Ocean Structures and Material
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Module - 3
Lecture - 10
New materials for coastal embankments l

Welcome to the 10th lecture on module 3 of Ocean Structures and Materials under the braces of NPTEL, IIT Madras. In this lecture, we will discuss some new innovative materials and design methodologies, which has been tried for protection of coastal embankments.

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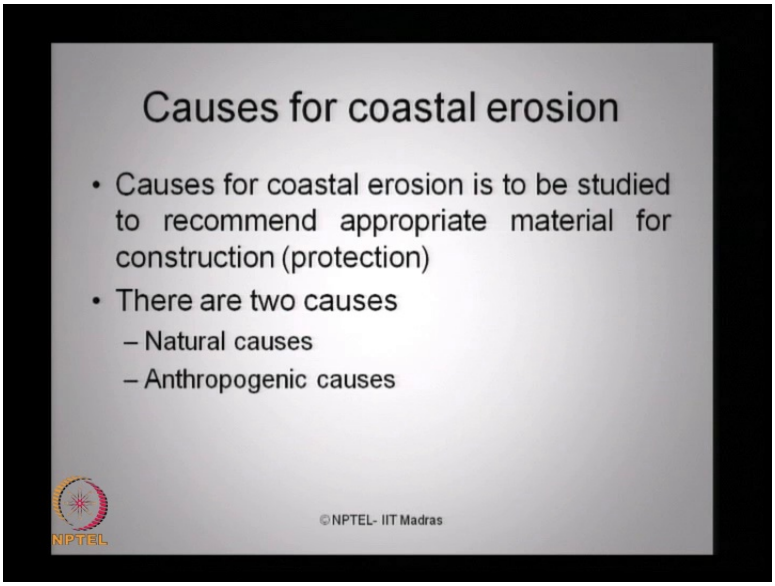

Let us quickly look at the primary reasons and causes for coastal erosion, because it is better to understand these causes first, before we think of designing or recommending an alternative material for coastal protection systems. The causes for coastal erosion is to be studied to recommend appropriate material for construction, because we aiming at the coastal protection. There are two primary causes, which are responsible for coastal erosion. As we see from the slide, we understand that natural causes and anthropogenic causes can be main principle causes for coastal erosion.

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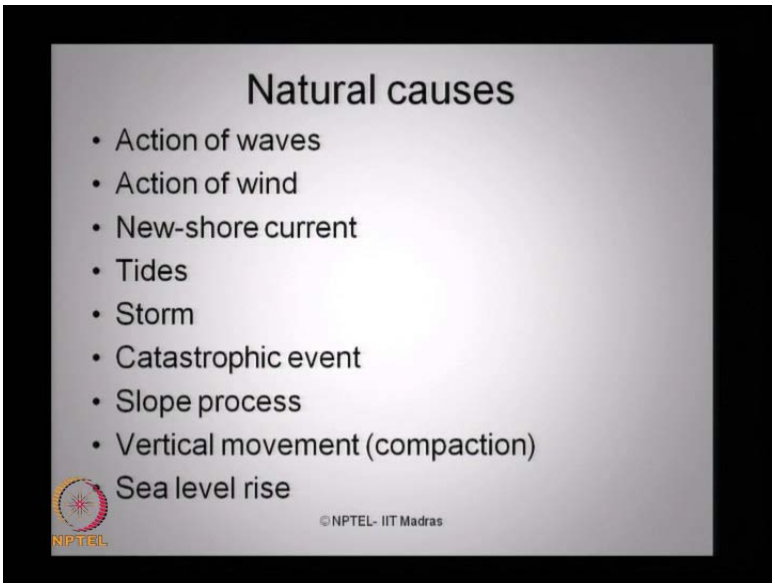

Let us look one by one in detail. Natural causes can be listed as the following. It can be due to the action of waves; it can occur, because of action of wind; it can be also due to new-shore current; it can be because of tidal action, it can result from storm, it can also result from un force in catastrophic events like tsunami. It can also be related to the slope deterioration process along the coastal line, and it can be also from the vertical movement what we called the sea bed compaction, and finally, it also due to instantaneous sea level rise because of geographical changes.

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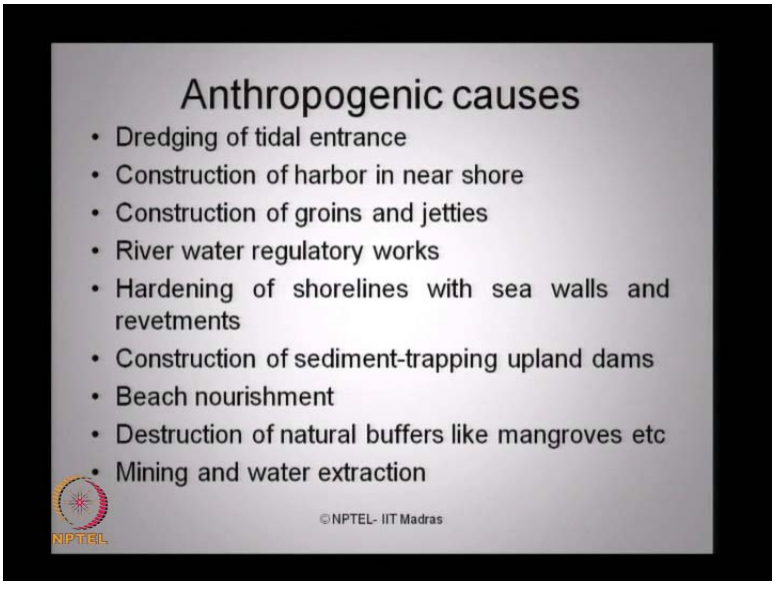

If we look at alternatively the anthropogenic causes, which are responsible for coastal erosion, they can be listed as follows as seen in the slide. Essentially and primarily, the first reason for coastal erosion predominantly seen in the practical problem is dredging at the tidal entrance; Can also be due to the construction of harbor in the near shore area, can result from construction of other protection structures like groins and jetties. It can also result from river water regulatory works, which have been planned in construction near the shore area. It can also come from hardening of shorelines by constructions of sea walls and revetments as one of the coastal protection system, which we already saw in the first module.

It can result from the construction of what we called sediment-trapping upland dams. Sometimes if we plan for any beach nourishment ideas, this can also result as one of the important anthropogenic cause for coastal erosion; can also cause because of destruction of natural buffers like mangroves forest which are generally develop along the coastal lines, can also because extensive mining of sand and water extraction from the coastal areas. So, ladies and gentlemen, there are two primary reasons why we can see coastal erosion takes place in a very series manner.

