Geosynthetics and ReinForced Soil Structures
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Lecture - 36
Erosion Control of Soils Using Geosynthetics

Very good morning, in today's lecture let us look at the erosion control using geosynthetics. What is erosion? Erosion is the process of detaching the soil particles from the ground and transporting it away by some means either by wind forces or by water forces.

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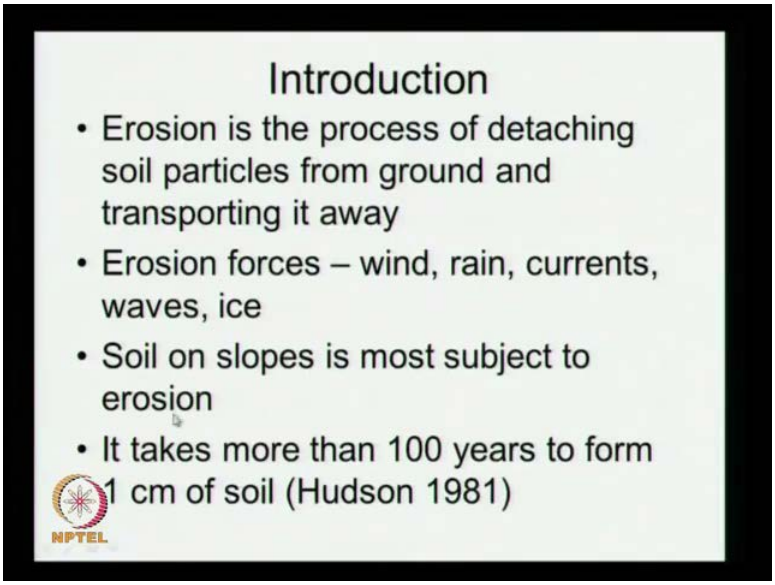

Some of the erosion forces are the forces that cause erosion are the wind, rain, ocean currents, waves, ice and so on. The soil and the slopes is the most subject erosion usually and the flat lines the erosion is less slightly as compared to the soil and the slopes. Why are we so interested in learning about erosion and its control, if we see this last sentence that it takes 100 years to form 1 centimeter of top soil that gives us the importance.

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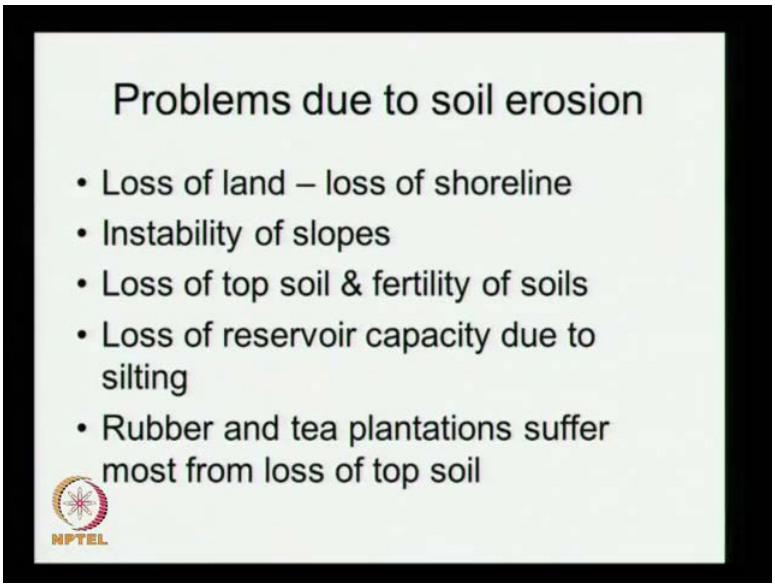

Why we need to control, because the top soil is the one that has all the nutrition properties, and we should not lose the top soil and some of the problems that arise due to the soil erosion are obviously the loss of land. For example, on the shore lines because of the fast flowing currents and the drift that is taking place, we may lose some land that we frequently come across in our news papers. The instability of the slopes, if there is too much of erosion on the slopes, there could be land slip that may take place.

Of course, one of the most serious problems that is of interest to farmers and the agricultural people, the loss of the top soil because the top soil is the most fertile soil. If we lose it, the productivity of the crops goes down and because of the erosion of soil and deposition in it. Some other place, the reservoir capacity may be lost especially the reservoir is the place where, we stored the water and whatever water is flowing from the rivers and the catchment areas is stored in the reservoirs. If it brings along with it all the suspended matter and deposits in the reservoir the storage capacity in the reservoirs is reduced. The rubber and tea plantations most of these, they are on the slopes and they suffer most from the lost of the top soil and we will see in this lecture some methods and how to control this erosion of problems.

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In this picture you see one result of coastal erosion is actually these are all the houses built by Tamil Nadu slum clearance board along the shore line. Originally, they were deep inside the shore line, but because of the continuous erosion of the sea and this is what is happening. One fine morning this is what happened, one entire house is just simply collapsed because the foundation soil is washed away by the by the currents during the high tides. It is just about to collapse and maybe in the next high tide, this entire building might be just simply washed in to the ocean.

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Another related problem is the bar mouth closure and here we see one estuary, that is home to lot of wild life, and lot of fisherman. That is fully closed by the bar mouth formation and once it is closed what happens is they estuary, the water within the estuary becomes highly saline because there is no recharging with the fresh water. So, once the water becomes very saline it cannot support the aquatic life or the other forms like, it could not become a home for the birds migrating birds and so on. So, it is a problem and we need to device ways and means of preventing this type of bar mouth formation.

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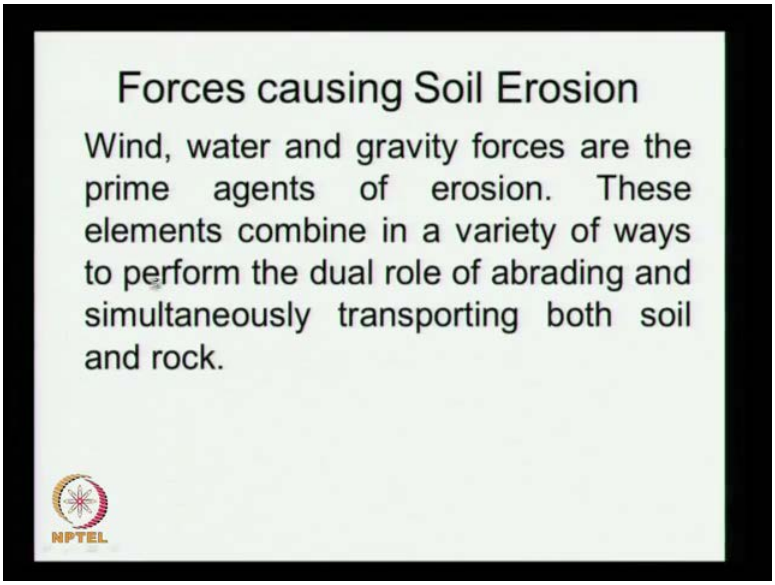

