of 100 mm by 100 mm. Collapsible means for packing and all, it is very easy. So it is collapsible, just you have to open it up. Over a period of time, the gabion boxes attain a stable slope and thereby prevent the dragging of the stones into the sea.

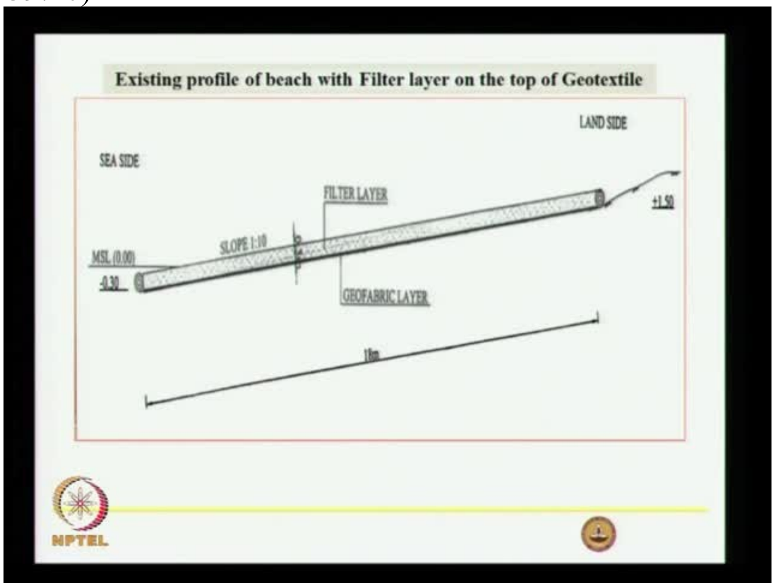
So it may get submerged, it may not be remaining vertical. It may change its shape but it will remain there where you have placed. So it will protect the stones, the core stones and the armour stones to slide into the sea. How to do this construction?

(Refer Slide Time: v)



Another 5 slides, we will show how the construction is there. Here we are seeing the seabed. So here what you are seeing is a roll of the geotextile fabric. You lay it here and then put some sandbags of about 300 mm thickness at intervals of maybe 2 metre or 3 metre. This is the seaside and this is the landside.

(Refer Slide Time: 39:10)



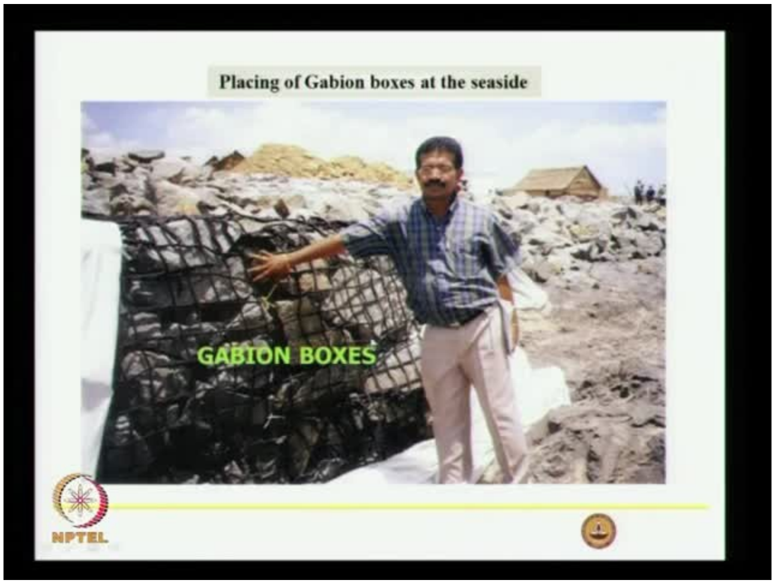
Next you place the filter layer that is 150 mm thickness. Up to 150 mm size, 300 mm thickness, you maintain the slope of 1 is to 10. Suppose the slope is flatter than this, you may rise it to make it 1 is to 10. If it is steeper also if it is steeper, you fill it and rise it. If it is flatter, you make it as it is. You do not make it slope 1 is to 10. Suppose it is 1 is 220 slope is there, you leave it as it is. Do not try to make it 1 is to 10. But you adjust in the core layer.

Then we place the gabion box of 0.5 meter height. Then next, you put the core stone. Next you place the another gabion box, next you place the armour stone. And this geotextile filter you can take it down inside like this before placing this toe mount gabion box you can take it here like this. This you can take it back like this so that it can be anchored. You can take it like this and take it like this also.

(Refer Slide Time: 40:24)

This here you see the houses here, they are very close to the shoreline. They have made some concrete wall here. There are some fishermen boats are here. Now what they want to make is this looks to be flatter than 1 is to 10. They are trying to make some slope what we have designed and then they have laid the geotextile filter.

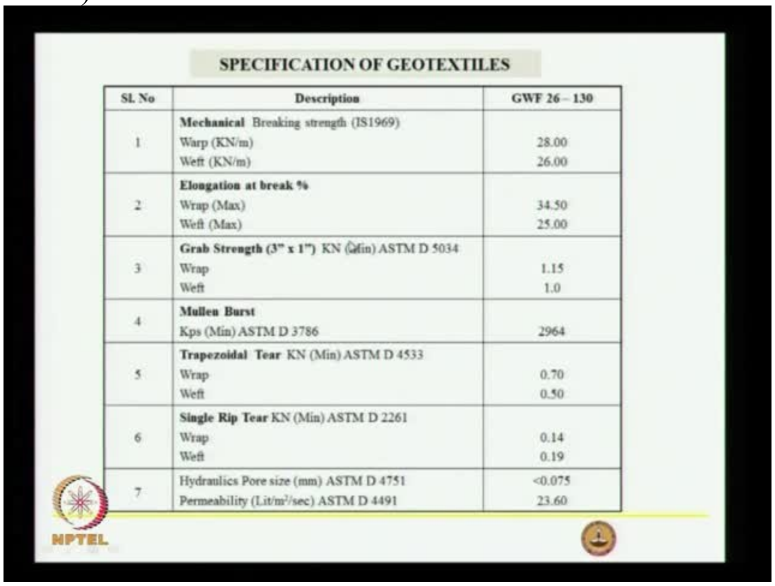
(Refer Slide Time: 40:49)



I was telling about 3 metre. This is the 3 metre width. And then they will put another 3 metre here, they will overlap here 300 millimetre. This is the sea side. Whatever sand they are excavating here, they have it as a core stone dam here. They have put the gabion boxes. Originally we have taken the filter fabric on top of the gabion box. Finally we found that it is not good. It is not as good in ultraviolet protection as before and does not allow the dissipation of waves also.

It gets damaged very easily. The best way is to take it below the gabion box. That is what we did earlier. This is a core stone which they are filling it up here. Then this is the gabion box. Afterwards, we removed this filter layer and you can see a person by height maybe about 1.7 metre, this height will be about a metre. These are collapsible type. This is called as aperture size which is about 100 MM by 100 MM. You are filling inside with stone, the size of stone should be greater than 150 millimetres.