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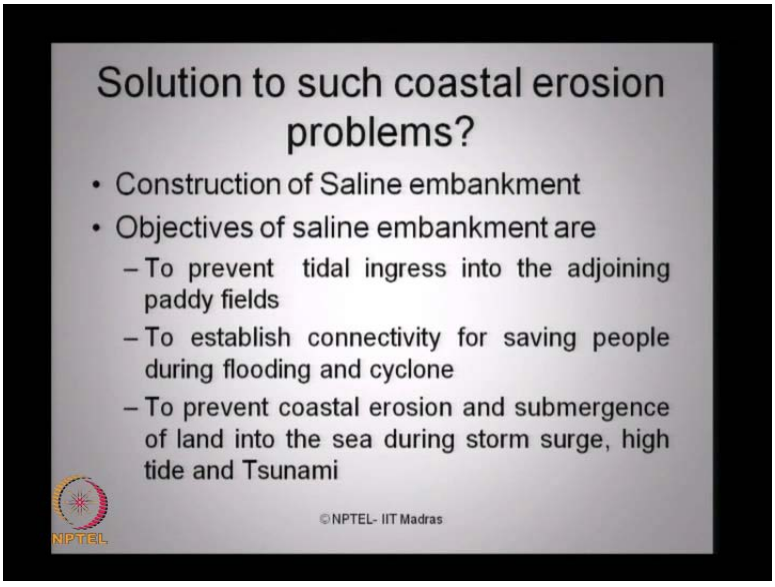

What are the solutions for such coastal erosion problems? The primary solution for coastal erosion problem can be construction of an embankment. Now we have a point here to say that one can also plan to construct what we called a saline embankment. Now

the necessity is why one is interested to control the spread of salinity from the sea bed or from the sea side towards the offline. The primary objectives of construction of sea saline embankment are the following. It is useful to prevent the tidal ingression into the adjoining paddy fields. There are many location, ladies and gentlemen, in India where agricultural cultivable lands are located in near proximity of the coastal sector, for example, state of Odisha have lot of agriculture lands which are located parallel and the close proximity of the sea water.

So, to prevent the tidal ingression from the sea into adjoining paddy field, we can construct an embankment which is otherwise called saline embankment. Also to establish connectivity for saving people in case of floods and cyclone which are un force in activities which can happen because of natural reasons, also to prevent coastal erosion and submergence of land into the sea during storm surge, high tide and tsunami. So, there are many objectives for construction of saline embankment which are generally constructed along the length of the coastline to protect essentially the off land from coastal erosion.

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Ladies and gentlemen, now I will show you series of picture which are evidently seen and taken from the site where coastal erosion as become one of the major problem in Odisha. You can see here, there is the very close proximity of the land getting eroded adjacent to the sea, and people are using some natural and conventional methods of

putting sand bags along the coastal line to protect or to prevent soil erosion further, because of advancement of sea.

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If we look at the following photograph which has been taken subsequently at different time period, for example, if you look at 2007, the photograph has been taken in the same site. The shoreline was about 20 meters away from the embankment. You can see here that is the embankment and coastal line of the shoreline is very close which is progressing towards the land where you can see here, these are all cultivable agricultural lands.

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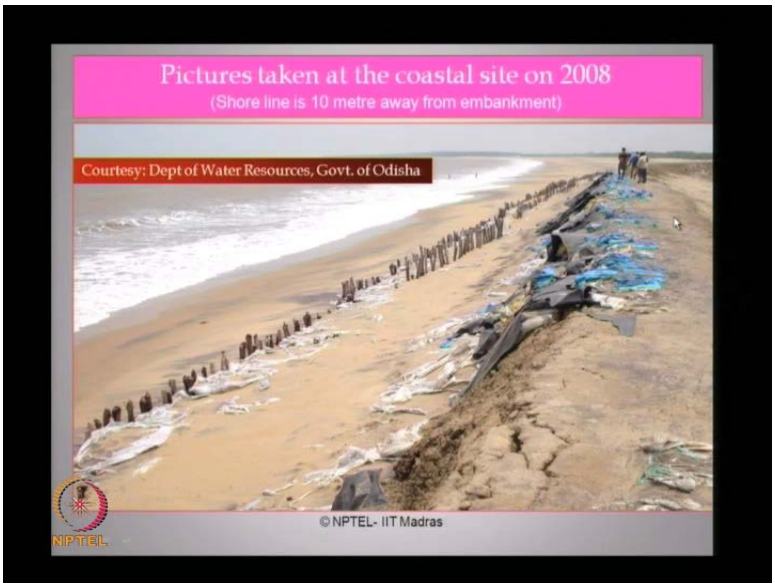

So, the shore line is hardly 20 meters away from the embankment, a successive photograph taken in the same site and year later show again it just 10 meters; that means, the sea rapidly advancing towards the land site.

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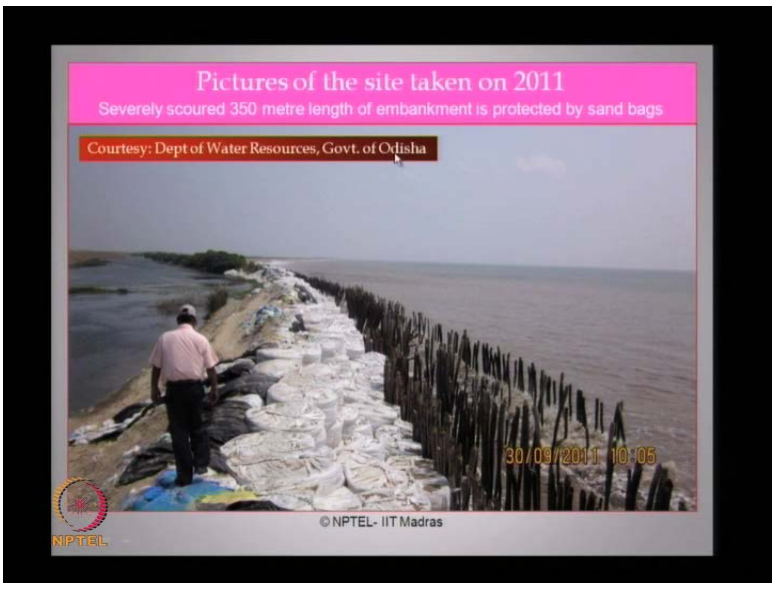

A further picture taken on 2011, which is about four years from the original problem, being noticed. You will see that the coast line has become completely merged with the land and the embankment has becomes completely ineffective about 350 to 400 meter long embankment is completely protected only by the local mechanism because of sand

bags. So, ladies and gentlemen, you can easily see people use rural technologies like putting sand bags along the coast, providing wooden pools as piles along the coast to protect or to prevent sand erosion or the beach erosion, because of the sea. On the other hand, you will see that these are all becoming completely ineffective as you saw previous photograph, in the period of 4 years sea started advancing at the very rapid rate at about 50 to 100 meters every year towards the landside. This has resulted in very severe erosion along the coast line in one of the sites in Odisha.