What are the forces that cause the soil erosion? As we discussed earlier, the wind, water and of course, the gravity forces are the prime agents of the erosion, the gravity forces because the gravity pulls down. You think that is at a higher evolution and on a steep slope, once the soil becomes a bit unstable it gets pull down by the gravity. These elements combine in a variety of ways to perform the dual role of abrading and simultaneously transporting both the soil and rock. So, we need some force to abrade that is to remove the soil particles, and then some other force to transport them as it is just not simply loosening the soil, but they need to be transported for this phenomenon of the erosion to take place.

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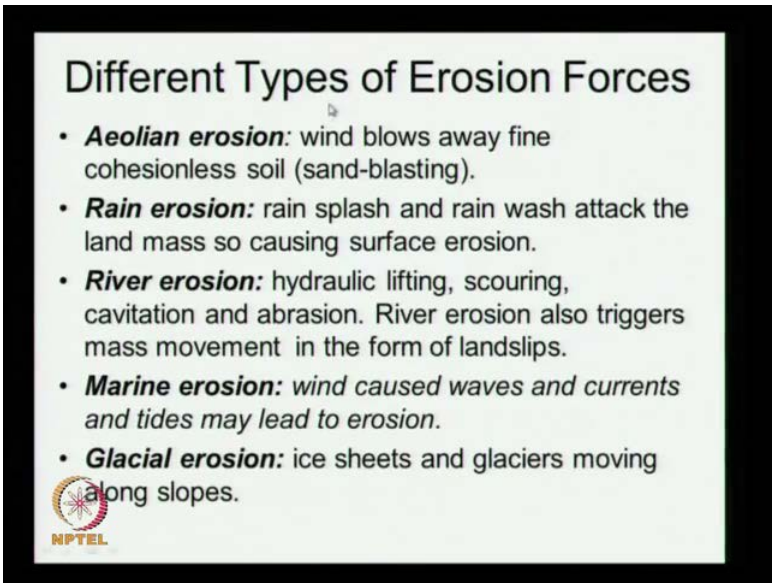

Let us look at the different types of erosion forces the first one is the wind forces or the aeolian erosion. The wind, we know that it blows away all the fine cohesionless soil or it is called a sand blasting, this is what we commonly see in the form of dust storms whenever there is a high wind there is lot of dust blown into the air. It sometimes becomes very difficult to walk difficult to breath, and this happens mostly in areas near to the deserts. Delhi is one good example, that suffers very frequently because of the dust storms and the rain induced to the erosion the rain splash, and the rain wash attack the land mass.

Thus cause in the erosion because when the rain drops fall on the ground with lot of impact energy and because of the splash the soil particles are loosen. If there is too much of run off because of heavy rain fall, whatever soil or the sediment that is loosen gets transported by the flowing water. Of course, the river erosion one good example for the river erosion is the erosion that is taken place in the rivers Brahmaputra and the Koshi river. This happens because of the hydraulic lifting covering cavitations and abrasion. The river erosion also triggers mass movements in the form of landslips, especially the rivers because they flow over a very long length, they can effect the soil slopes over very long length. If there is simultaneous erosion at several places, the entire land the slope can slip resulting in the land slips.

The marine erosion that is very common along the sea coast, the wind caused the most of the waves and currents are caused by the wind. Of course, the carioles force because of the rotation of the earth and the wind induced the waves and currents. The tides may lead to erosion and the glacial erosion because of the movement of the ice sheets, and the slopes they could dislodge some soil deposit at some other place.

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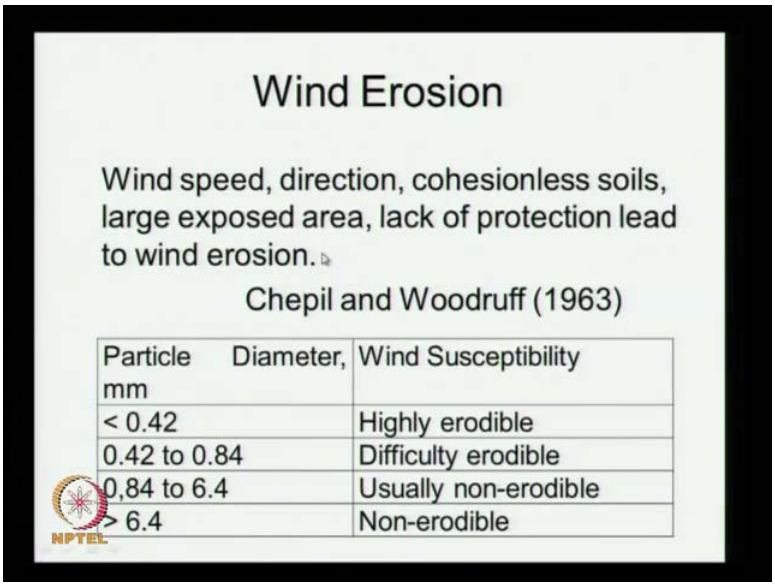

The wind erosion is one of the most common erosion forces, especially this happens on a flat land and a very wide terrene without any cover of buildings, or visitation or the trees. The wind erosion depends very much on the wind speed and the direction of the wind, and then it is predominant in the case of cohesionless soils. The sandy soils are most subject to wind erosion and we need the very large exposed area for the wind induced erosion to take place. The lack of protection leads to wind erosion and this protection could be by providing visitation, or the trees or some buildings top straight the wind forces. This particular table it shows the susceptibility of the sand particles to wind when the sand particle diameter is less than 0.42 millimeters. It is highly erodible and about 0.42 to 0.84, it is difficult to erode and 0.84 6.4 usually not erodible and greater than 6.4 millimeters particle size. It cannot be dislodge by means of wind and usually the wind erosion does not take place in such cases.

