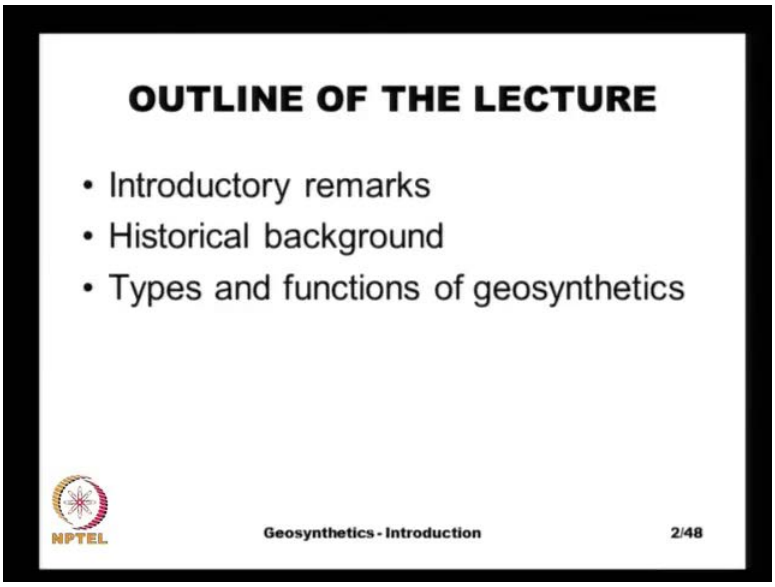
Geosynthetics and Reinforced Soil Structures
Prof. K. Rajagopal
Department of Civil Engineering
Indian Institute of Technology, Madras

Lecture - 1
Introduction & Need for Geosynthetics

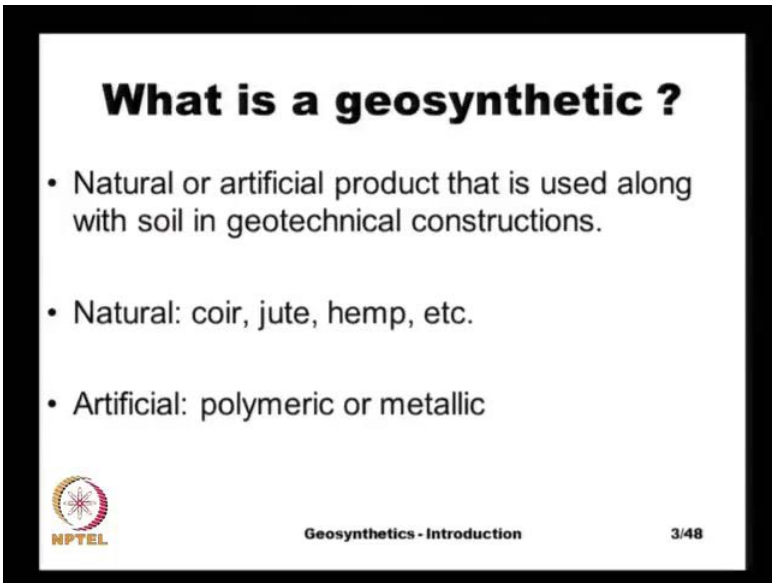
Hello students, this NPTEL course is on Geosynthetics and Reinforced Soil Structures. And I will take you through the different concepts of the geosynthetics and the reinforced soil structures in about 40 lectures in this course.

(Refer Slide Time: 00:26)