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If we look at the another photograph very recently taken in about 30-9-2011, in the retard embankment built at 60 meter away on the country side of the old embankment, this is a new construction, this is the old one and it is the new one. The new construction, again thinking that the advancement can be stopped, because of these kind of rural (( )) construction. Ladies and gentlemen, it is very interesting for us to academically know that these kind of treatment of embankment are not worthy for the specific site, because the erosion in the particular site is very severe.

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As the result of which retarded embankment constructed was completely washed the way by even though the protected by sand bags.

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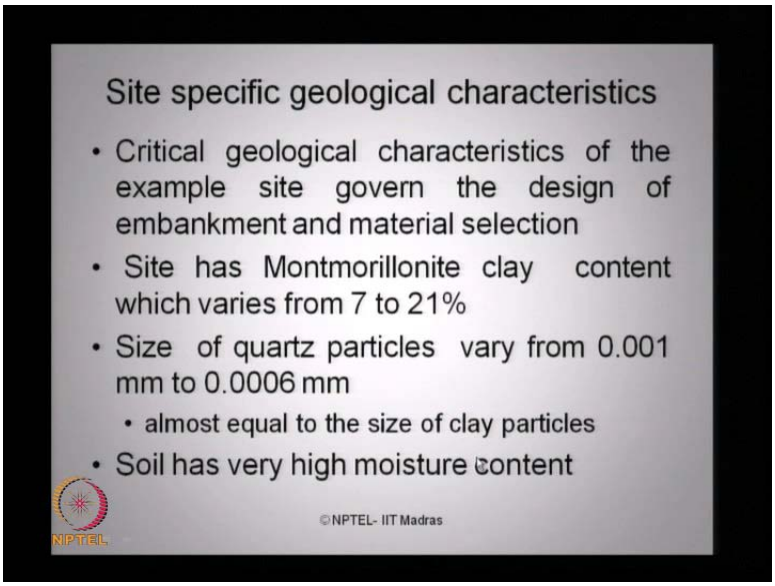

Now the question comes, what are those the sites specific geological characteristics, which generally govern these kind of design and construction methodology of embankments to prevent advancement of sea into offshore. The critical geological characteristics of the example site what we saw in the photograph govern the design of embankment as well as material selection for construction of embankments. The site has

Montmorillonite clay content which varies from about 7 to 21 percent. What is the specific contribution of this type of clay in erosion? The size of quartz particles available in the site vary from 0.001 millimeter to 0.0006 millimeter, which is almost equal to size of clay particles; it means, the site around even the quarts particle of a larger diameter are not found. It is fine clay content present along the coastline in the specific site of subject of discussion, resulting which the soil has attain very high moisture content.

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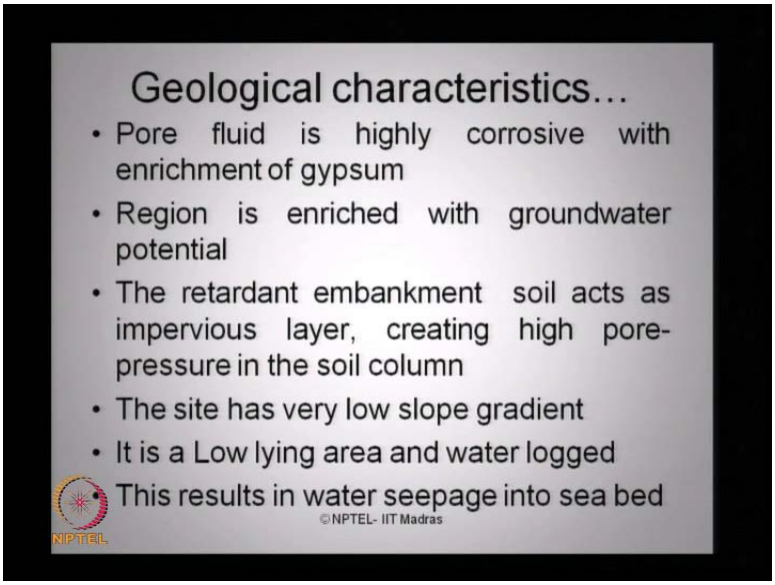

The moment of soil has very high moisture content. The pore fluid is very highly corrosive, because of enrichment of gypsum present in the content. As the result of which, the region is enriched with groundwater potential. The retardant embankment soil acts as impervious layer, creating a very high pore pressure in the soil column. And this high pore pressure is quit dangerous for any type of conventional gravity type construction, which can be used for protecting these coasts as the coastal embankment. And further, the site has one more characteristics which is having a very low slope gradient, because the soil stability at this particular site has being a problem because of very low slope gradient maintainable in the site. And further, it is a very low lying area, which is generally a water logged even in case of rains. As the result of which, there is an extreme water seepage into the seabed which result in rise of sea water level actually at the specific site. So, you can see here, there are very critical geological characteristics which is govern the discussion of subject here for advising or recommending a specific type of coastal embankment for Odisha.

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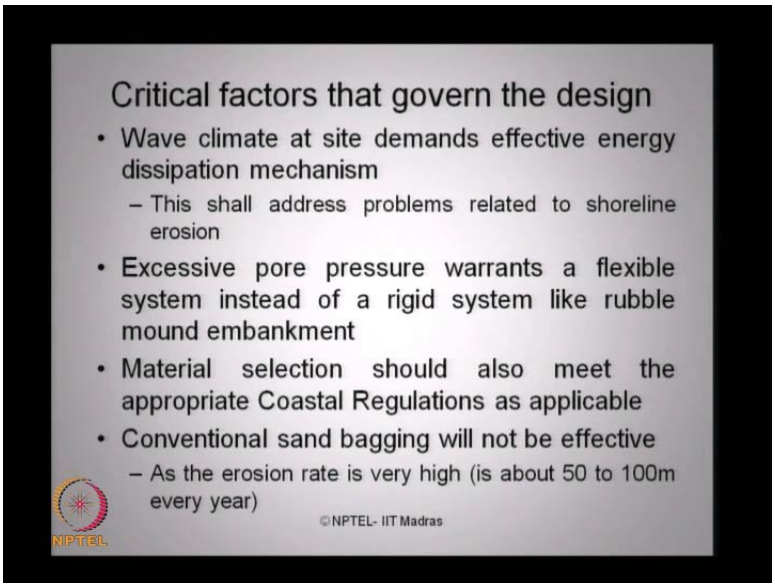

Now let us quickly see, those critical factors that may govern the design of an embankment under such soil conditions. The foremost, of course, the data which governs the design of the selenium magnet is that the wave climate. The wave climate at this site demands essentially a effective energy dissipation mechanism, because as you saw right from 2007 till 2012 there has been a rapid progress of sea water into the coastal into the land area. And to affect or to stop or to retard, this kind of sea advancement, we should have design of embankment which effectively dissipates the wave energy, so that the further soil erosion or the beach erosion is prevented.