(Refer Slide Time: 42:06)



SPECIFICATION OF GEOTEXTILES

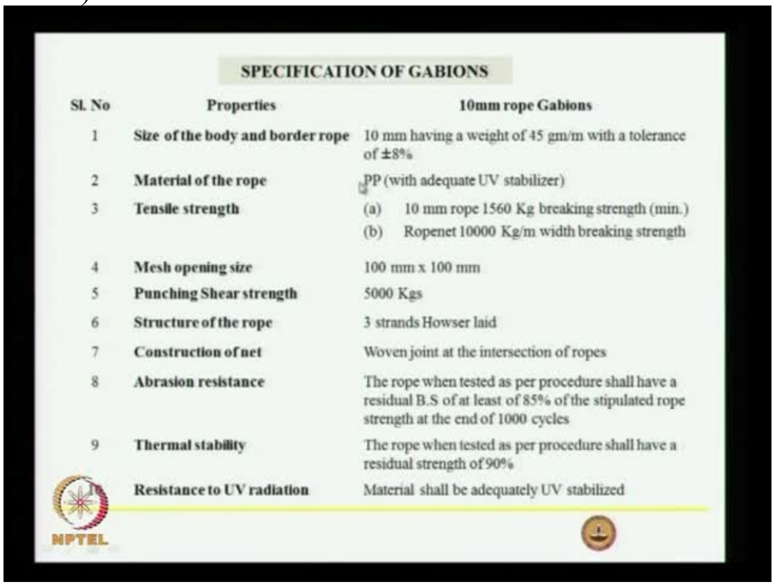
Sl. No	Description	GWF 26 – 130
1	**Mechanical** Breaking strength (IS1969) Warp (KN/m) Weft (KN/m)	 28.00 26.00
2	**Elongation at break %** Wrap (Max) Weft (Max)	 34.50 25.00
3	**Grab Strength (3" x 1")** KN (Min) ASTM D 5034 Wrap Weft	 1.15 1.0
4	**Mullen Burst** Kps (Min) ASTM D 3786	 2964
5	**Trapezoidal Tear** KN (Min) ASTM D 4533 Wrap Weft	 0.70 0.50
6	**Single Rip Tear** KN (Min) ASTM D 2261 Wrap Weft	 0.14 0.19
7	Hydraulics Pore size (mm) ASTM D 4751 Permeability (Lit/m²/sec) ASTM D 4491	<0.075 23.60

There are certain specifications. Geotextile woven fabric some 26 by 130 these are some the 26 is nothing but some strength which it should have weft strength in kilonewton per metre which is 26. That is mentioned here. Weft and warp are 2 directions where we are doing the woven geotextile, there are 2 directions. One direction is called as warp, another direction is called as weft.

The direction of the woven direction, it will be more otherwise it will be less. This 130 is grams per square metre. That is if we take 1 square metre of this geotextile filter and find the rate, it will be about 26 grams per square metre. So if you want higher strength even up to 80 we can have. So it can go up to 360, 380 grams per square metre. Then we have some elongation at which it will fail.

Then some grab strength and trapezoidal sheer and hydraulic pore size 0.075 and less. What is the permeability? These are all to be decided based on your seabed material, the size of the pores of the geotextile fabric.

(Refer Slide Time: 43:44)

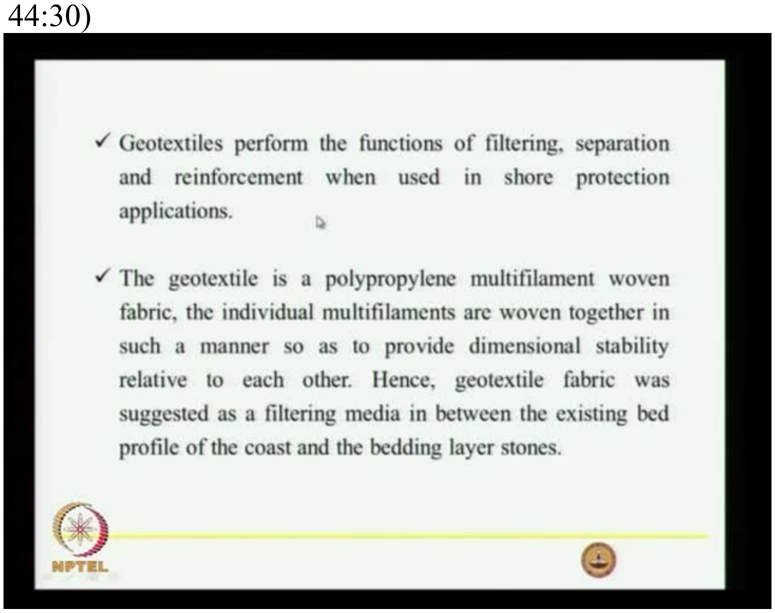


SPECIFICATION OF GABIONS

Sl. No	Properties	10mm rope Gabions
1	Size of the body and border rope	10 mm having a weight of 45 gm/m with a tolerance of ±8%
2	Material of the rope	PP (with adequate UV stabilizer)
3	Tensile strength	(a) 10 mm rope 1560 Kg breaking strength (min.) (b) Ropenet 10000 Kg/m width breaking strength
4	Mesh opening size	100 mm x 100 mm
5	Punching Shear strength	5000 Kgs
6	Structure of the rope	3 strands Howser laid
7	Construction of net	Woven joint at the intersection of ropes
8	Abrasion resistance	The rope when tested as per procedure shall have a residual B.S of at least of 85% of the stipulated rope strength at the end of 1000 cycles
9	Thermal stability	The rope when tested as per procedure shall have a residual strength of 90%
10	Resistance to UV radiation	Material shall be adequately UV stabilized

This is for the gabion box. This weight is 45 grams per metre. This is a polypropylene rope. The breaking strength is given. Mesh opening size is given, punching shear strength, the type of the rope, abrasion resistance, thermal stability, resistance to UV radiation. Normally they claim, it is resistant for about 10 years, 15 years, 20 years like that. Actually it will not fail. Maybe the strength will reduce by about 40 percent over a period of time.

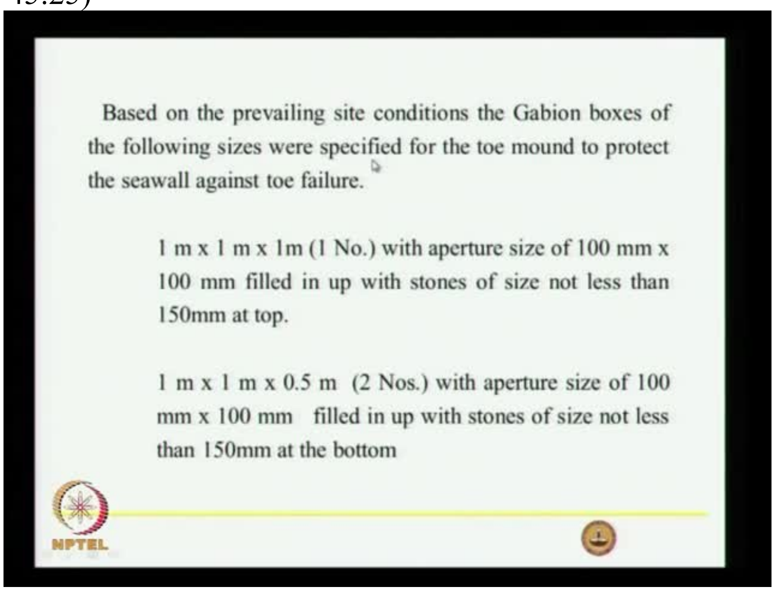
(Refer Slide Time: 44:30)



What are the functions of various materials we have used? One is the geotextiles, they perform the functions of filtering. Filtering means allowing the water passage. Separation between the seabed material and the filter material. It acts also like a reinforcement when used in shore protection. If you put a geotextile filter, the whole mass above the geotextile filter acts as a single unit.

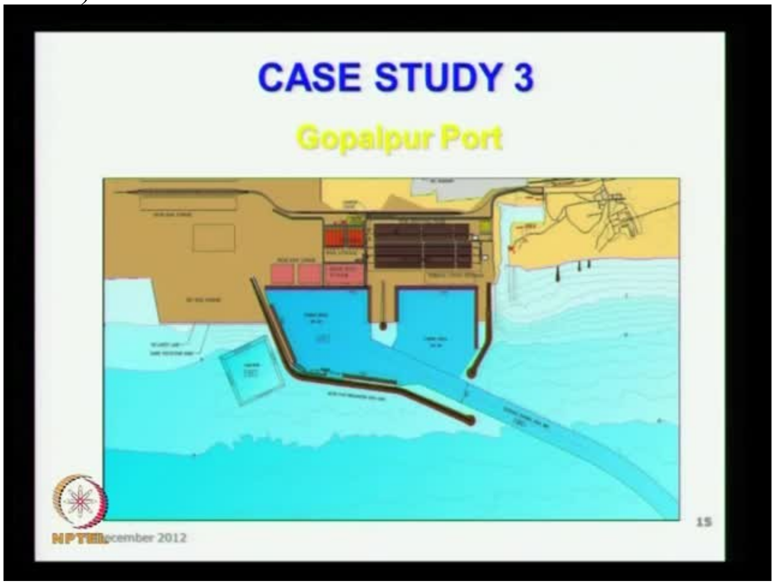
This is a polypropylene multi filament woven fabric, the individual multi-filaments are woven together so that it provides a dimensional stability related to each other and that is why we suggested this as the filtering media. Earlier days what did they use? They used sand itself as a filter media. Where we have clay bed, we use sand itself as the filter media but this is a better material. The cost is not very high. Maybe, it may be around Rs. 100 per square metre now.