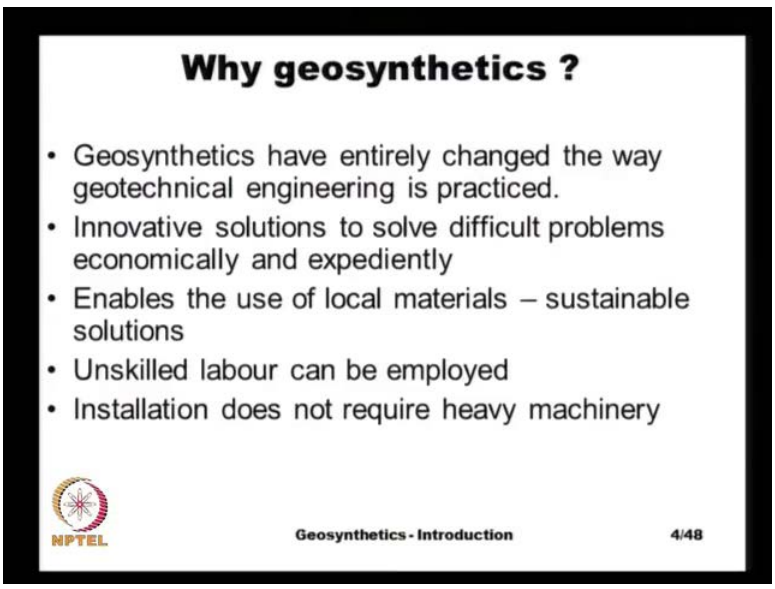
So, the brief outline of this today's lecture is, I will give some basic introductory remarks then historical background of the geosynthetics and the reinforced soil structures. And then we will learn about the different types of geosynthetics and their functions and their applications.

(Refer Slide Time: 00:51)



So, let us first see what is a geosynthetic? This product it could be either a natural product or a artificial product, that is used along with soil in geotechnical constructions. And some of the natural materials are coir, jute, hemp and other similar products, especially India is very strong in producing jute products and then the coir products. And both of these, they are employed extensively in several parts of India especially for erosion control applications, and for low volume road reinforcements and so on and then the artificial or manufactured geosynthetics or the polymeric or metallic type.

(Refer Slide Time: 01:49)



See, the question may arise why geosynthetics? These geosynthetics they are recently introduced into the civil engineering field and the introduction of the geosynthetics have entirely changed the way the geotechnical engineering is practiced. And we can come out with very innovative solutions that could not have been done just a few years back, even 20, 30 years back. And we can solve very difficult problems at a very economical cost and expediently at a very reasonable speed and it enables these geosynthetics.

They enable the use of local materials that is, the local soil or some other local aggregate and local materials and that lead to sustainable solutions. And we will see, how these geosynthetics lead to more economical and more sustainable and more faster solutions, as we progress along in this course. And the most important factor in the geosynthetics is, we can use unskilled labor because especially for countries like India where, we have very large labor force.

This is a boon because the use of geosynthetics does not mean that, we need highly skilled labor and the installation of geosynthetics also does not require any heavy machinery, we can do them with vary light machinery or many times just with a manual means.

(Refer Slide Time: 03:28)

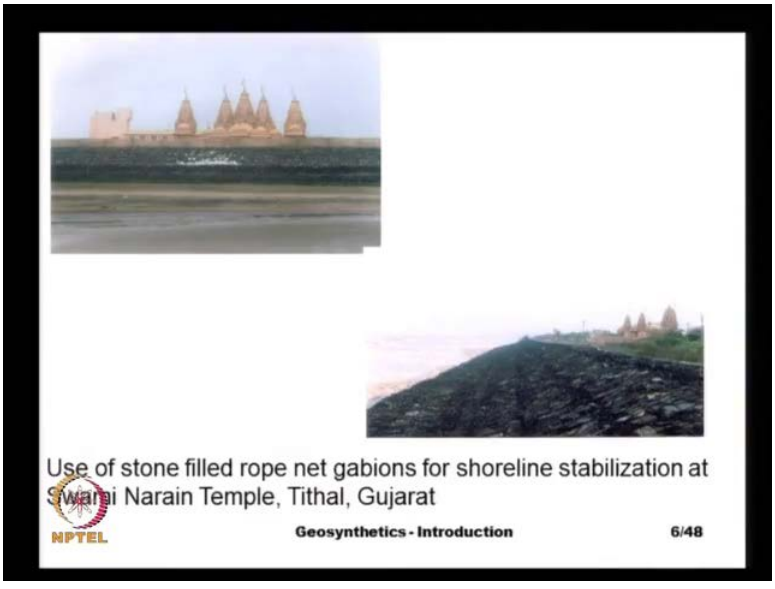
Let me show you some of the typical applications that could be done with geosynthetics and in this slide, we see the application of a coir mat. First showing the application of a natural material because the coir is very widely used in India and probably, India is the

leading producer of coir geotextiles in the world. And the top of the slide, on the left hand side, you see a typical railway embankment that is subjected to severe erosion, because of the rain water flow and gully formation.