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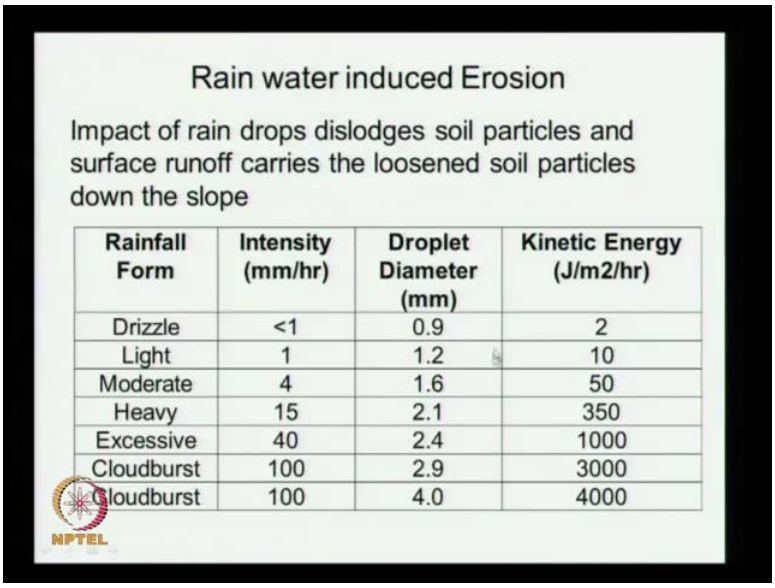

Another form of erosion is because of the rain water induce the erosion and the impact of rain drops dislodges the soil particles, and the surface runoff carries the loosened soil particles down the slope. This is one phenomenon that happens frequently on the hill slopes and also along the river beds. The river banks and the rainfall itself can be categorized into different categories like drizzle that is less than 1 millimeter per hour.

The droplet diameter is about 0.9 and the kinetic energy is 2 joules per square meter per hour. Light rainfall about 1 millimeter moderate 4 millimeters per hour, heavy rainfall 15 millimeters and the droplet diameter goes on increasing with the intensity of rainfall. The energy given to the soil is also increasing exponentially, and the cloudburst is something that is very heavy rainfall. As if there is no end like it is a continuous stream just like opening a tap how we get the water the cloudburst the rainfall comes down like that. The intensity could exceed 100 millimeters and the droplet diameter could be very, very high 2.9 to 4 millimeters diameter and very large kinetic energy is given to the ground.

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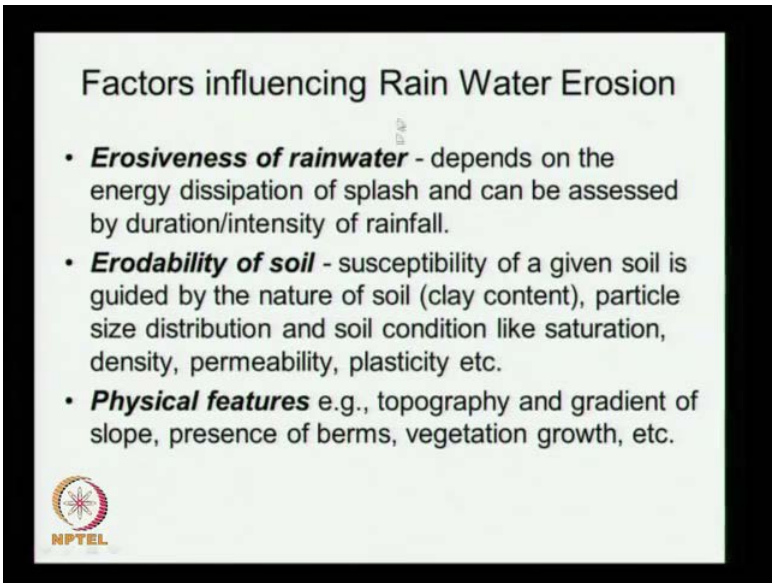

The fact is that influence the rain water erosion, they include the erosiveness. The erosiveness of the rain water depends on the energy dissipation of the splash, and can be assessed by the duration. And the intensity of the rainfall because mainly the duration is very important. If the rainfalls last for a very long time whatever soil particles are loosen, gradually they can get transported.

The erodability of the soil the susceptibility of a given soil is guided by the nature of soil that is by the granular nature of the soil. We have seen that cohesionless soils are more easily erodible as compare to the clay soils. If there is some clay content the erodability of the soil reduces, and it also depends on the particle size distribution and the soil condition like the initial saturation density permeability plasticity and so on.

So, most of the erosion takes place if there is a larger surface runoff and if the soil is a dry much of water maybe observed. It might infiltrate into the ground resulting in lesser runoff and in such cases the soil erosion maybe of a lesser intensity. Then of course, the physical features like the topography and the gradient of the slope the presence of berms vegetation growth etcetera are also factors that influence the rain water erosion.

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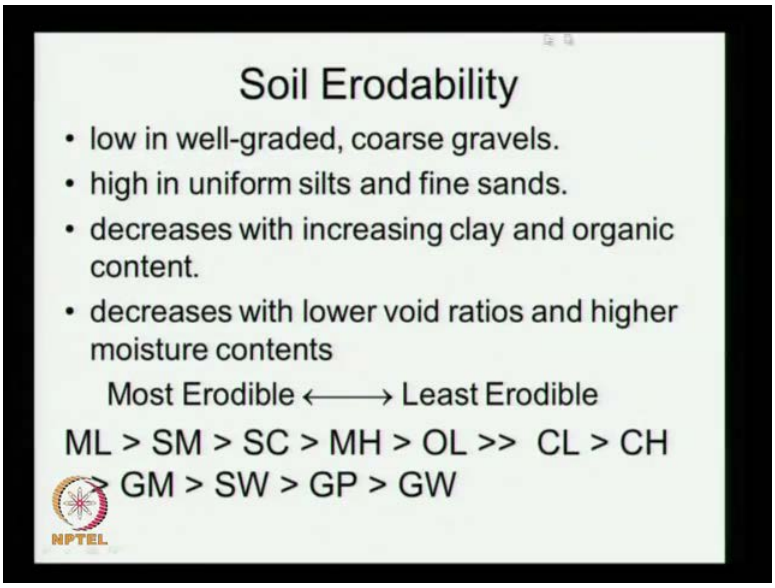

The soil erodability is best characterized in terms of the gradation, it is low in well graded the soils. And also in the coarse gravels, because the well graded means there is a good inter locking between the particles. It requires lot of force to dislodge the inter locked particles just as how we see that in the case of shear strength to determination. The same thing happens even when there is a there is rain water in erosion, or wind erosion and the course gravels because they have higher mass, it requires higher force to dislodge them.