(Refer Slide Time: 45:25)



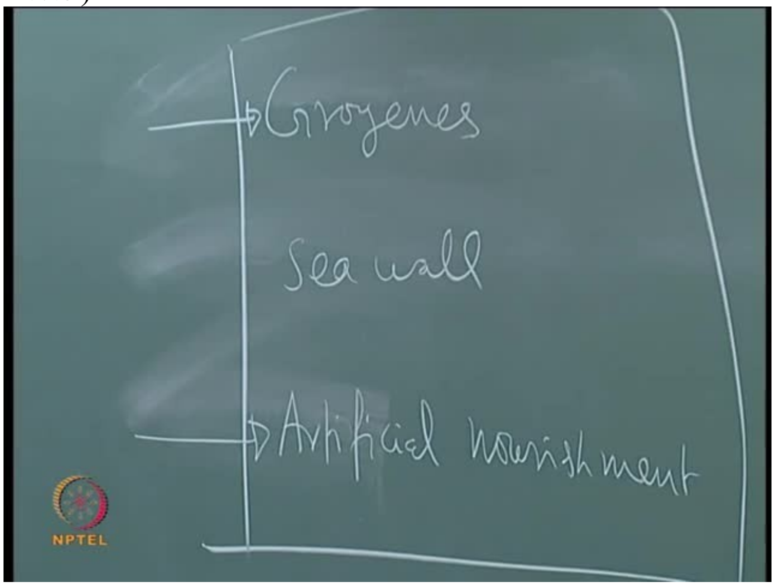
Then we have the gabion box. The cost of 1 metre by 1 metre by 1 metre box will be around 1500 rupees and this is the size of the opening, 100 by 100 filled with stone of not less than 150 and another size is 1 by 1 by 0.5.

(Refer Slide Time: 45:44)



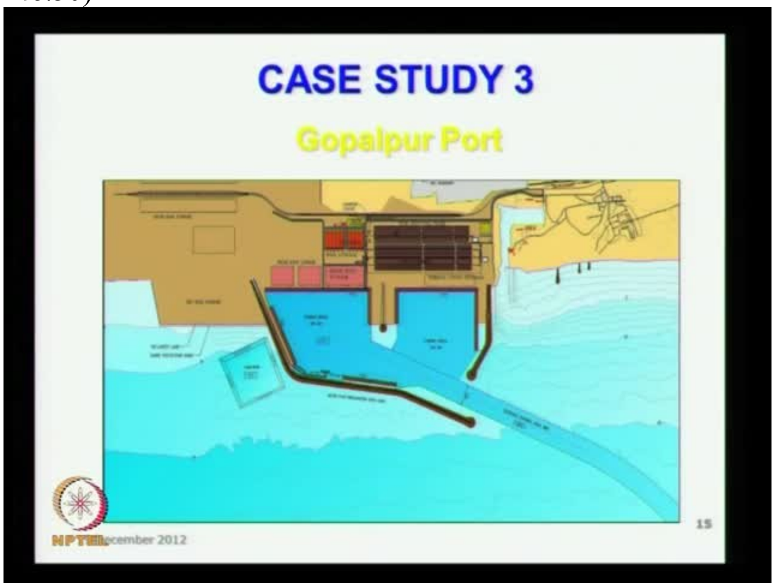
So with this we have completed the 2nd case study. 1st case study is artificial nourishment, 2nd case study is the seawall. The 3rd case study what we are going to see is for Gopalpur port. There we will be seeing 3 types of shore protection.

(Refer Slide Time: 46:09)



The 3 types of shore protection that will be considered are, we will have groynes, we will have a seawall, we will also have artificial nourishment. So all the 3 we will be doing. This port is under construction now. They have completed the groyne construction partially completed. Artificial nourishment, they are going to do shortly. This is in the East coast between Andhra and Orissa border in the Orissa state.

(Refer Slide Time: 46:50)



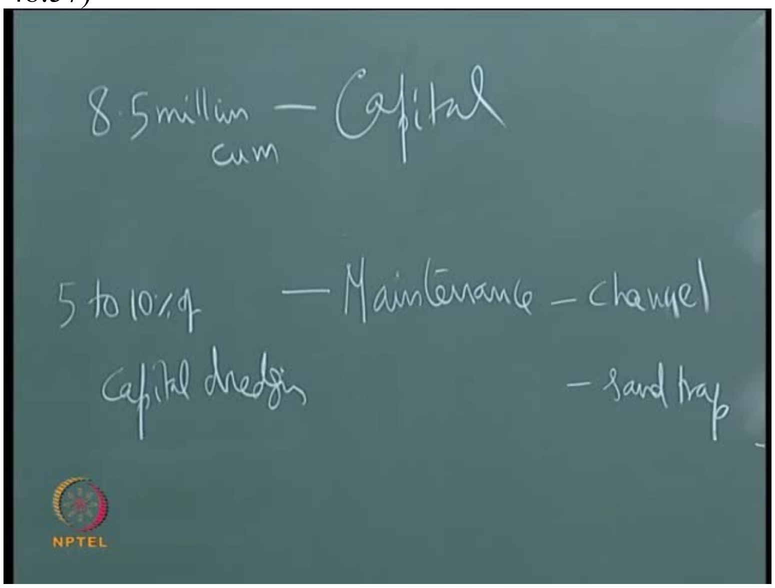
So this is the southern breakwater. It is about two and a half kilometre long. Now they are building this intermediate breakwater called as the North breakwater. Already there is a coastal inlet inside. They have two breakwaters here and these are the groynes which are schematically shown but detailed design has been carried out recently and this is your 5 metre contour, this is your 1 metre contour, this is about 15 metre contour.

This 10 metre contour is available at a distance of about 700 metres or so, a very steep slope, ideal location for a port development. If we go about 700, 800 metres, if we get 10 metre contour, it is really good. Most of the other places, it is varying from Tuticorin, it may be 10 metre contour may be available after 3 kilometres, Chennai one and a half kilometres, here it is only 700 metres.

This is your existing shore line. After development, we want to, when you start building this breakwater, the shoreline also will advance like this. And this is the sand trap which will be created 1 kilometre by 1 kilometre for about 10 meter depth. So when there is a nourishment, when there is a deposition taking place, so they, it will get deposited. Original water depth will be increased in the sand trap by about 5 to 6 metres. So the sand will get deposited here.

The dredger will come and remove the sand and then they will go here. They will nourish the beach on the northern side using now we have what is known as rainbow technique. I have a slide, I will show that. At present, what they are doing is, they are making this navigation channel and the turning basin. The 1st phase is under construction now.