And the easiest method to treat this type of thing is to promote vegetation growth and the coir is very ideal material for promoting the vegetation growth. Because, the coir is being a natural product, it degrades with time and as it is degrading, it produces the nutrients that are necessary for the growth of vegetation. And the other advantage that we have coir is that, when there is some rainfall, the coir retains the moisture and it can supplies the moisture to the plants for a very long time.

And so because of both the reasons, because of the provision of moisture for a longer time and the nutrition, the vegetation can take a root very easily. And in this slide at the bottom, you can see the treated slope just within about two seasons, after the installations of the coir geotextile mat, how beautifully the vegetation has come out.

(Refer Slide Time: 05:13)



And here, we see the application of geosynthetics for rehabilitation of a course line, in Gujarat, in Tithal Gujarat, there is one ancient temple Swami Narain Temple. And because of the extreme current, the ocean currents and then the wave conditions, the coast line has come very close to the temple and no amount of treatment by using boulders and other forms of treatment could stop the sea erosion. And finally, the

solution that was given was very simple using stones but put in a rope net gabion and then just simply lining the coast line.

And at the bottom, some training works were given, so that the beats can build up and here, the main advantage that we gain is, we are still using the same boulders. But then because they are encased inside rope net gabions, and which are all tied up together, no amount of wave force or current force can discharge them. Because, all of these now the entire about 300 meters stretch of these structure is monolithic.

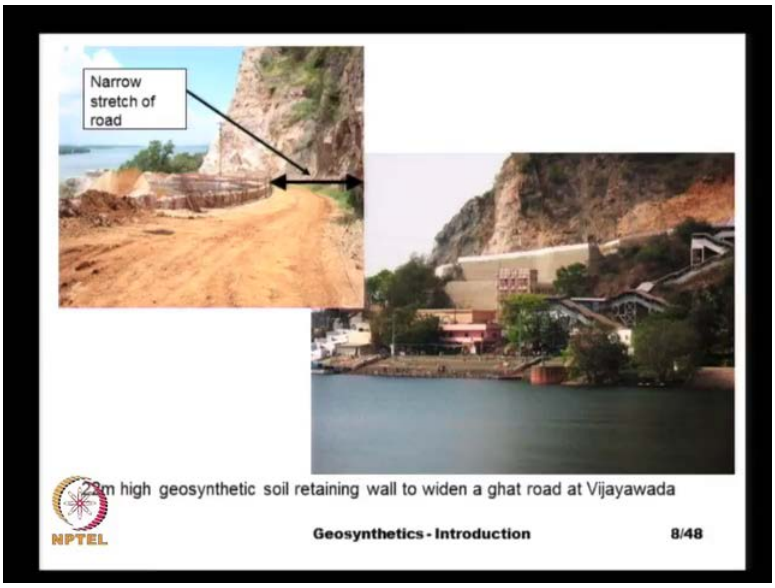
And so because of that, it is very strong and very stiff and it is able to survive the severe ocean environment at this place and it could easily stabilize the coast line at this place.

(Refer Slide Time: 06:56)

And here, we see in the application of a three dimensional geosynthetic for canal lining especially, when canal goes through sandy soil like in the desert areas and so on, the seepage losses could be very high. And in that case, we like to give a concrete lining or some other lining and unfortunately, the concrete lining will not last for very long time, because of the shrinkage and other problems, the stood cracking. And one way of stabilizing the cement ground is by encasing it in geocells, that provide the necessary reinforcement.

So that, the concrete does not crack, it has been successfully employed at several locations for preventing the seepage losses.

(Refer Slide Time: 07:52)



And here, we see an example of the construction of a 22 meter high retaining wall using a geosynthetics, actually this particular application is in the city of Vijayawada. There is a ghat road leading upto a temple on the top of the hill and this ghat road is very narrow and when it was constructed about 50 to 60 years back, there was not much traffic. Mostly, the people used to walk or go on bicycles, at that time, they dint need a very wide road.