So, I should have a design which addresses the problem related to shoreline erosion, in addition to in effective energy dissipation in mechanism to control the wave energy progress towards the off land. Further the excessive pore pressure warrants a flexible system, because if you have a design based gravity type massive system, it will not work in the site, because a soil has got a very high pore pressure. So, an excessive pore pressure in this specific site, demands a flexible system instead of a conventional rubble mound embankment, which is generally constructed are along the coast line for costal protection.

So, I should look for the design which has gone in effective energy dissipation mechanism as well as the design should warrant for excessive pore pressure located in the site. So, it should be a flexible system, at same time it should dissipate energy

effectively. And of course the material selection based on which the embankment will be constructed should also meet the appropriate coastal regulations act as applicable to any specific site. So, the conventional sand bagging and wooden piling will not help as you saw in the previous photograph, they were not able to stop the advancement of sea progress into the land. The erosion rate is very high; it has been see the erosion is approximately about 50 to 100 meters every year.

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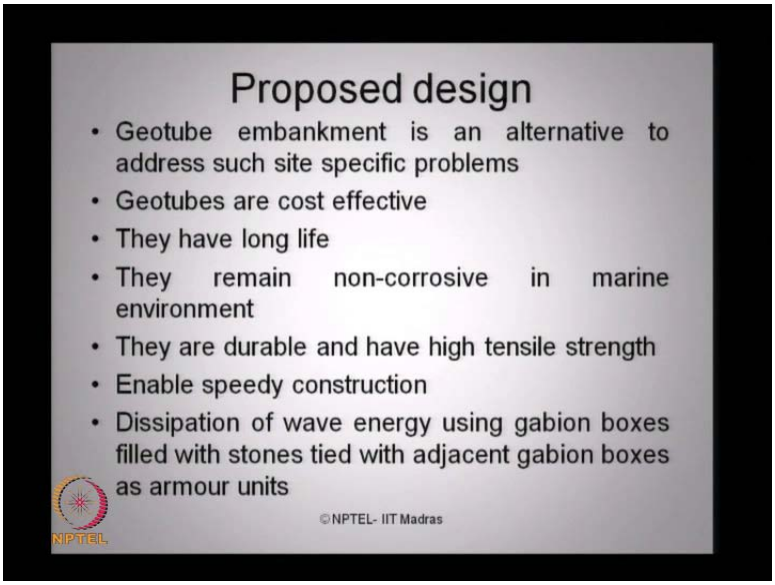

Now let us look at the question what is the proposed design for catering to the geological conditions we just saw. The proposed design is a geo tube embankment. The embankment will be constructed using a geo tube, which is an alternate to address such site specific problems. Now let us see the detail design cross section detail and construction methodology of the newly innovative proposed embankment for Odisha coast, which is using geo tube as one of the primary core material for this embankment.

Now we before understand the cross sectional design of embankments, let us quickly see what are the principle advantages of using geo tube as a construction material or a core material for a coastal embankment. Geo tube has been seen in the literature has very cost effective. They have a very long life. They remain non-corrosive in marine environment, which is the one of the very important criteria of recommending a geo tube for coastal protection system. They are highly durable and have a very high tensile strength. They enable a very fast construction, the period of construction of embankment, when used

with geo tube are relatively less in comparison to the conventional rubble mound type embankment.

It is also in addition, ladies and gentlemen, dissipate wave energy because of design, the design uses gabion boxes filled with stones tied with adjacent gabion boxes as armour units, which is not preventing or which is not protecting the geo tube from further erosion. The geo tube movement is being flexible in design and nature, dissipates wave energy as the wave approach in embankment, so instead of having a rigid conventional gravity type massive rubble mound embankment, a newly proposed flexible geo tube core gabion box cover embankment is an alternative suggestion made for this coast in the literature.

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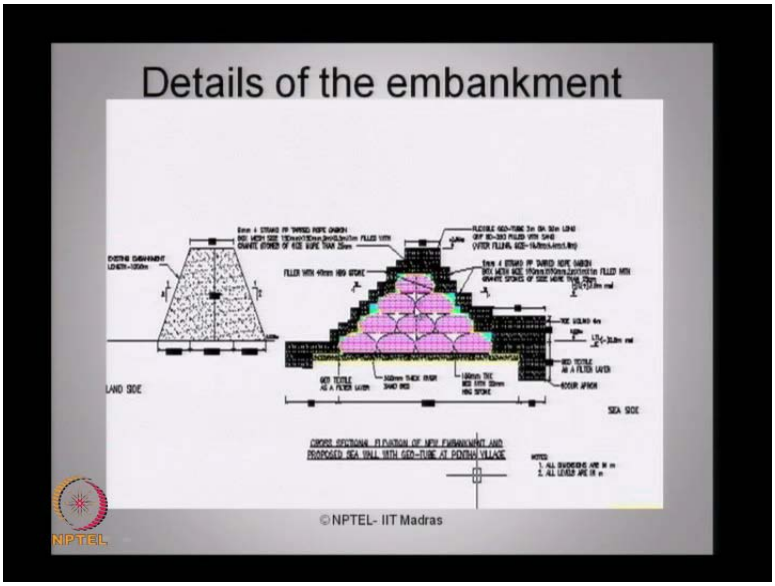

Ladies and gentlemen, now the figure what you see here shows the detail of the embankment in its cross section. If you carefully watch this figure, you will see that the core consists of about four layers of geo tubes, which are placed in pyramid order as 4, 3, 2 and 1 in a specific order as you see in this cross section. Now once the geo tube are being fixed and laid over these we provide gabion boxes which are mounted and cover with 200 mm size rubble stones which can offer by enough resistant by counter weight to these geo tube to help be health in position.