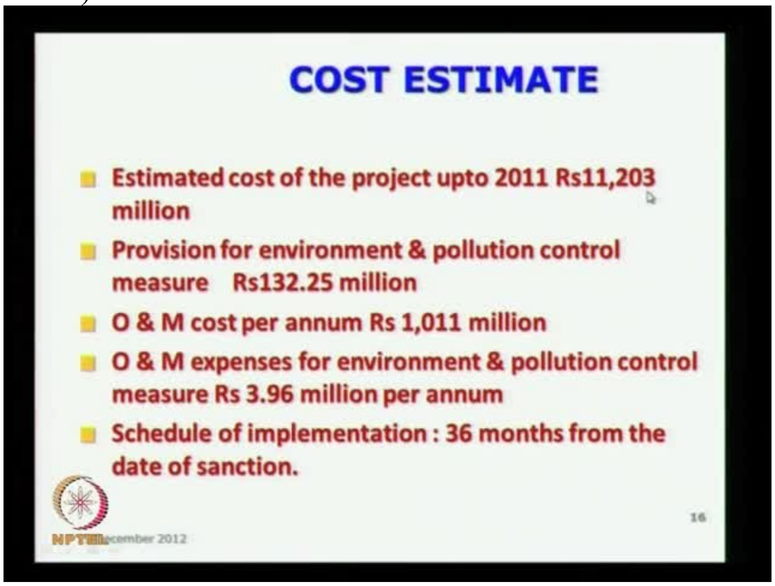
(Refer Slide Time: 48:57)



When they do this dredging, there are 2 types of dredging-one is called as capital dredging, another is called as maintenance dredging. So in the maintenance dredging, they will maintain the channel, they will remove the material from the sand trap, these are the things they do it. Generally, this maintenance dredging will be about 5 to 10 percent of capital dredging. In capital dredging, they want to do about 8.5 million cubic metre.

So maintenance dredging will be 10 percent of this means 0.85 million cubic metre. So every year they have to remove 0.85 million cubic metre and deposit on the northern side to make this shoreline stable.

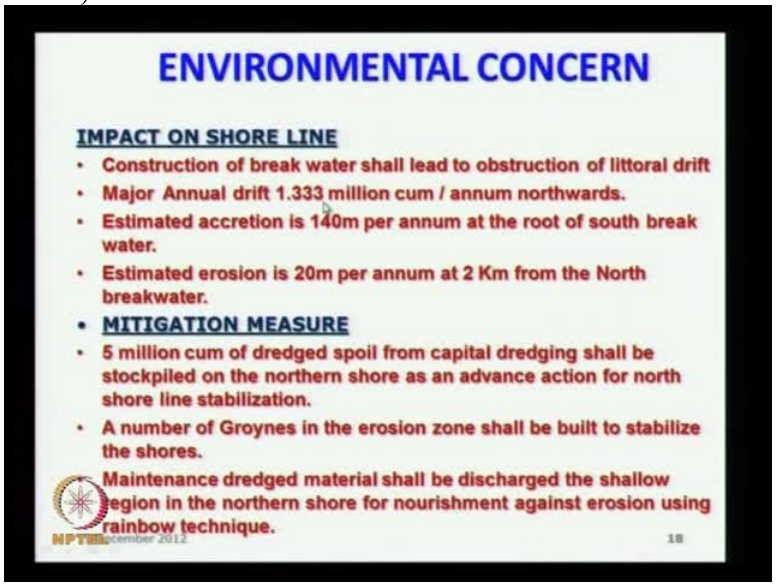
(Refer Slide Time: 49:48)

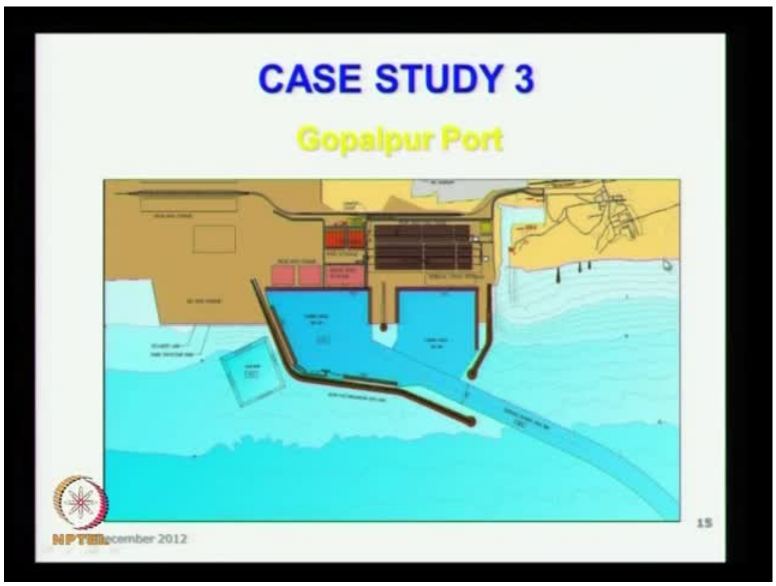


So these are showing some cost. Cost of the project is about Rs. 11,203 million. Out of which, about 10 percent they have provided for environment and pollution control. The operating and it iscoming about a percent, 1 percent right? About 1 percent. Operation and maintenance cost is about 10 percent. Then these are O and M costs for environment and pollution control measure that is every year they will be spending about Rs. 3.96 million and they will complete the total project in about 36 months time.

It takes about 3 years to make the port operational, phase 1 and phase 2. Phase 1, they are planning to do in 18 months.

(Refer Slide Time: 50:42)





What are the environmental concerns? This is what I had told in the beginning. When you want to build a breakwater, there will be certain issues in the environment. What are these issues? One is the conversion of the breakwater will lead to obstruction of littoral drift. The major annual drift will be about 1.333 million cubic metre annum Northwards. There will be a southern drift also but northern drift is about 1.33 3 million cubic metre per annum.

Estimated accretion is about 140 metre per annum at the root of the South breakwater. That is when you have the South breakwater, the South breakwater, the shoreline will advance by about 140 metre every year if we do not do any protection measure. Estimated erosion is 20 metre per annum at 2 kilometre from north of the breakwater.

Suppose you have the North breakwater here. At 2 kilometre away from this, it will erode by 20 metre. This accretion will be like this. The accretion will go like this. At the root of the breakwater it is 140 metre. As you go towards the southern and southern side, it will get reduced. Similarly, erosion maybe more here but as we go about 2 kilometre, the erosion is about 20 metre per annum. This is based on the numerical model study and this is happening also.

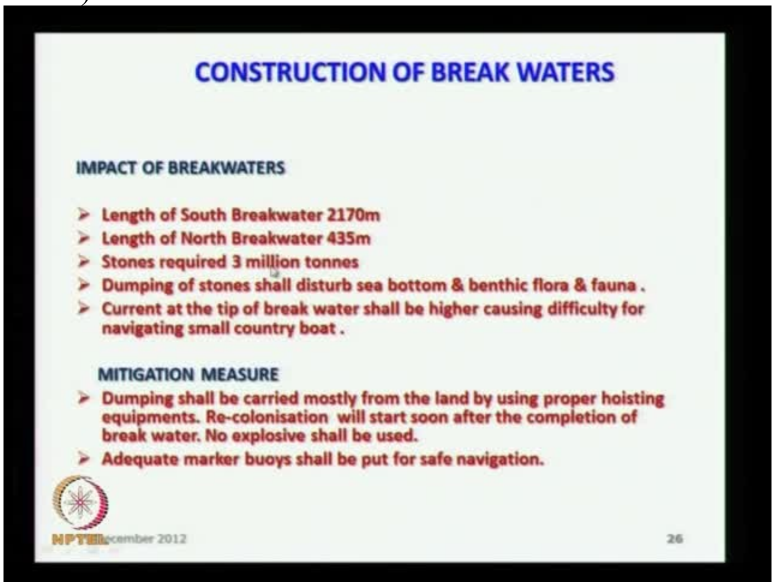
We have seen that after construction of breakwater, this much accretion on the southern side and this much erosion on the northern side. What is the mitigation measure? We have to for capital dredging to create the entrance channel, see this channel, I have seen this is 5 metre, 10 meter and 15 metre contour. The channel depth should be 15 metres, that means the whole area here they will dredge to 15 metre.

Whatever material that they are dredging, some of them will be disposed into the sea, some of them will be put on the northern side. So that is about 5 million cubic metre. They will be stockpiled on the northern shore as an advance action for north shore line protection. This is an advance action. So we make a stockpile. Stockpile means we put more sand, then it will get eroded so that for another 5, 10 years, you do not have to do any artificial nourishment.