Now, since everybody is driving cars, we need a wide road and that the only way, that this road can be widened is by filling up this entire area with soil. But then this height is about 22 meters and construction of a normal reinforced concrete retaining wall is not possible because the height is too much. And so the solution that is provided is, by using the geosynthetics and very small modular blocks. One wall is built and here on the right hand side, you can see this picture, it is come out very beautifully.

And in spite of restricted working space, this wall could be constructed, I will explain about this in future lecture.

(Refer Slide Time: 09:24)

And here, you see the application of geosynthetics for the construction of a land fill to contain a highly toxic jerosite waste in the city of Visakhapatnam, this length of the land fill is nearly 200 meters and the width is ranging from 100 to 150 meters. And this entire land fill was constructed using very innovative techniques, normally the landfills are constructed below the ground level. But, this being a hill area, the ground could not be executed, because of the rocky strata, it has to be entirely built above the ground level.

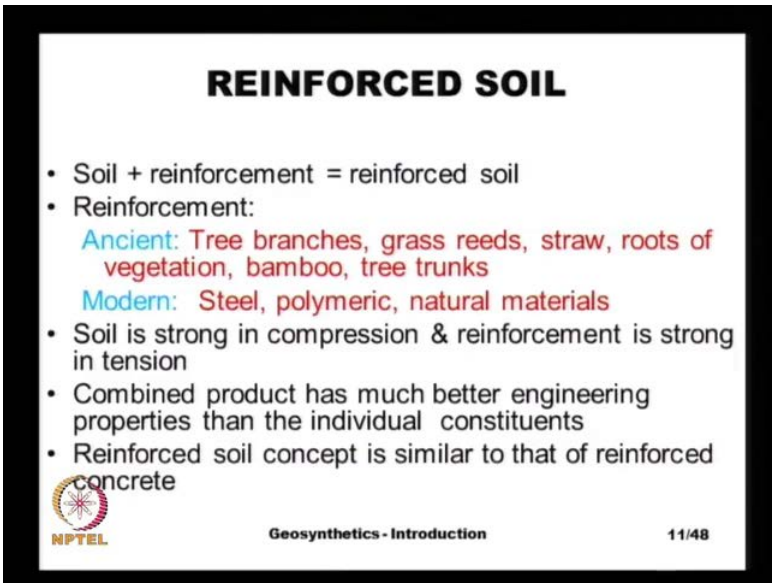
And for the construction of this embankment, the material used was the jerosite granules and by putting in some geosynthetic reinforcement, this jerosite granules which is otherwise a waste product, could be used usefully for construction of this embankment. And then here on the right hand side, you can see the outside of this embankments, this height of the embankment is 10 meters to 12 meters, it was lined with coir textile so that, vegetation can grow and this entire thing can blend with surroundings.

(Refer Slide Time: 10:55)

And here, you see the construction of a break water unit using once again geosynthetics, this technique it uses geotextile bags filled with beach sand and these geotextile bags are placed inside rope net gabions and all of them are tied up. And on experimental basis at IIT Madras, we are taken up this project, constructing of break waters and other costal treatment structures using these structures. And here, you see an example of this, this is about one and half to 2 meters height and you can see the wave nicely breaking against this structure.

So, these in the previous few slides, I have shown some applications of the geosynthetics and all these could not have been possible just a few years back. And now, let us see the bit more details of the reinforced soil and the geosynthetics.

(Refer Slide Time: 12:04)



Basically, the reinforced soil is nothing but soil plus reinforcement and we call it as reinforced soil and the reinforcement, some of the ancient reinforcement products. That means, I mean ancient means, some 2 to 3000 years back, people have used the reinforcement but in the form of tree branches, grass reeds, straw, the roots of vegetations, bamboo, tree trunks and so on. And even the ancient past, people built very high towers and very high tall structures using the soil plus some form of reinforcement.