The soil erosion is high in the case of uniform silts and fine sands because these are fine soil particles. If they are uniform gradation the wide ratio is high and because of that it is easy to dislodge them and the soil erodability decreases with increasing the clay, and organic content because of the clay content is high. There is a binding force and that prevents the soils from dislodging and that decreases the soil erodability. The soil erodability also decreases with wide ratio and higher moisture contents and in terms of characterizing the soils.

We can list out the different type of soils from left to right, the left of the most erodible and as we go to the right they are lesser erodible. The silts of low plasticity they undergo lot of erosion SM medium sand and SC clay soil and so on. The well graded gravels because they are well graded and then their particle size is high they have the least

susceptibility to erosion is actually it is an approximate guide to assist the erosion potential of a of a given soil.

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Here, we see some examples of erosion that took place on embankments and one thing that we should notice is all the soils that find silty soils, and actually see these are all very fine silt, silty soils which are very easily erodible which can easily be eroded. We see these deep gullies that are found because of the water that is flowing on the on the slopes. Here, we can see a big tunnel that is in the formation because of the flowing water and in fact this is below a railway embankment these two pictures are on the sites of highway embankment. The erosion would precede the failure or a long term or a large scale failure of the road embankment or railway embankment. So, it is very important that we prevent this type of erosions from taking place.

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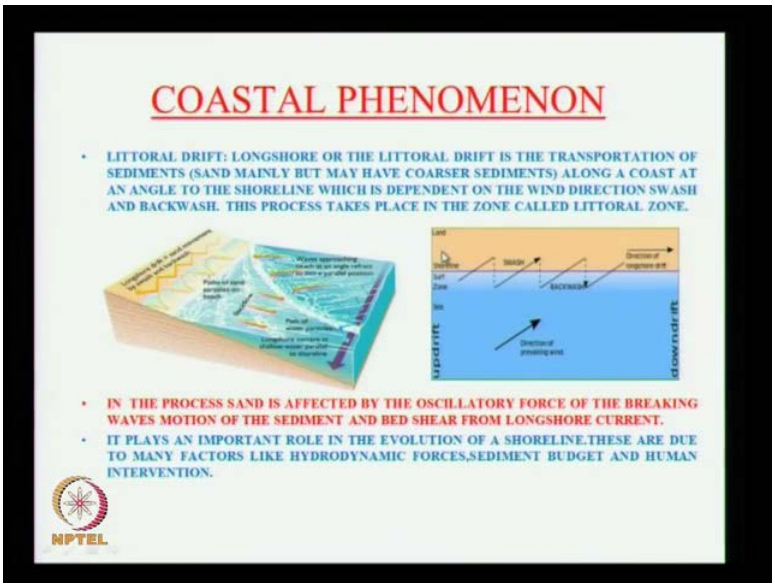

Well opposed to the wind and rain water erosion the coastal erosion is entirely of different phenomenon. There is a one thing called as littoral drift that happens because of the long shore current and the sediment is transported along the costal line, and in India the eastern coast. There is lateral drift going all the way from south to north and that means that if we do not abstract the abstract the flow of the current the sediment goes on transported.

If we do not abstract, it may not cause any problem because whatever the sediment is transported away is deposited by the next wave that is coming in when we abstract the literal drift by constructing a break, water or a groin structure. There is deposition of soil on the upstream side and erosion of soil on the downstream side and is actually this the long shore current, and then the waves when the impact they also set up some currents could lead to erosion.

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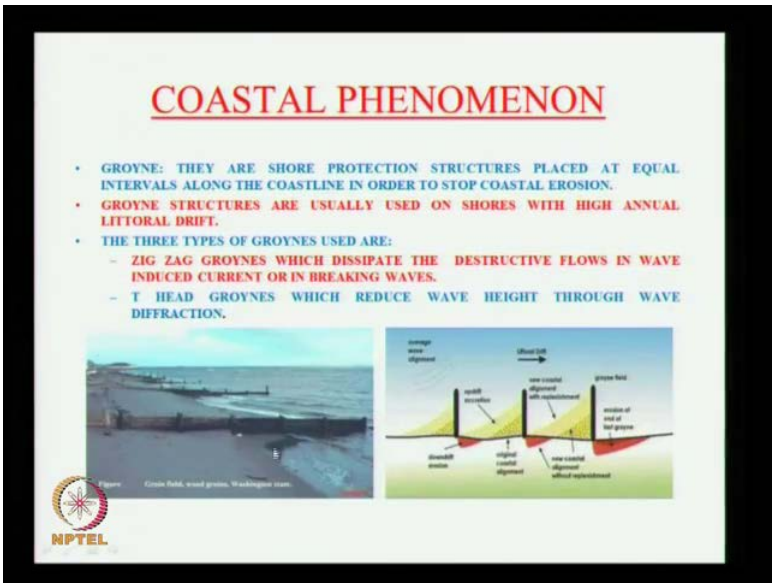

Some techniques for controlling the erosion because of the literal drift are by constructing the groins and on the down downstream side. On this side, there is a deposition of soil where as on the other side there could be depletion. So, we need to do some proper model studies to determine the alignment of these groins, and then how far they should be they should be provided and so on.

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What are the different protection systems that we can use to protect against erosion the rip rap or the rubble machinery. That is placed on the on the shore lines, or on the river

banks is one good example of controlling the erosion the concrete lining. The guniting that is the spry concrete, we can use gabion mattresses and the geotextile covering. The cellular mattresses and the nets bitumen, and asphalt spray, and vegetation. By far vegetation is the best means of the controlling the erosion because the roots of these plants. They can hold the soil together and then increase the permeability, so that there is lesser surface run off.

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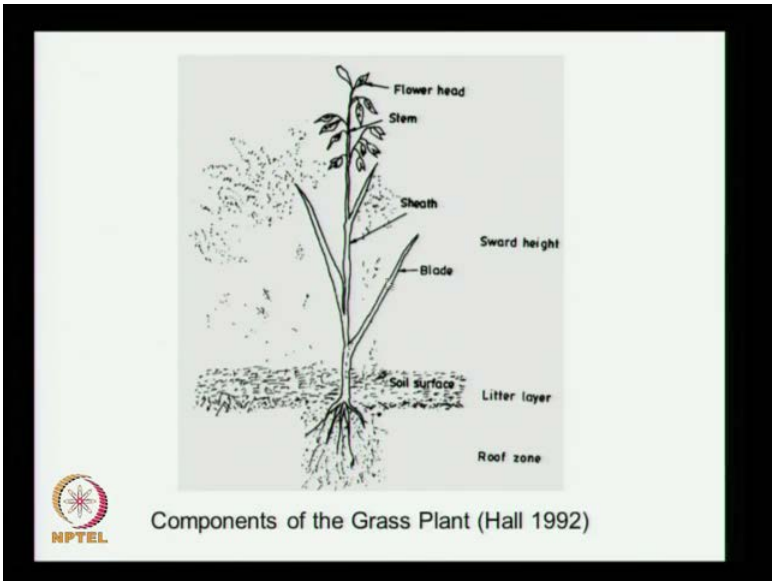

Here, we see a schematic how the vegetation can prevent or reduce the soil erosion first of all balance the ground surface. We have the root zone that binds the particles together and it prevents them from getting eroded, and above the ground surface they act as small check dams to slow down the running water. Then in the case of wind they act as small abstractions to reduce the intensity of the wind very near to the ground surface. So, the vegetation is known to be the best form of defense against either wind erosion, or rain water induced erosion the protection.