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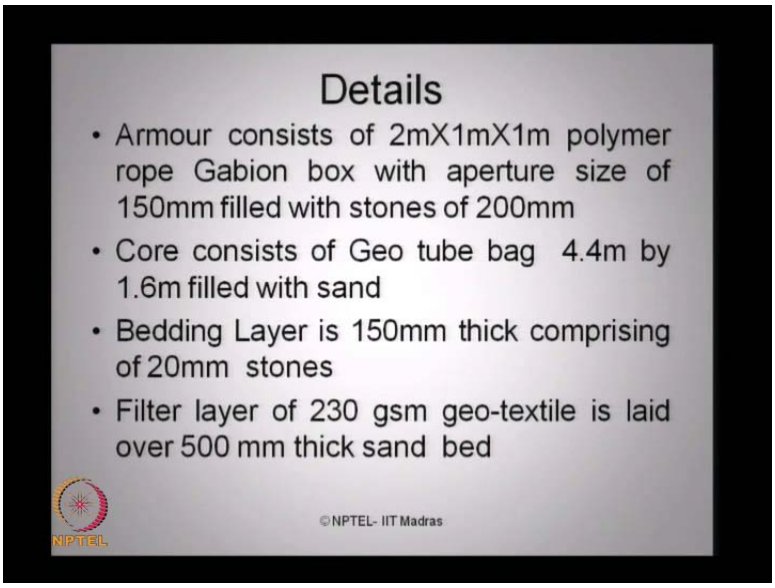

If we look at the detail of these construction, the armour essentially consists of 2-meter by 1-meter by 1-meter polymer rope gabion box with an aperture size of 150 mm, which is filled with stones of 200 mm, which act as the counter weight on the top of these core material of geo tubes which forms an embankment. The core of the embankment consists of geo tube bag of 4.4-meter by 1.6-meter, which are essentially filled with stand. The bedding layer where the geo tube layer will be laid is about 150 mm thick sand layer consisting of 20 mm stones. The filter layer of 230 gsm geo-textile will be also laid 500 mm thick sand bed layer to as sub grade for the geo tube arrangement.

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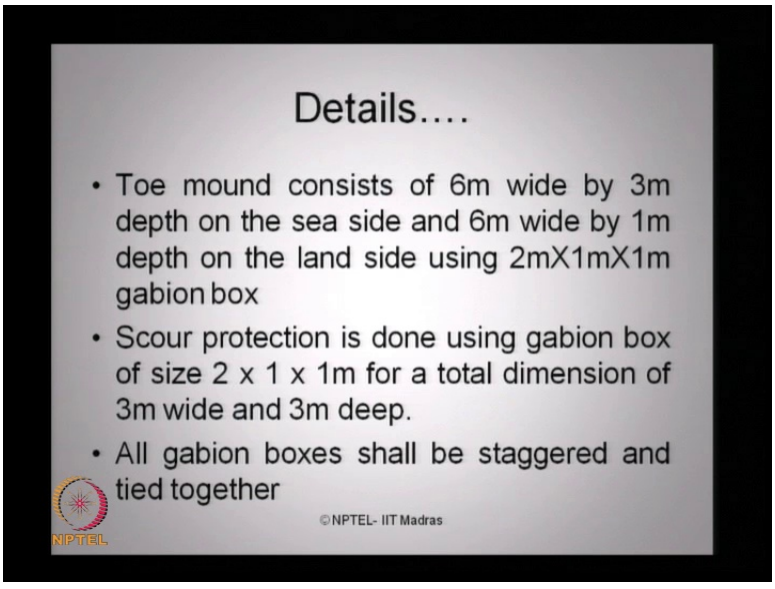

The toe mound is also design to protect the embankment, which consists of 6-meter wide by 3-meter in depth on the seaside and 6-meter wide and one meter in depth on the land side using 2-meter by 1-meter by 1-meter gabion box. The scour protection is also an important component of this embankment design, which is done using the gabion size of box 2 by 1 by 1-meter for a total dimension of 3-meter wide and 3-meter deep. All gabion boxes in the arrangement are kept staggered in position and they are tied using high-density polyethylene ropes, what we called HDPE which is echo and environmental friendly and non-degradable.

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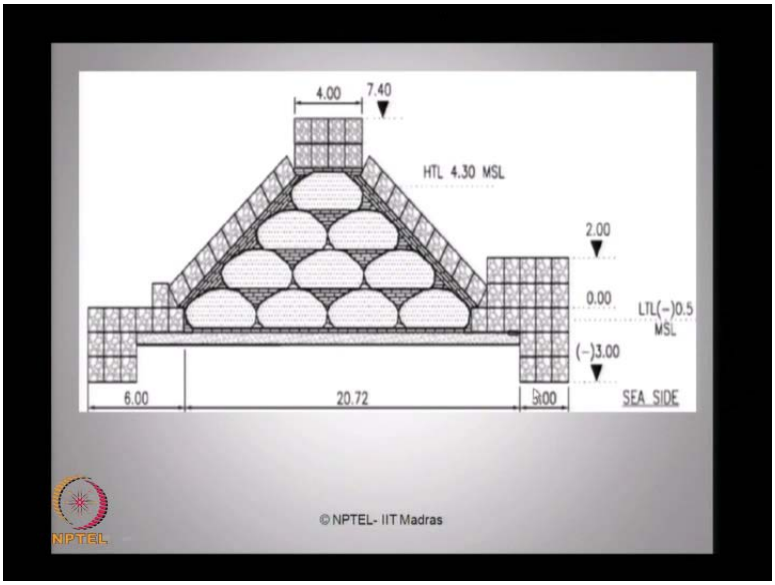

The overall view of the finished saline embankment as propose an alternate design for the conventional of rubble mound embankment is shown in the slide now. The base width of the embankment will be about 20.72-meters, which is having have a 6-meter on and 3-meter on the right side on the sea side essentially for protection. The core material has got sand filter beds which is essential for gabion boxes which consists of 200 mm stones being built which is act as the counter weight on the top to whole the gabion to whole the geo tube in position. The high tide level see which is see in the specific site as be indicated as 4.3 MSL, whereas the top level of the gabion box arrangement of the embankment goes about 7.4-meters. The top crust bed is about 4-meter, while the bottom crust bed about 20.72-meter can easily find out the gentle slope of this, which is provided for this embankment. Of course, the embankment has a foundation depth about minus 3-meter on the seaside as well as on the landside.

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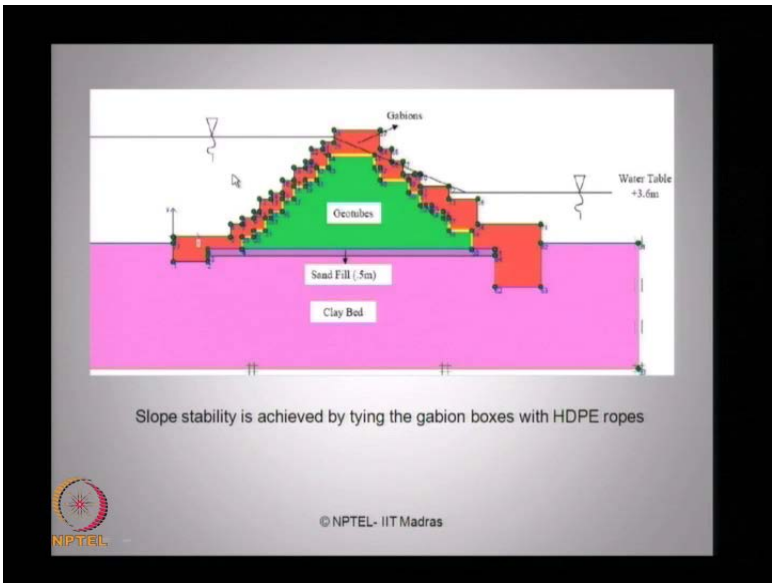