And the modern reinforcement materials, they are steel, polymeric materials and then of course, the natural materials like the coir and jute. And reason why, we use reinforcement or we need to use the reinforcement is, the soil is very strong in compression. See, if you are able to apply pure compression stress on the soil, it can take any amount of compression. But then unfortunately, because of the poisson's ratio of it, if we apply compression in one direction, there is tension in the other direction and the soil is very weak in tension and starts failing.

And because of that, the soil undergoes quick failure and this combined product of this soil and the reinforcement, it is a very good synergetic combination and it has much better engineering properties than the individual constituents. And so it can provide very strong soil and very stiff soil so that, we can build any structures in that type of material. And the concept of reinforced soil is very similar to that of the reinforced concrete and if

you know reinforced concrete, you can appreciate the reinforced soil also because it has the same thing.

The concrete is very strong in compression but very weak in tension and the same thing with the soil. It is very strong in compression, but not so strong in tension so the reinforcement takes the tensile load when we apply them.

(Refer Slide Time: 14:32)

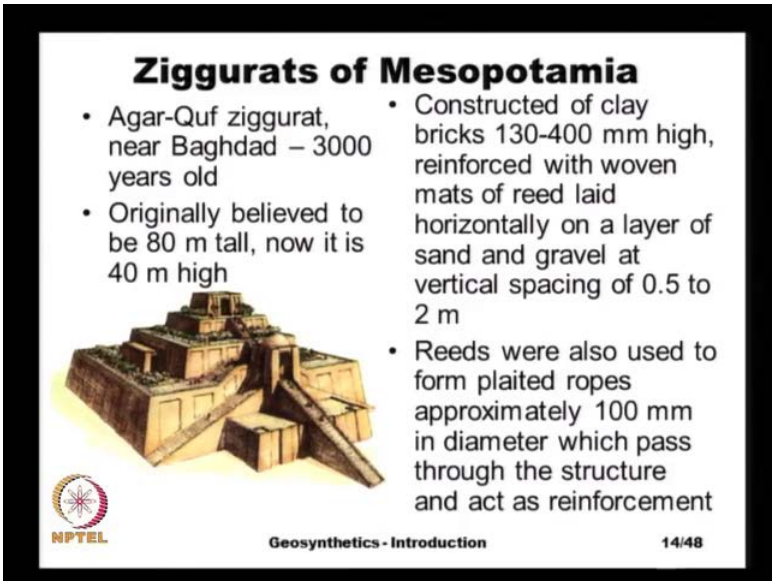
Let us see some of the historical application of the reinforced soil.

(Refer Slide Time: 14:40)

It is actually, even before we talk about the human beings, let us see this wonderful animal it is called beaver, which is very common in North America and in some parts of Europe. Actually, it is more like a rat, it is a semi aquatic rodent somehow, it moves on the land but then it likes to live below the water. And it is been building abstractions of the dams across the river, across the small water bodies and it builds this, it is a dwelling at very deep depth.

And it uses the twigs and this type of things and soil in an excellent engineering manner and it builds it is nests so strong, that it is not easy to destroy these nests. And because of this, beaver is thought about the first civil engineer, we do not know how long they have been building this. But, it is very wonderful and in many countries, they issue stamps with beaver and many of the civil engineering societies, they have beaver as their logo.

(Refer Slide Time: 16:06)



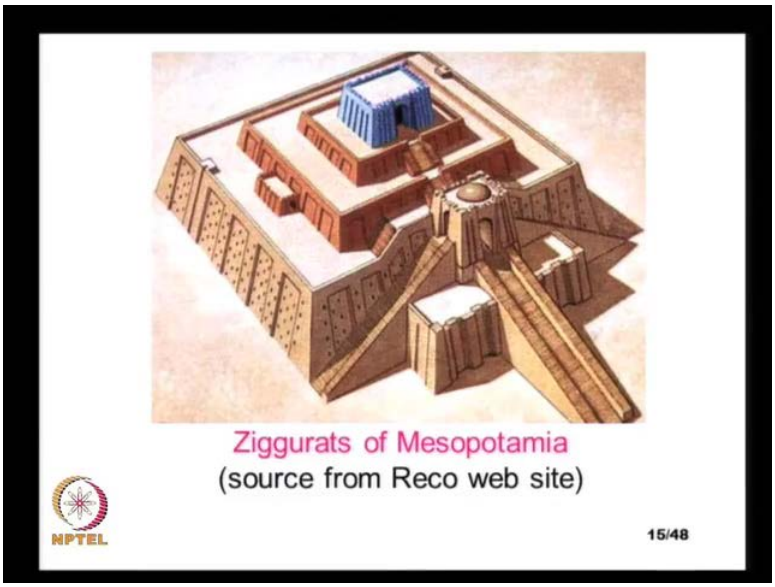
And there are several historical places with good evidence of the application of the soil reinforcement concepts in the ancient past. About 3000 years back, in the present Iraq, in Baghdad city, there was very famous temple and it is originally, it is thought that the original height is nearly 80 meters high. And now, it is only 40 meters high, even 40 meters high is not very short structure, it is very, very tall and probably, people have built them as a place for worship.