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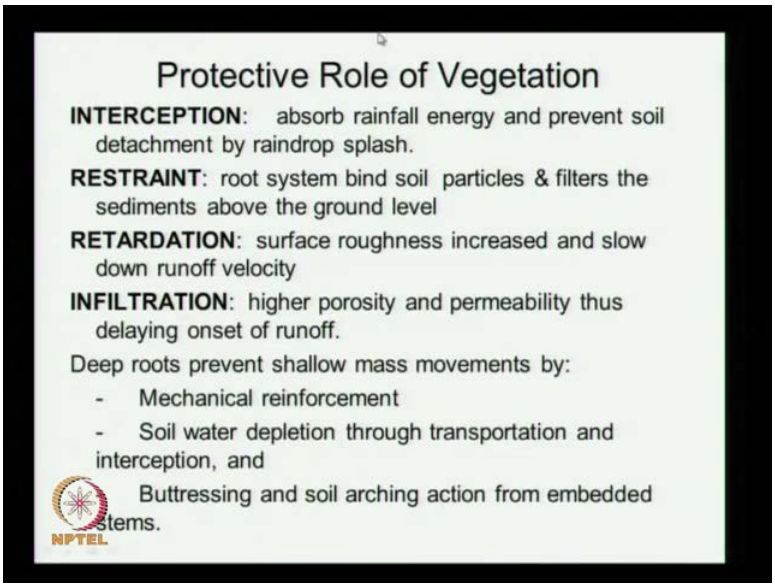

Protective role of the vegetation, interception it absorbs the rain fall energy and prevents the soil detachment by rain drop flashes cause once there is a vegetation in the form of grass or the plants. They can directly receive the impact of the rain, the rain water drops and transfer lesser energy into the ground and restraint the root system binds the soil particle and filters. The sediments above the ground level that is filtering means it allows the water to flow while stopping the sediments from getting transported away, and retardation the vegetation increases the surface roughness and slows down the runoff velocity.

Once the runoff velocity is reduced its erosion force or erosive capacity also reduces and the treep, the vegetation also increases the infiltration because it induces higher porosity and permeability. Thus delays in the onsite of runoff because most of the cases the runoff starts only after the soil is saturated fully. That means, that it cannot absorb any more water. Then only the water starts flowing on the surface until that time the water the soil goes on absorbing the water just like how the sponge absorbs the water.

So, this deep root of the plan the vegetation prevents the shallow mass movements by mechanical reinforcement and the soil water depletion through transportation, and interception, and buttressing. Soil arching action from embedded stems because of the soil arching also we know that the pressure is reduced. Then the same way when there is

a some type of sliding that is taken place even the sliding forces reduce because of the reinforcing action of the of the vegetation.

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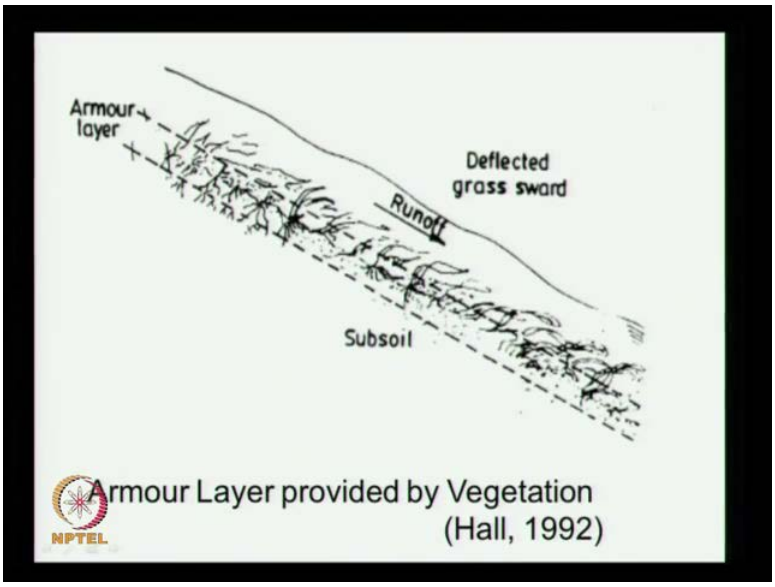

Here, we see the effect of vegetation on the slopes is actually the roots of the vegetation and then the stems they act as a armour layer protecting the soil here. We surface the runoff that is flowing along the slopes and the vegetation either in the form of shrubs or grass it absorbs, and does not allow the soil particles from getting dislodged.

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In this picture, we see one example of how the surface can be treated by growing vegetation. The left hand side we see railway embankment with lot of gully formations because of the rain water flow, and if this is treated by allowing the vegetation to grow this type of gully formation will not take place. Here, we see an example of a coir mat that is seeded beforehand, so that it can be just simply brought to the site and spread like a carpet, so that the vegetation can take place.

For the vegetation to take root the natural geotextiles ,or the geosynthetics are very good because they not only provide the moisture to the plants because they can absorb the water, and gradually release it when the plants require it. Also because of their multigaction, they are biologically decaying they produce some nutrients for the vegetation to grow.

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Here, we see another application of geosynthetics here this irrigation canal is lined with spray concrete or goneiting, first it is covered with geocells of very low height about 50 millimeter height. These geocell pockets are filled with concrete to line this canal is actually in these cases the geocells. They act as small farm works for the concrete to be pored in under set without this geocell confinement is not easy to form the concrete concrete lining on the slopes.