If we look at interesting component of holding down the gabion boxes in position, you will see that the slope stability of the landside as well as the seaside is being achieved by tying these gabion boxes as you see here, which are staged alternatively by tying these gabion boxes using high-density polyethylene ropes, and therefore, they are placed in position. Now there has no permanent rigidity offered by these kind of arrangement in the whole embankment, we can see that the integral component of the geo tube with that of the gabion box maintenance high degree of flexibility in heap direction as well as in the direction of wind action or the wave action. So, because of this flexibility impose or important, by the combined action of geo tube on the gabion boxes as well, this system is able to dissipate energy which is coming from sea waves to very high extent. And that dissipation prevents further progress of the sea wave as well as protects the land side interestingly, because of further erosion.

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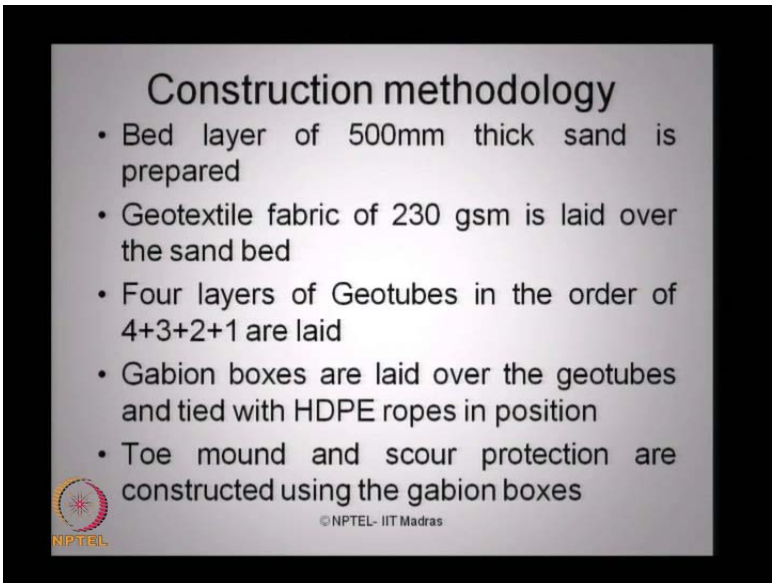

If you look at the construction methodology of newly proposed saline embankment, which is geo tube core, which is placed over and above the gabion boxes as an integral arrangement. The bed layer of these arrangements consists of 500 mm thick sand, which is first prepared. Over which the geo textile fabric of 230 gsm is laid over the sand bed to act as a filter. Four layers of geo tube in the pyramid order of base as four forward by 3, 2 and 1 which is on the top are laid subsequently. The gabion boxes are laid over the geo tubes and tied with high-density polyethylene ropes in position. The toe mound and scour protection are also constructed using the gabion boxes for the respective purpose.

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If we look at the photograph here, this is how a geo tube will be looking like before the sand is being filled in. The geo tube is being laid in the ground, and geo tube is now filled with sand you can see initially it is flat, now it is got bulge out.

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Now after the geo tube is completed in sand filling, it is again provide with counter weight of sand bag on the top.

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This is the one of the views after installation., these are the HDPE ropes with the gabion boxes placed in position.

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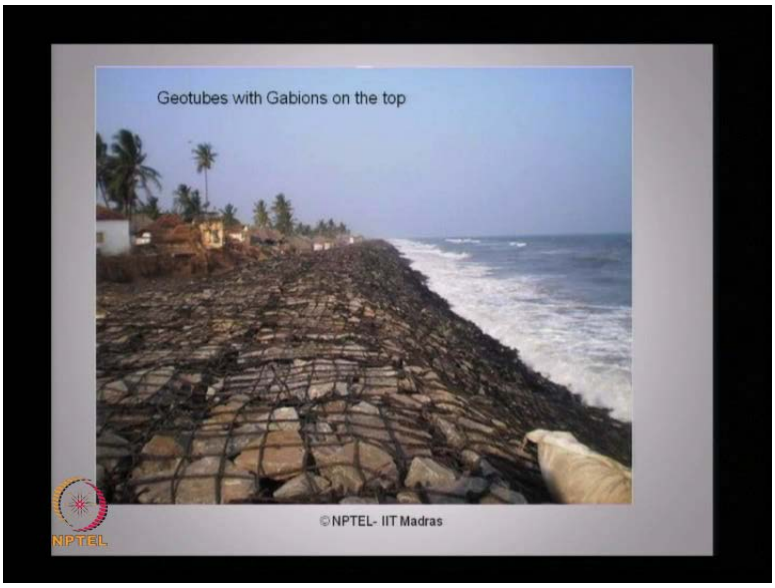

So, now, you will see the geo tubes and gabion boxes placed on the top will what we look like. Now here the gabion boxes filled up with the stones, there are stones, which are directly laid and being tied in position. So, instead of this, we can also have the alternate arrangement where the gabion boxes specific size of 2 meter by 1 meter by 1 meter which is filled with 200 mm size stones are laid on the top. And they have been held in the position by staggering them in the arrangement using the HDPE ropes - that is an improved version of the existing type of design which can now be effective, which can also offer high degree of flexibility for dissipating wave energy on the coastal side.

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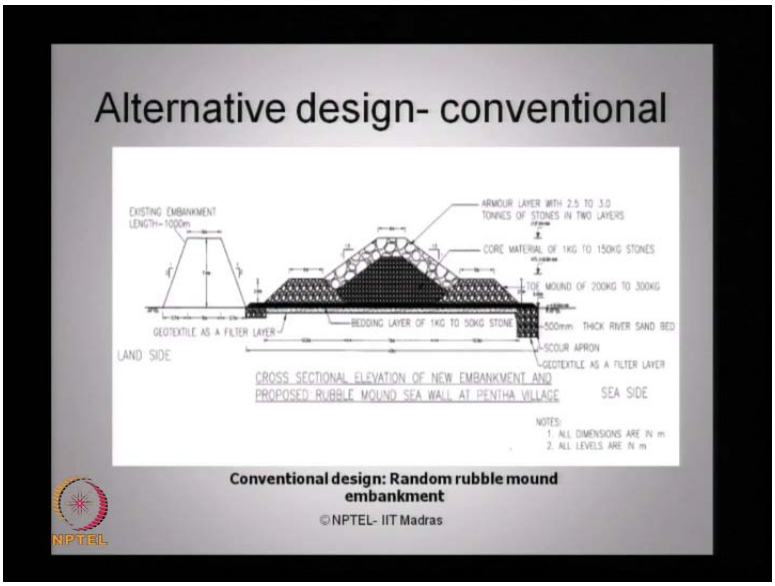

If we look at the conventional design of embankment protection using the rubble mound design this what people generally do for a rubble mound embankment, where the core material is essentially and hard rigid core material of 150 kg stones present here, whereas which is covered by armour layer of about 2.5 to 3 tons of stones in two layers. So, this is the rubble mound conventional type of construction, which offers very high rigidity which does not suit for a specific site, where that is already a high pore pressure in the soil. This pore pressure is because of the soil erosion and interactment of water and the high level of the sea rise in this specific site.