Because, in the ancient days, people were worshipping nature, they like to worship moon, the sun and the natural elements like the rivers, trees and so on. So, they need an

open place and at a very high elevation so that, they can be as close to the sun as possible and this entire structure was built using clay bricks, each of about 130 to 400 millimeters high. And interestingly, the structure was reinforced with woven mats of reed laid horizontally on a layer of sand and gravel at vertical spacing of about 0.5 to 2 meters.

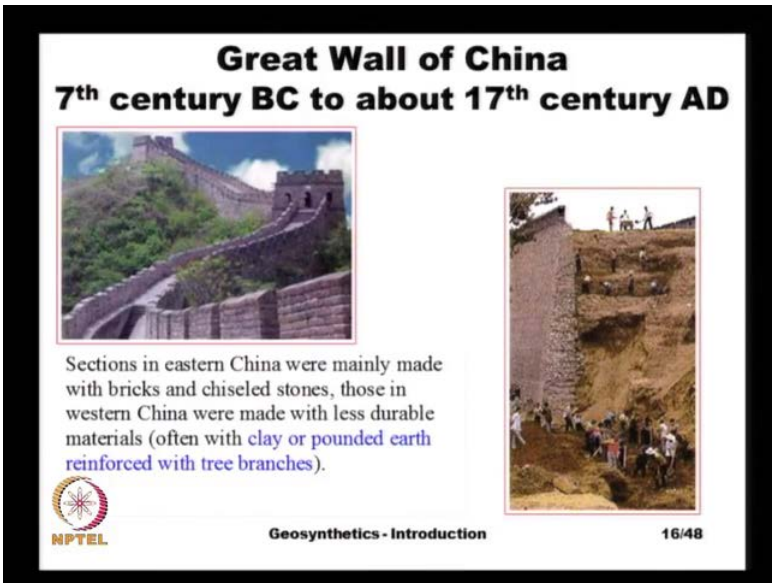
And the concept is very, very similar to the concept of the reinforced soil structures, that we have employ now. And these reeds would also used to form plaited ropes, approximately 100 millimeters diameter to encompass the entire structure, as an enveloping thing to keep the entire structure together. And so this could be thought about a one of the earlier applications of the reinforced soil.

(Refer Slide Time: 18:02)



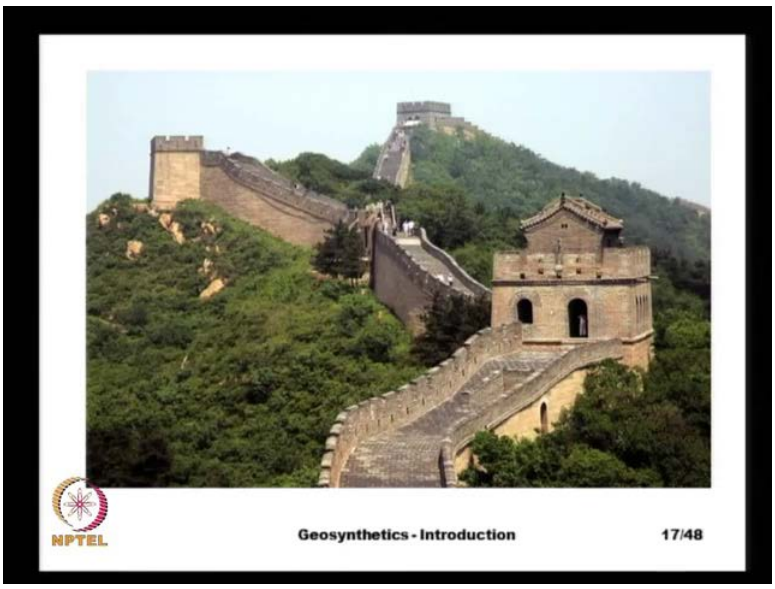
And here is a close up of the same structure, at the Ziggurats of Mesopotamia, that is in Baghdad.