So we make a stockpile. But this stockpile will remain in place if you do a groynes. You have a groyne field along with the artificial nourishment, then even for about 25, 30 years, you may not have to do any artificial nourishment. We have to see what happens with the groyne. And the maintenance dredged material which is about 5 percent or 10 percent of the capital dredging, they also will be discharged on the northern side for nourishment against erosion using rainbow technique. This is the mitigation measure.

Whenever you submit a environmental management plan, you have to give 2 parts, one is the what is the impact and what is the mitigation measure. And you have to enforce the mitigation measure.

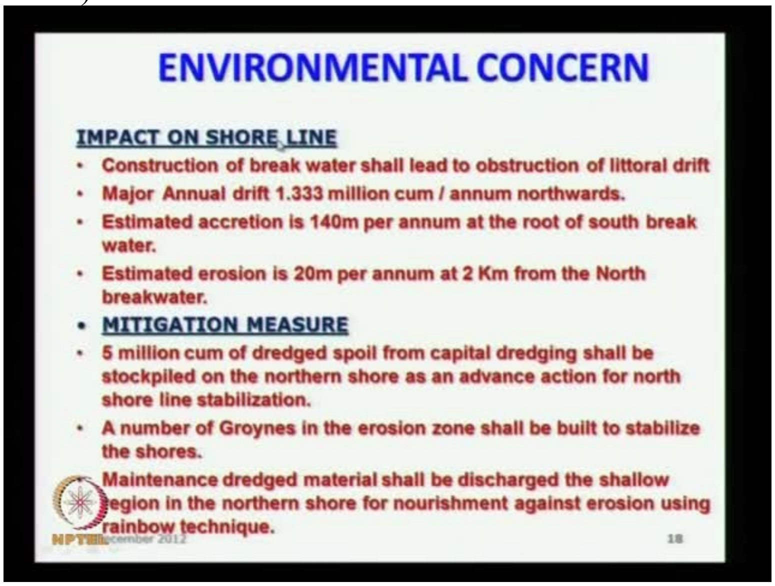
(Refer Slide Time: 53:48)



So when you want to construct the breakwater, southern breakwater is about 2 kilometre, North breakwater is about 500 metres, the stones required are about are about 3 million tonnes with artificial armour. Now it has gone up, about 6 million tonnes with breakwater. When you dump the stones, they will disturb the sea bottom and benthic flora and fauna, current at the tip of the breakwater shall be higher causing difficulty for navigating small country boat.

These are all the impact. Mitigation is, damping shall be carried out mostly from the land by using proper hosting equipments. Then the recolonisation of the benthic and flora will take place immediately. And we should not use any explosives or anything like that at this location. This is mainly if you want to make trench and things like that. And you have to make marker buoys or safe navigation from the tip of the breakwater, you should mark some distance so that they know where the tip of the breakwater exists.

(Refer Slide Time: 54:54)



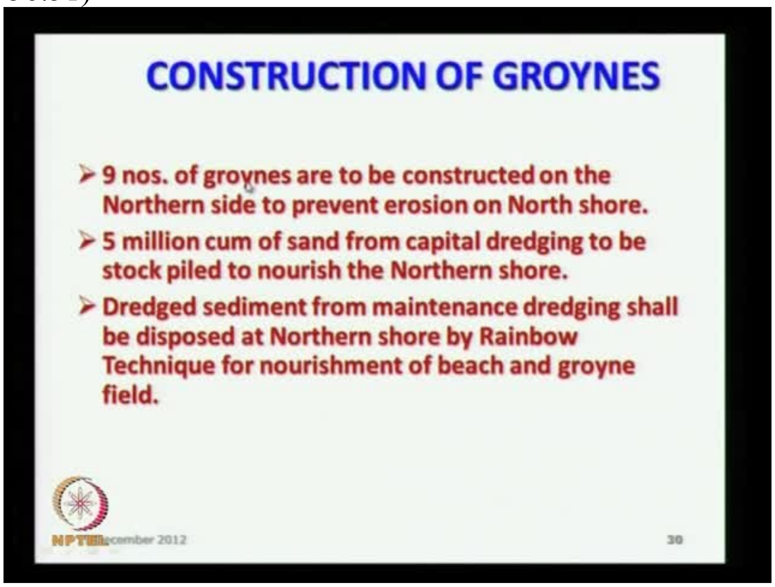
Then we have one more item that is what is the effect of dredging. I am discussing about 3 issues, one is what happens to shore line? What is to be done when you build a breakwater and what is to be done when you do a dredging? The dredging volume is about 8.5 million cubic metre. 5 million cubic metre is sent to the northern side, 3.5 million cubic metre at about 25 meter water depth.

This dredging and disposal, they also will disturb and it will also create some turbidity. So the mitigation measure is, there will be limited temporary dislocation of sea bottom flora and fauna in the Harbor as well as the approach channel during construction period. The recolonisation will start soon after completion of dredging. This can be done by Marine EIA studies. What you have to do is, you have to carry out a monthly study to ascertain what is the that parameters.

Before starting the work, we should collect the data and that, you use it for comparison with the data when you do various activities. This control you have to do for dredging and disposal by using latest technology putting silt curtain limiting the area of turbidity. And if the material is sand, the turbidity will be less. If it is a clay material, the turbidity will be more. Mostly in Gopalpur it is sand material. So turbidity will not be a problem also.

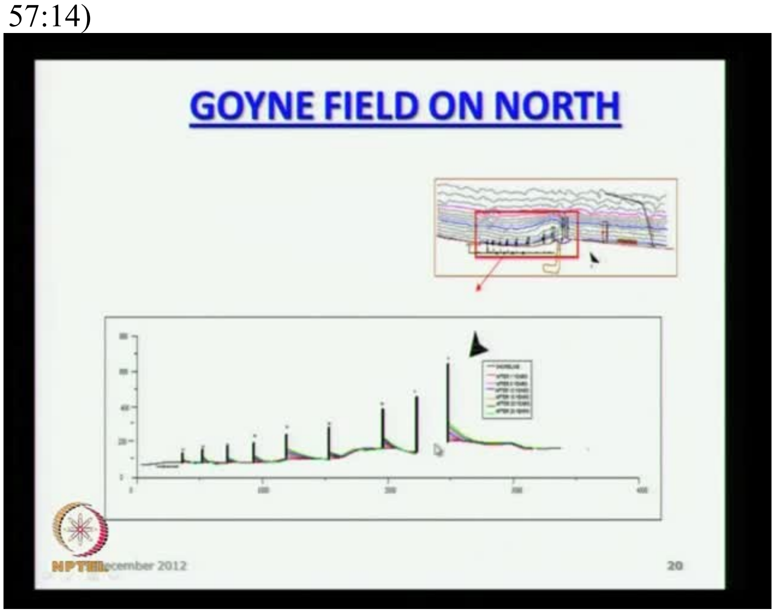
And when you are depositing in a 25 meter water depth, when you are depositing 8.5 million cubic metre over an area of about 3 kilometre by 3 kilometre, the bed level shall not increase more than 1 foot, that is 0.3 meter. Because we are removing the soil and we are putting a 25 metre contour, the water depth shall not very too much. So that also you have to see.

(Refer Slide Time: 56:51)



And to keep the artificial nourish the sand in place, we are planning about 9 groynes. Now we have increased it to 11 and about 5 million cubic metres will be nourished on the northern side as the stockpile and further when you do the maintenance dredging, we will use it by rainbow technique to the northern side.