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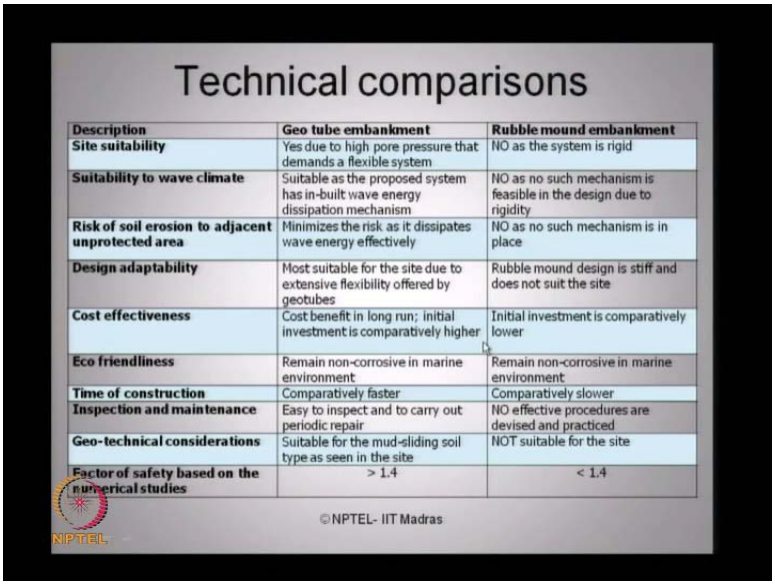

Now a fundamental question that comes to an engineer's mind is how a technical comparison will look like between the proposed new innovative type of embankment design with that of rubble mound embankment which is highly conventional. There are many factors which are considered to compare them their technical performance. Let us look at the site suitability as we saw in the previous slide, geo tube embankment is suitable to the site because of high pore pressure that demands a flexible system; obviously, rigid mound system like rubble mound embankment is not applicable to this site, so it is not suitable for the site under discussion.

If you look at the suitability to the wave climate, the geo tube embankment methodology suitable as the proposed system has inbuilt wave energy dissipation mechanism because of vertical movement of the geo tube under wave action or under the water body. No

such vertical dissipation mechanism is available, because rubble mound embankment are very rigid in its construction methodology as well as in design. If we look at the soil erosion to the adjacent unprotected area where the embankment constructed, the geo tube embankment methodology reduces and minimizes the risk, because it dissipates the wave energy in a more effective manner. Since the rubble mound embankment does not have a provision of dissipation wave energy at all, there is no guarantee that the adjacent unprotected area will not have soil erosion.

If we look at the design adaptability, geo tube embankment is seen as most suitable for the site due to extensive flexibility offered by the design principles. Whereas, rubble mound system is highly rigid and does not suite for this specific geo aspect. Of course, look at the cost effectiveness, which is one of the important mile stone for deciding any type of new innovative construction methodology for such coastal structures. Yes, the coast benefit is there in the long run; however, the initial investment on geo tube embankments is relatively higher. Study shows that there approximately about 70 percent costlier than that of rubble mound embankment. The initial investment on this kind of embankment is comparatively cheaper.

If you look at the eco friendliness, yes geo tube embankment remain non-corrosive in the marine environment, and therefore eco friendly off course rubble mound embankment remain eco friendly, because they are essentially constructed of using stones an earth. If you look at the time of construction or period of construction, which is one of the important factor to select the type of embankment design, geo tube embankment are comparatively fast in relationship to that of rubble mound embankment which are relatively lower. For that inspection and maintenance becomes very easy, because it is possible to carry out periodic repair and systematic manner in this kind of embankment, whereas in this case it is not possible no such procedure exiting in the literature, and they are ever practiced.

If you look at the geo technical embankment investigation and consideration as applied for the specific site of discussion, we can see that the geo tube embankment remain suitable for mud-sliding soil types as seen in the specific site, whereas, under this situation, the rubble mound environment are not at all suitable. Above all, the most important technical factor says that based on numerical studies, they have seen, the geo tube embankment the factor of safety shows more than 1.4, whereas rubble mound

embankment for the same dimensions, it shows effect of safety less than 1.4. So, looking at the important factors, based on which two different designs can be compared, we come to a conclusion that geo tube embankment as lot of technical advantages compared to that of rubble mound embankment.

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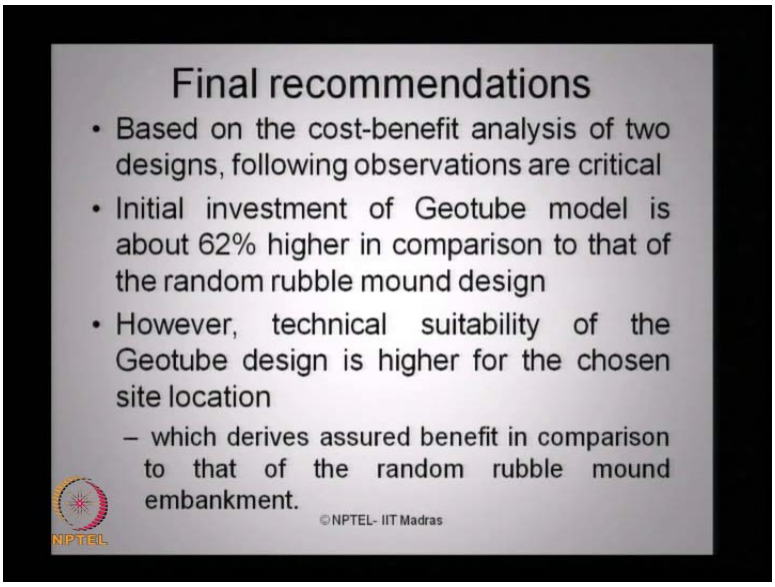

So, before we go for final recommendation, one would like to know the cost benefit analysis one can do to get compared with geo tube embankment with that of the conventional rubble mound type embankments. Based on cost benefit analysis studie s conducted of two designs following critical observation are made. Initial investment of geo tube model is about 62 percent higher in comparison that of conventional random rubble mound design, there is no doubt on that. However, the technical suitability of the geo tube design is far superior for the chosen site location, so it is site specific design. Therefore, this derives an assure benefit in comparison to that of random rubble mound embankment, because it is highly suitable for a specific site under discussion.