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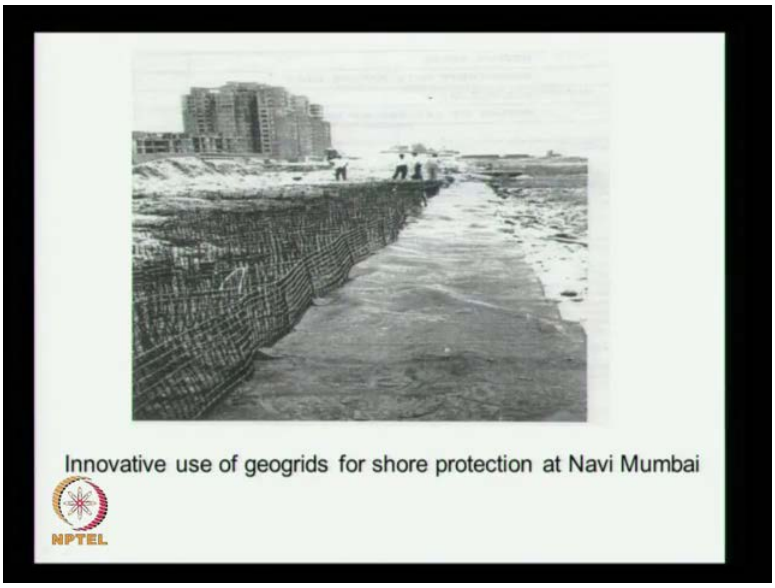

Here, we see an innovative application of the geogrids very low strength geogrids for shore protection at Navi Mumbai is actually, this picture is that was taken the mid 1980s and here we see the geogrids that are installed in the form of open geocells. These nets they are filled with sand and then the first few pockets they are filled with stones, so that any wave that comes it will just simply, it will not be able to allow the soil to be dislodge because of the combined action of the geogrids. The pockets inside the geogrid grovels and then the aggregate the soil together acting together to absorb the wave energy.

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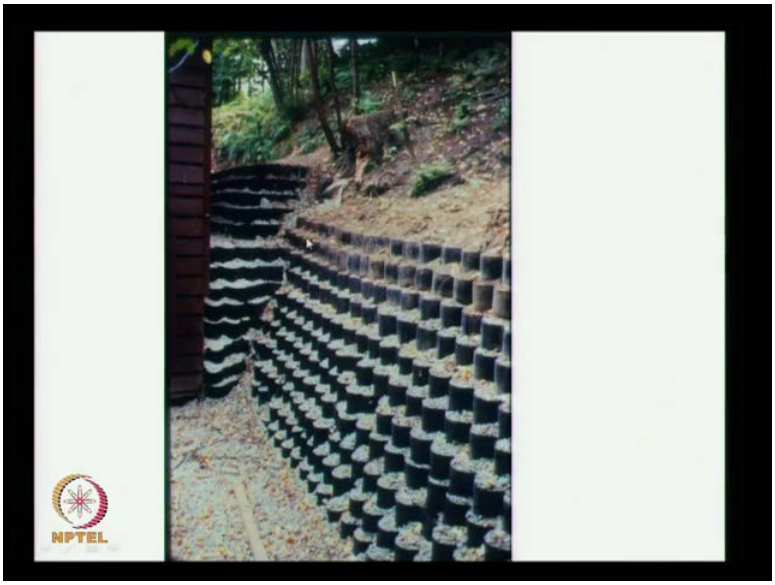

Here, we see the application of geocells for stabilizing the soil on the steep slope. The one advantage with these geocells is you can just simply stack them one above the other, and because of the very good surface friction that takes place between the geocells. They do not need, they do not require any external mechanism to support them.

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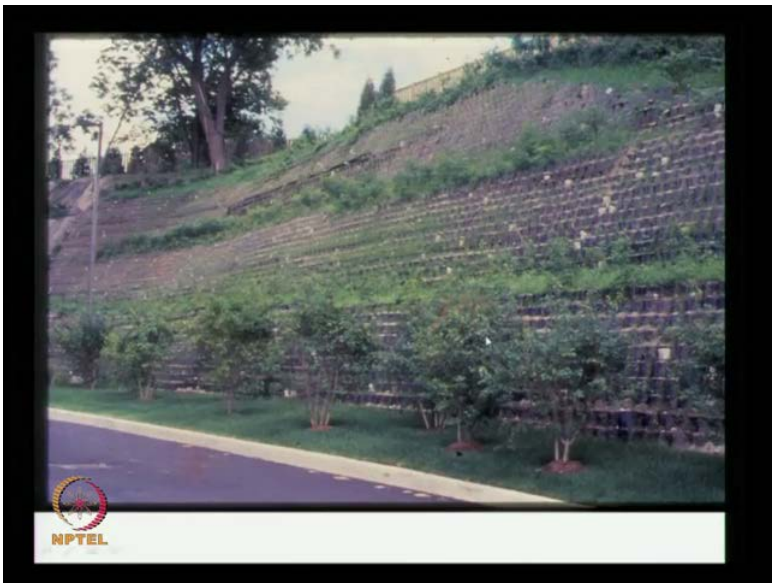

Vegetation can take root a through the soil within this pockets like this is actually here we see a very high steep slope and that is stabilized by using geocells. The vegetation is growing through the pockets, and after one or two seasons the entire slope may be covered with vegetation, at that time we may not even see that there is some plastic buried there.

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Here, we see one example of shore line stabilization at Swaminarayan temple site in Tithal Gujrat is actually this temple is located on the Arabian Sea. There is very severe erosion at the site due to wave, and current action at one point the sea coast has come very close to the temple and that needed to be supported is actually here.

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This temple is there and at some point the beach has come very close to the shore line and any amount of dumping of stones was not sufficient because the current is very fast. The wave action is very severe and any boulders that are dumped there, they just simply

get washed out. The solution that was given here is the stones filled in rope net gabions we know that gabion is nothing but a basket. In this case these gabions are made of polypropylene ropes, which are stable in marine environment and all these gabion mattresses are tie to together. That means that there combined mass is very huge and no amount of wave energy can dislodge them.