(Refer Slide Time: 57:14)

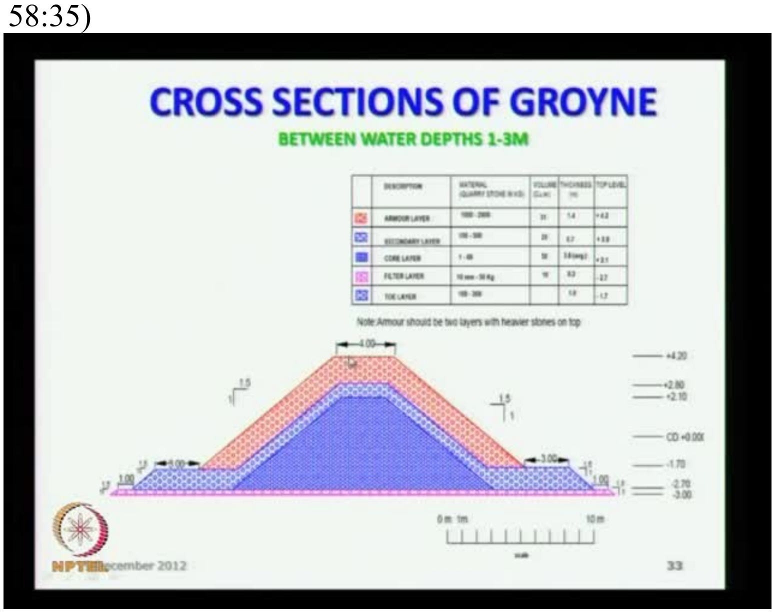


This shows the photograph of the groynes on the northern side. Your this shows your southern breakwater and the intermediate breakwater. This is the groyne field which is on the northern side. So you can see here the groynes. This is called as a transition groyne. The length of the groyne typically reduces as we go towards the north and the spacing between the groyne is proportional to the length of the groyne.

Typically, the spacing between the groyne is about 2 to 4 times the length of the groynes but you have to do some model study. So over a period of time, shoreline after 25 years, the shoreline advances like this. So actually, this has happened in Chennai port. I will show the satellite imagery how the shoreline is advancing. Generally, the shoreline is advancing on the southern side and the seawall is built beyond this last groyne. Right?

We have the groynes and we have the seawall. This artificial nourishment as a stockpile what we will do is, we fill up to this point originally itself. So this whatever we have filled, it may get removed over a period of time. Ennore port, we have done the stockpiling. I will show the photographs how we have done that.

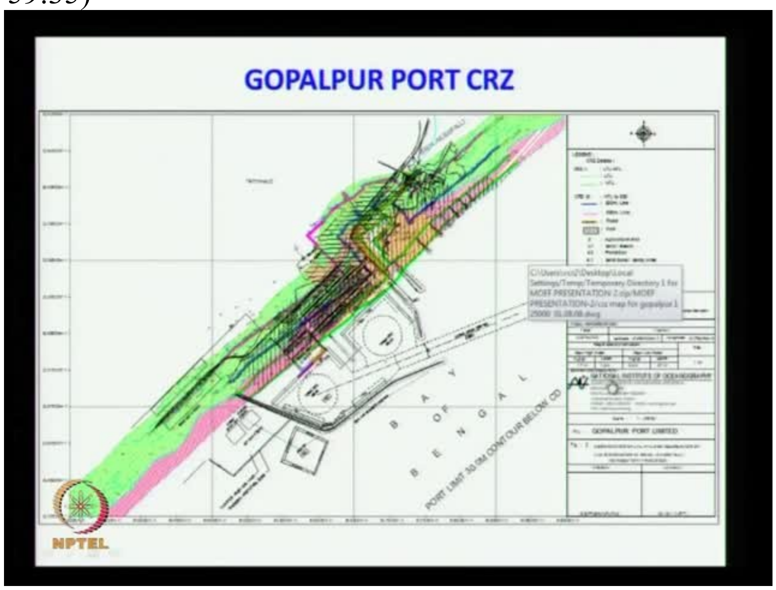
(Refer Slide Time: 58:35)



The groyne cross-section is shown here. So we have the seabed at about minus the tip of the groyne varies at different contours, may vary from 1 metre to 4 meter. At about 3 meter water depth, if you want to put the groyne, we have to put the top layer, the width of the groyne is 4 meter for construction purpose, normal layer is bigger size stone, 1000 to 2000 kg. Then we have a secondary layer, 100 to 200 kg. then we have the core layer, 1 to 50 kg, then we have a filter layer, 10 mm to 50 kg.

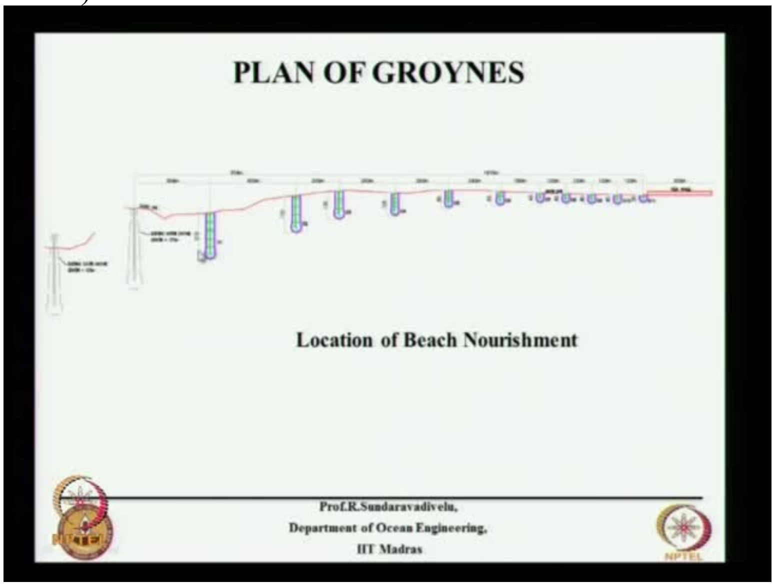
Then we have the toe mound here which is about 100 to 300 kg. So this toe width is 3 metres, depth is about a metre. And the slope on both the sides are about 1.5 horizontal to 1 vertical. The top-level is 4.2. The highest water level is somewhere around plus 2.2 or so. We are keeping it much above this point.

(Refer Slide Time: 59:35)



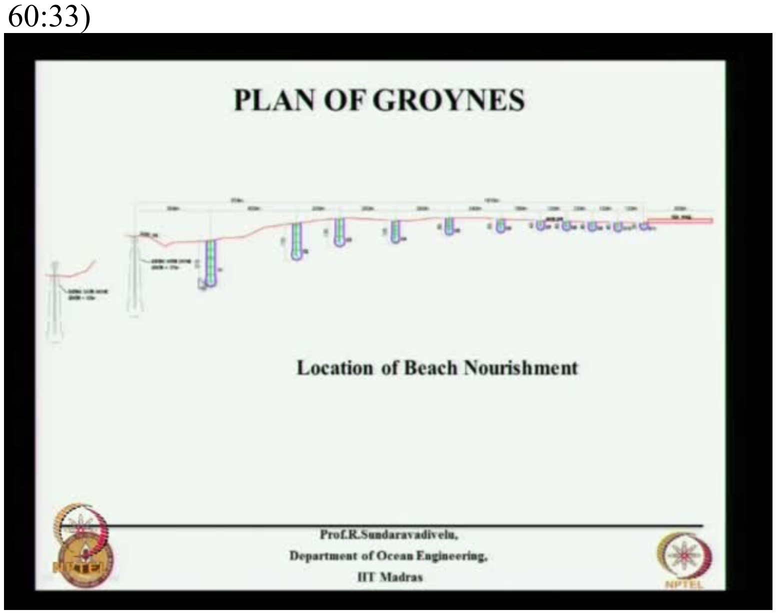
This shows the CRZ map. The CRZ map in this case has been made by National Institute of oceanography. There are only few agencies which are authorised to make this, 7 agencies. One of them is in Avo. They are marking various coastal features, they are putting the groynes also. They are putting the sand trap, entrance channel and the turning circle. This is the 1st phase, this will be the 2nd phase, this is the groyne which is built for the inlet. These are the 9 groynes. Beyond that we will have the sand trap.