(Refer Slide Time: 18:11)



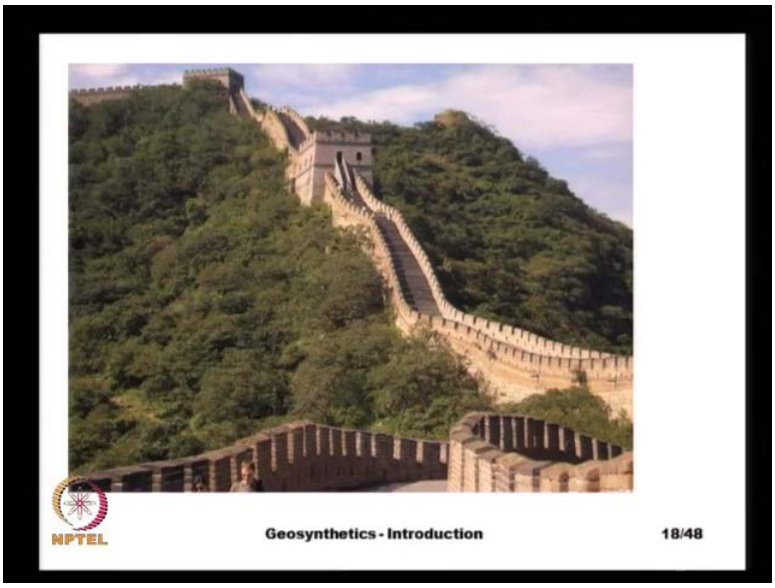
And nearer to India, in the china, we have this great wall of china, that was built in during the 7 th century BC to about, as recent as 17 th century. This great wall of china was built to keep the Mangols out of china and they had employed the soil reinforcement concept for constructing this tall structure. And this is another good example of the use of reinforced soil concept in the ancient past.

(Refer Slide Time: 18:51)



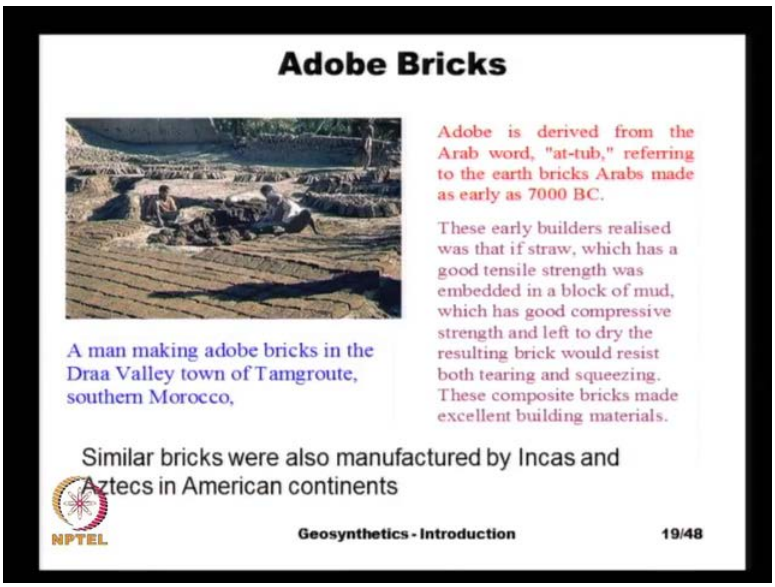
And here is another picture of the same great wall of china.

(Refer Slide Time: 18:58)



And here is another picture.