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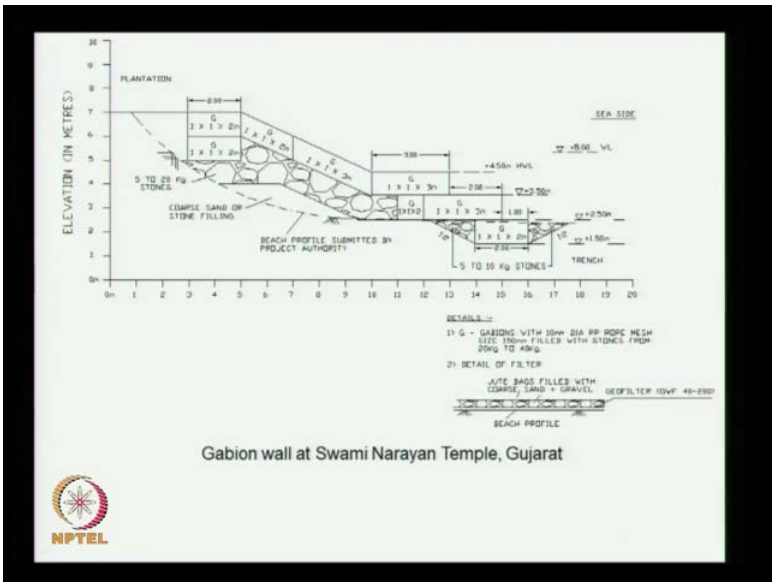

This is the cross section at this at this particular site, they some top protection given and this is the protection along the along the height.

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This is the close up of these stone filled gabions and here you can see another close up.

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This is the temple and the shore line has come very close to the temple at some point.

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Here, you see another picture of same thing of the shore line stabilized by stone filled gabions.

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Here, we see the gabions filled with stones is actually it is a manually intensive process, but then it is sufficiently low scaled that even rural people, or uneducated people can easily take part in this type of constructions.

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Here, we see the gabion mattress that was built at Swaminarayan temple and some small projection is given to act as groins to help in deposition of the of the sea sand of the beach sand.

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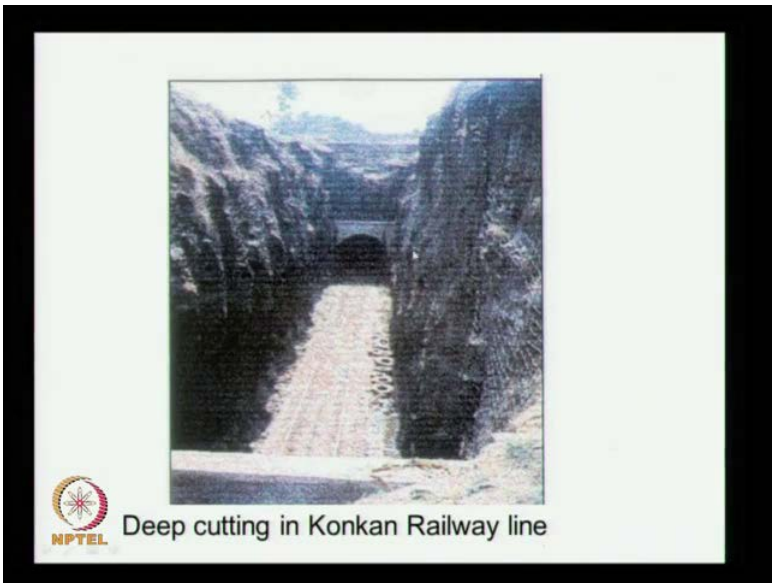

Here, we another example of how the geosynthetics are used for erosion control on a steep slope this is a picture of deep cutting in the Konkan railway line. The problem here in the Konkan region is this area receives very, very heavy rainfall during the monsoon time and because of the heavy rainfall there is a heavy surface runoff. It just simply erodes all the top soil and in the process of removing the soil, all the boulders that are on the slopes they become highly unstable because all their support is washed out and to prevent.

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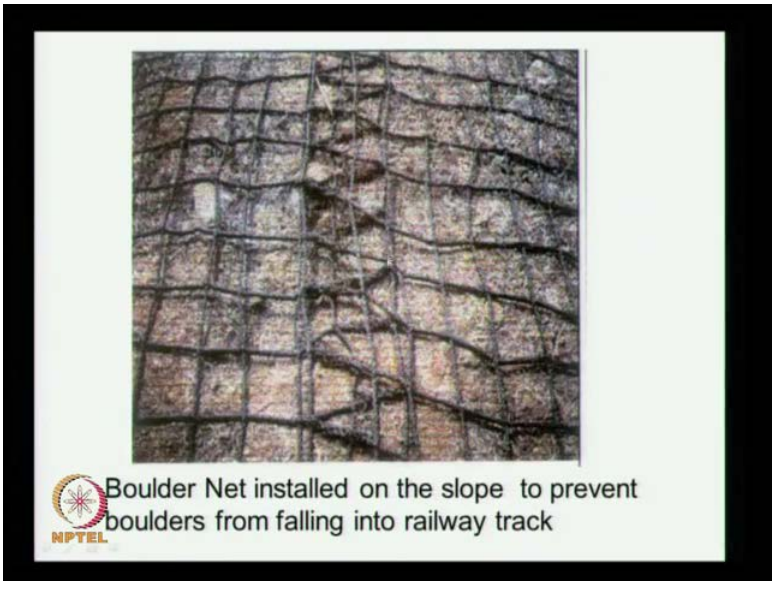

The boulders from falling into the railway track a boulder net were installed, and this boulder net apart from preventing the boulders from falling into the railway track. They also help in a secondary manner in reducing the erosion because as you can see all these cost members. They have certain thickness and when there is a surface runoff, all these cost members they act as a small check dams to slow down the surface runoff. In the process of slowing down they also help in deposition of whatever suspended matter is there in the runoff.

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In the process they can also help in the growth of vegetation and here, you see the view from the top of the slope this boulder net is anchored securely, at the top in a anchor trench that is later filled with soil.

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The result of this treatment is like this is actually, we can see the vegetation that is going up because of because of the slowing down of the surface runoff.

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In this picture we see the stabilization of the river bank using two types of geotextile. One is jute a geotextile and the other one is polypropylene geotextile, one is a synthetic material and the other is a natural material.