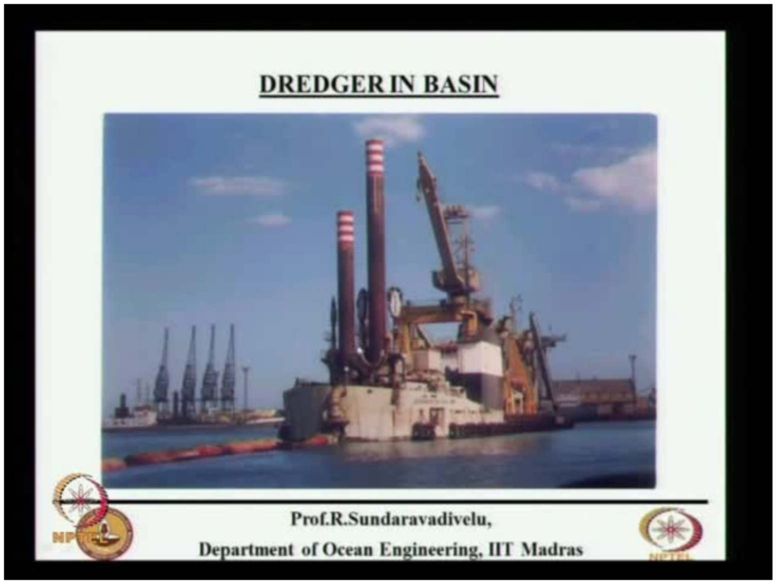
(Refer Slide Time: 60:13)



This is what is actually now being built now. These are the inlet groynes, these are the 11 groynes. The distances are shown here. This is the seawall which is shown here. These groynes are built 50 percent now. Now they will be stockpiling the sand right up to this toe of the breakwater.

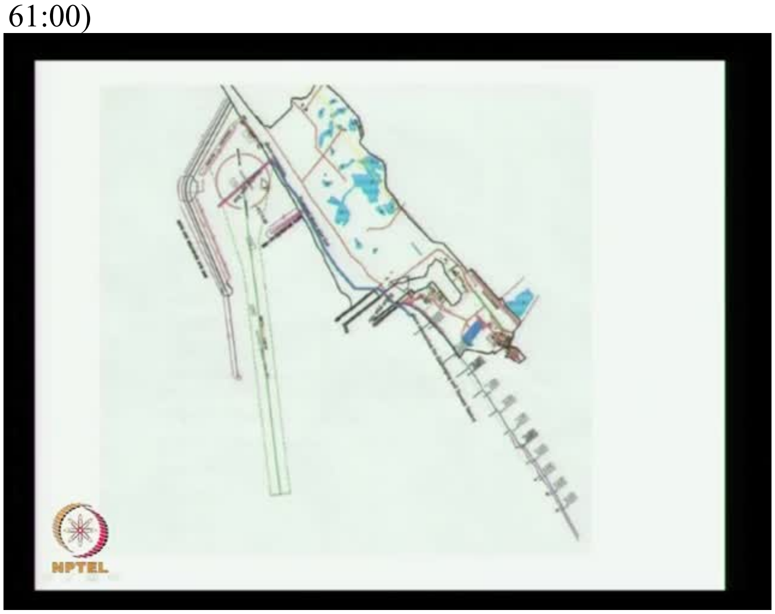
(Refer Slide Time: 60:33)





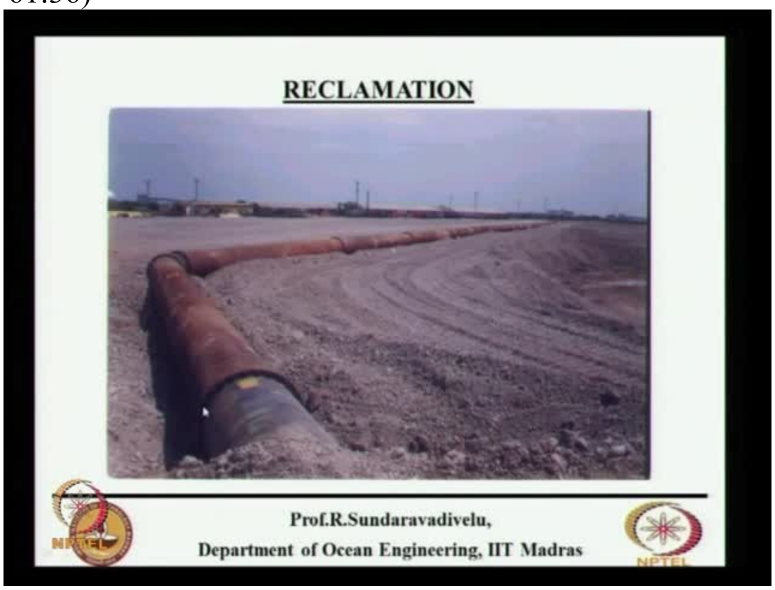
Normally they use a dredger to dredge the basin and there is a pipeline here. Initially what they want to do is, they want to nourish the portion between this existing breakwater for the inlet and the 1st groyne by laying a pipeline. Other thing, they will go into the sea here by another dredger and then do a rainbow. I will have a slide, I will show that. So they are dredging and there is a floating pipeline.

(Refer Slide Time: 61:00)



A floating pipeline will go, they will take it to the shore. They are dredging here, the pipeline will go like this, go here like this, it will cross. It will cross like this and it will get here. These are the 2 groynes for the inlet. There is an approach tussle earlier and this is the 1st groyne. So the floating pipeline and the pipeline on the land will nourish the distance between the 1st groyne, northernmost groyne of the inlet and the groyne number 1. This is earlier built to make this mouth opening.

(Refer Slide Time: 61:36)



So this is the pipeline which is being laid for one of the projects for reclamation purpose, same thing they can use.

(Refer Slide Time: 61:45)

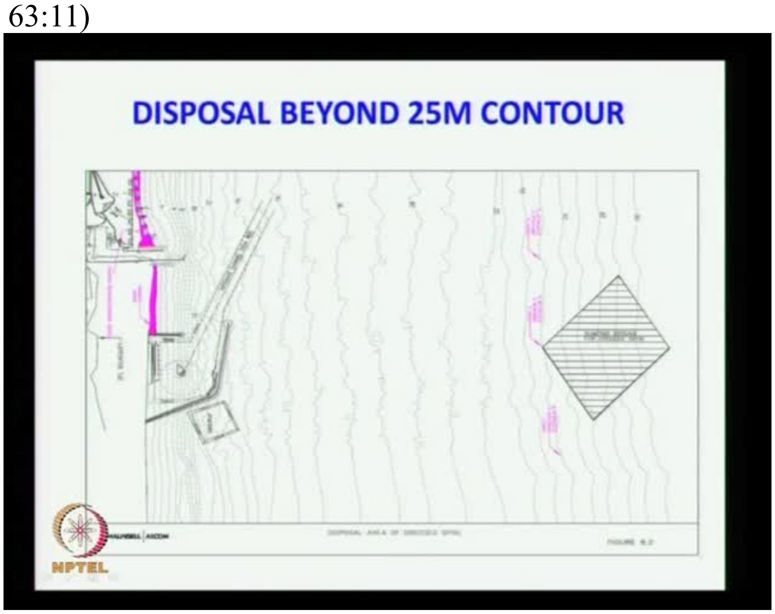
This slide show the groynes built and the red line shows the shoreline when the groynes been started. That is in December 2011 this was the shoreline, now December 2012, this is your shoreline, about 20 to 40 metres, the shoreline has got eroded. This is what we predicted, about 20 metre will get eroded as we start constructing our groynes. So this figure is clear? This is the shoreline in December 2011 when we started the construction of breakwater and construction of groynes.

Over a period of time, the erosion has taken place like this. Now we are doing the artificial nourishment and bringing the shoreline, green line to this level,(())(62:35). This is called as the rainbow method.