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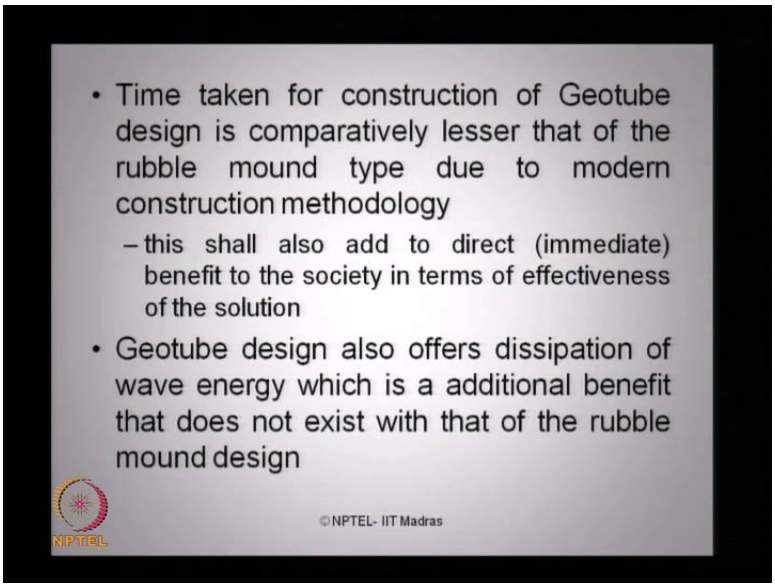

Further, if you look at the time of construction or period of construction taken, the time taken for construction of geo tube design is comparatively lesser than that of the rubble mound type, due to modern construction methodologies. This should also add to the direct benefit to the society, because we can construct such embankments in a shorter period of time, which can again benefit the society in short period of effectiveness. The geo tube design also offers dissipation of wave energy, which is an additional benefit divide because of flexibility in the design. In this specific site of discussion, we believe that this is essentially important, because sea as be progressive into the land at the very faster rate. So, I need to have a mechanism in the embankment design which dissipate the waves energy effectively, therefore further erosion is either reduced are completely mitigated.

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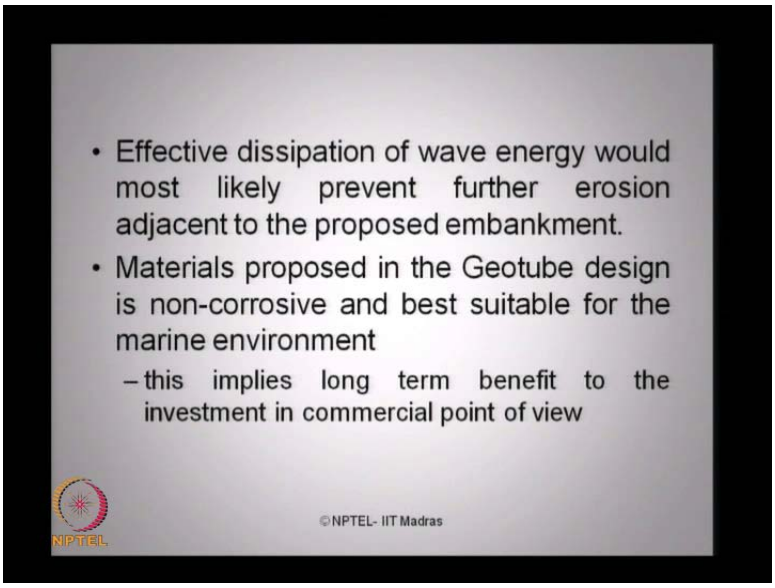

The effective dissipation of wave energy would most likely prevent further erosion adjacent to the proposed embankment. Materials proposed in geo tube design are non-corrosive and highly eco-friendly, and they have been best suitable for the marine environment. This implies the direct long-term benefit to the investment in commercial point of view of the suggested innovative design.

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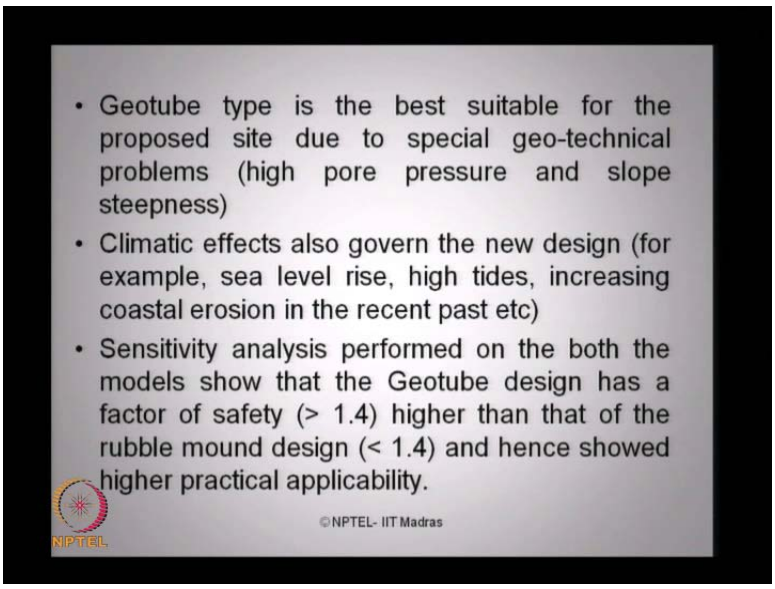

Therefore, geo tube type environment embankment is the best suitable for the proposed site due to special geo technical problems, for example, high pore pressure and slope

steepness. Also, the climatic condition govern the new design, for example, sea level rise which is consecutively happening in the sites high tides being seen in the near vicinity, increasing coastal erosion in the recent past of 4 to 5 years are all important natural factor which govern and alternative innovative type of design for the specific sites, which dissipates not only the sea energy - wave energy, but also protects saline ingression into the land, which is (( )). Further, importantly the sensitivity analysis performed on the both design show that the geo tube has a higher factor of safety which is more than 1.4 when compared to that of the conventional rubble mound design, and therefore, this shows very higher practical applicability of the design.

Therefore, ladies and gentlemen, in this lecture, we learned a new type of coastal embankment design using modern construction methodology and modern construction materials. These design which are proposed as an example in the specific lecture are site specific, therefore instead of going for conventional methodology of coastal protection system, people are now approaching use of new innovative construction material and construction methodologies for such coastal protection structures.

Thank you.