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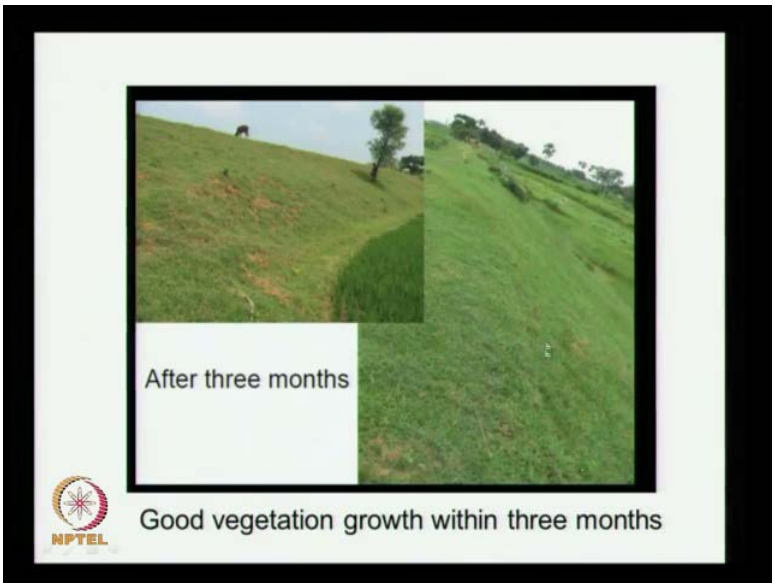

The result is there is good growth of vegetation within a short time because of the provision of the jute geotextile is actually, this particular picture is within the jute treated portion.

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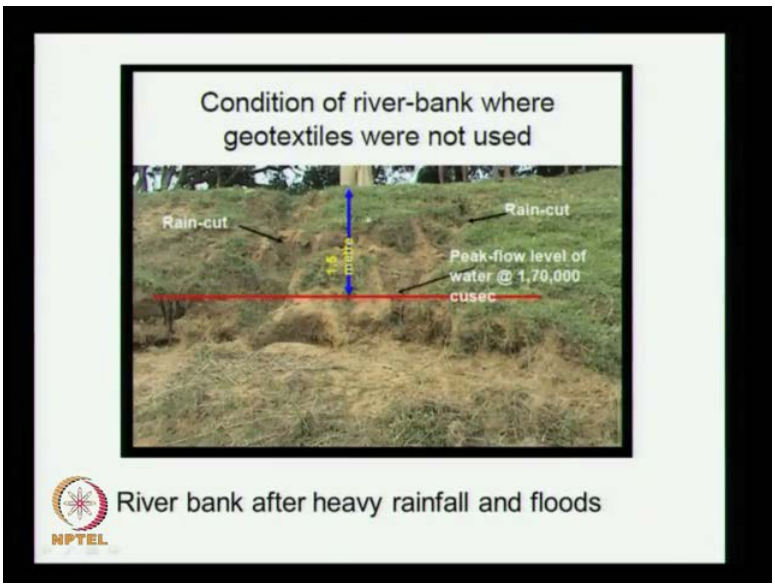

After short duration, after the instillation there were heavy rainfalls and heavy floods. This is the picture of water happened because of the rain water erosion the rain cuts everywhere and this is the portion, where there was no geotextile used for stabilizing the banks.

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This you can see in overall picture is actually on this side without the geotextile. On the right hand side we see the part that is very stable because that is laid with geotextile layer.

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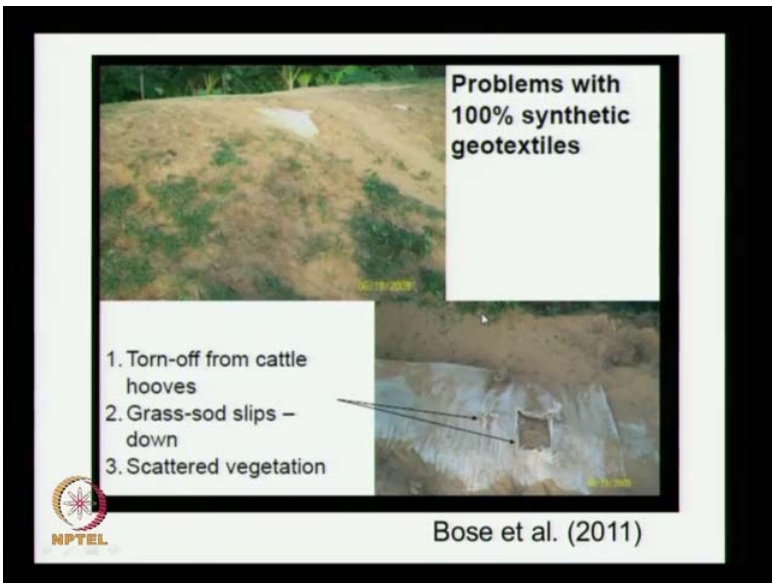

Another distinguishing feature between the treatment with a natural geotextile, and polypropylene geotextile is actually the vegetation could not grow properly, in the portion that is covered with polypropylene type of geotextile because it is not compatible with soil or vegetation. Then because of the smooth texture there was sliding down of the

of the grass sods the gross that is placed in lumps and this, so that means that 100 percent synthetic geotextile is not very good for stabilization of the slopes.

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Here, we see another example of the use of geosynthetics for shore line stabilization. Here we have the metallic gabions filled with stones, this particular picture is from Trivandram in one just before the monsoon. The cost line got eroded very badly and the water has come all the way here at that time some shore line treatment was given.

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Here, the same beach short distance away here the sea wall was built using polypropylene rope net filled with stones.

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So, we can use beach sand itself for constructing our shore line stabilization work. The main difference between this type of construction using stones, and using beach sands is that using the beach sand is more sustainable because this plenty of beach sand that gets replenished. Whereas, for getting the stones, we need to get the stones by breaking up mountains or hillocks. Here, we see one experimental small break water being built by one of our students, we have this geotextile bags that are filled with beach sands.

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These are intern placed inside this rope net gabions and these rope net gabions are all tied together to act as a small small break water, here you see one under construction.

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Here, we see the wave breaking nicely against this the break water unit that is fully built using geotextiles. And then beach sand and we call it is a flexible break water because it is all built using flexible materials.

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What causes the erosion along the cost apart from the wind induce the wave and currents even the cyclones can cause a lot of erosion or deposition of sand. Here, we see the coast line at INS Adyar site in Chennai before the cyclone that came in some time in December 2011. The coast line was like this, you notice that how close the coast line to these buildings and after this cyclone this beach got, so widen that means that this sand has come from some other place.

There was a very heavy loss of ground because of the erosion and that whatever was brought by the by the cyclonic waves. It got deposited because it is a relatively protected area because both to the south and north. There are abstractions to the north of this INS Adyar's we have this Chennai harbor or port with huge very long break water. Just to the south, we have this Cuvam river with some river training works. And because of that this INS Adyar's site is relatively protected and this is one good example of the affect of cyclones and the shore line. So, in this lecture I have given a brief introduction to the erosion that caused by wind waves, and then rain water and then the sea currents and how we can utilize geosynthetics for controlling the erosion process. If you have any questions you can send an email to me.

Thank you very much.