(Refer Slide Time: 62:42)

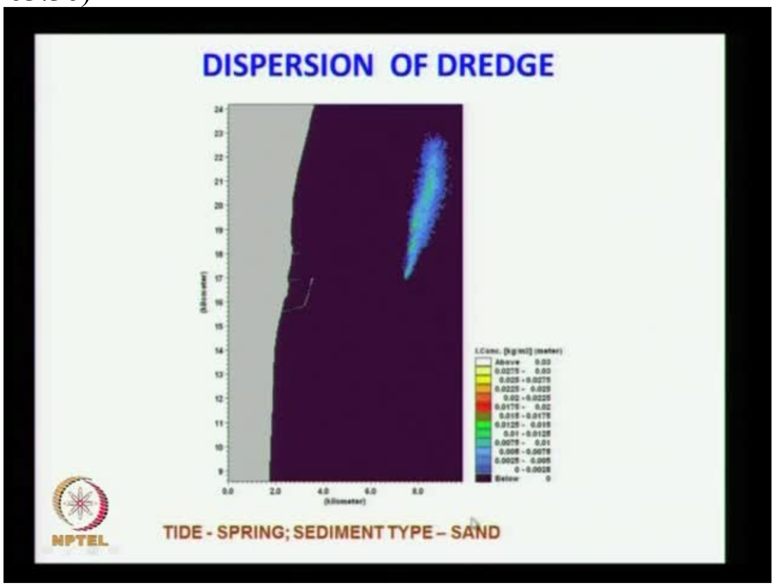
So what they do is, from the dredger, they put it on another vessel or the same dredger will come here, then they pump it like this. About 300 metres it can go and then pump and then it will stockpile. So groyne number 2 to 11, they will be doing this rainbow technique. So here, groynes are there, seawalls are there, artificial nourishment by pipeline as well as by rainbow technique.

(Refer Slide Time: 63:11)



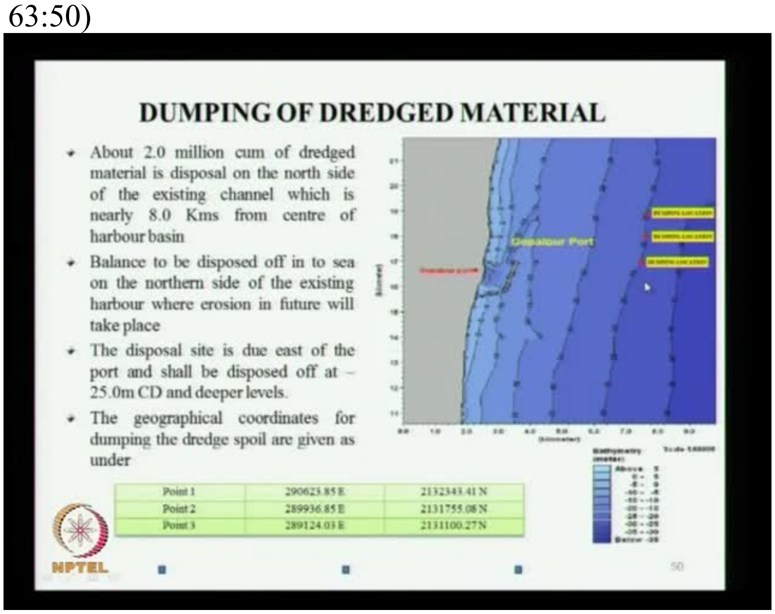
Then some of the material what they are dredging here, they will be taking it to a place somewhere here for dumping between 25 meter and 30 metre contour. So part of them will be going by pipeline between these 2 points, part of them will be going by rainbow technique from this point to this point. This is the sand trap and entrance channel where they will do some maintenance dredging and put it on the northern side.

(Refer Slide Time: 63:36)



So this is the dispersion of the dredge material which is put in 25 meter water depth. How much depth it is increasing, that is what is shown here. For various tide, we can do a numerical model.

(Refer Slide Time: 63:50)



And we have shown the locations where this dredge material will be dumped. So 2 million cubic metre will be disposed on the northside of the existing tunnel which is nearly 8 kilometres from the centre of Harbor basin. On the balance, we have to dispose it off into the sea. This deposit is about 25 meter CD, the coordinates also are given. So now this estimate has been revised. About 5 million cubic metre will disposed to the northside and 3 and a half million cubic meters will be disposed to these locations.

(Refer Slide Time: 64:27)

This slide shows 2 ports near Chennai. This is your Chennai port, this is your Ennore port. You are able to see this accumulation on the southern side, right? This is taking place and this is your fishing harbour and you have a very good Marina beach on the southern side of it which I am not showing it here. There were series of groynes built before the Tsunami in 2004 which had saved a lot of lives and properties all along the shoreline.

(Refer Slide Time: 65:04)

This next Google map will show the groynes. You are able to see the groynes, right? These are all the groynes which are built. Earlier, this is the road. What you are seeing is the road earlier. Now also, the same road. Only thing is, earlier the shoreline was all along this road. Now the shoreline has advanced. Earlier, our shoreline was along this road. Sea has penetrated inside. What has happened is originally, the road was here.

Then it has eroded the road, then they shifted the road inwards. Then it has eroded that road also. Then they shifted the road. Like that they are going on in the road. Now after construction of the groyne, the shoreline has advanced. They do not have to prepare the road or rebuild the road. That is the advantage and they are getting a lot of land also here. The cost of the land is much more than whatever the money we have spent.

Which is the northern side for this breakwater, for the groyne? This is the northern side, this is the southern side. It is very strange that here, northern side we have the deposition for this groyne and southern side we have the deposition for this groyne. Depends on the season, which season you are taking the photograph. If you are doing it in the north-east monsoon, your deposition will be on the northern side. If you are doing it in the Southwest monsoon, your deposition will be on the southern side. How much it has deposited, how much it has eroded based on that, your final shoreline will see you see the next slide.

(Refer Slide Time: 66:47)

One of the groyne here, you have the deposition on both the sides. Whereas this groyne, you have the deposition only on the southern side. Some more deposition on the southern side and less on the northern side. So it depends on where it is, what is the spacing between the groynes, what is the depth at which it is going, what is the bathymetry, all these things decide how much, when the tsunami has come, most of the deposition has been taken away by the tsunami but within a period of 5 to 6 months, the shoreline has advanced after the tsunami.

(Refer Slide Time: 67:31)

In Ennore port, we have made a stockpiling of an artificial nourishment using the capital dredge that is shown here. So this is the Ennore breakwater, northern breakwater, southern breakwater and as they have started construction of this breakwater, the shoreline has advanced, maybe about 500 metres. And whatever material they used to create the basin, they put it on the stockpile on the northern side. These are natural deposition, this is artificial nourishment as the stockpile. Now the stockpile has got, is getting eroded, as you see here some portion has got eroded. Then they have to the maintenance dredging of this.

(Refer Slide Time: 68:10)

This photograph shows the Visakhapatnam port. So this is the southern breakwater. This is the famous Ramakrishna beach. So one of the advantage of this particular structure is this breakwater is not starting from the shore. There is a gap between the shoreline and the breakwater so that the sand will deposit here, they have created the sand trap inside so that the dredger can come and work in calm environment to remove the sand. That is the advantage of this. But nowadays, they are not doing this shore disconnected because it is very expensive.

(Refer Slide Time: 69:04)

One of the 1st slide what I have shown in this lecture is your Pondicherry fishing harbour. Actually this is your southern breakwater. They did not start from the shore. They have put an approach bridge but then they started but they did not dredge inside for artificial nourishment in the sand trap. That is why the whole bridge has got closed and the shoreline also has got advanced.

So this coastal erosion typically on the northern side and accretion on the southern side is to be studied carefully and the erosion should be avoided on the northern side. The 3 methods which are normally used nowadays are artificial nourishment as a stockpile, as a maintenance dredging. The 2nd one is to build the groynes while doing the stockpile. Ennore port, we did not do that. Gopalpur port, we are putting a groyne field, transition groynes. In the end of the groyne, you put a seawall. So these are the 3 methods that are used to mitigate the impact of breakwater on the shoreline. Okay thank you.