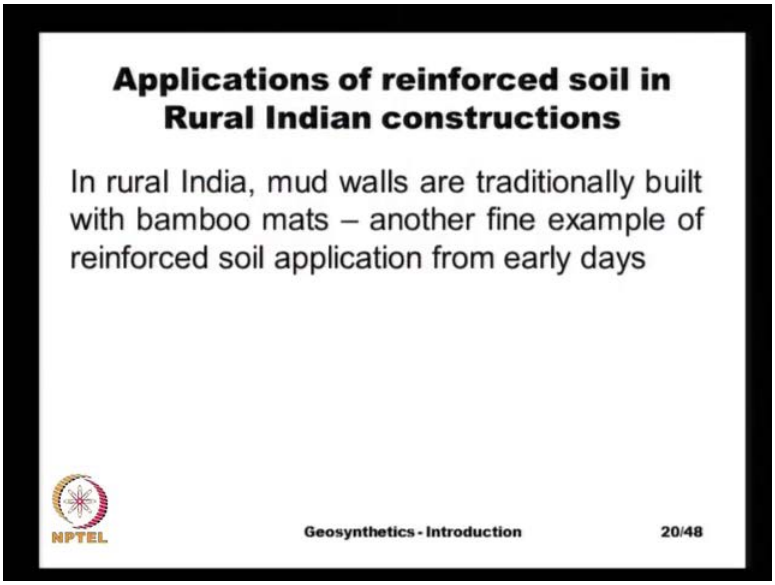
(Refer Slide Time: 19:01)



And adobe bricks, it is actually the very good examples of the use of reinforced concept and these bricks are mostly manufacture in North Africa in the rural areas where it is traditional practice to mix with small, small fibers with the bricks, while making the brick. And is very interesting that similar bricks are also used by Incas and Aztecs in the Americas, North America and South America. Recently, I had been there and I had seen the evidence of this type of adobe bricks.

So, it is possible that, at one point of time in the ancient past, all the people may be they had some form of contact with each other to exchange the technology and to pass on the new materials and new construction techniques and so on.

(Refer Slide Time: 20:00)



And in rural India also, is very common to see the use of bamboo mats and other things for a construction of these mud walls in the huts and other things. So, it is another example of the application of reinforced soil for human habitation and so on.

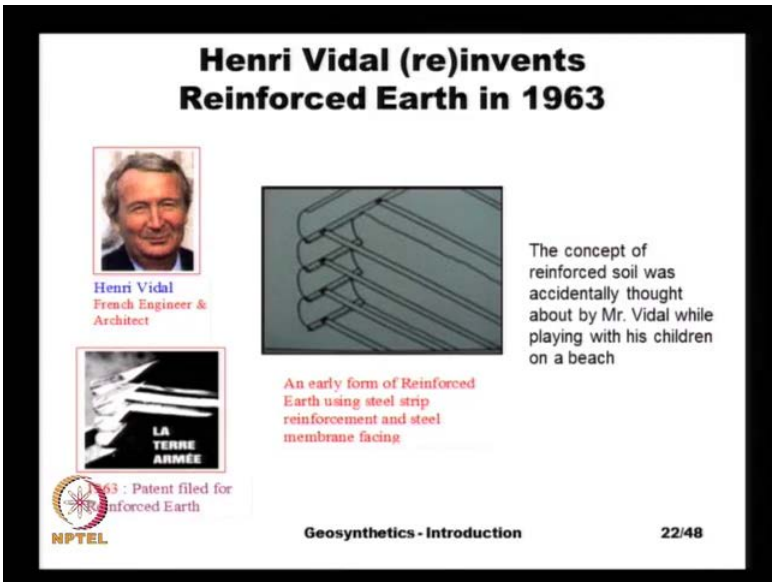
(Refer Slide Time: 20:26)

In the past 100 years, the geosynthetics have been employed, it is actually in the past the word geosynthetic was not coined, it is actually the word geosynthetic came into being only in the 1970's. So, in the 1920's, in South Carolina where, they have lot of forest, the forest access roads, which are usually temporary in nature, and they have to pass through very soft soil or marshy lands. And there, they used a cordierite mats for constructing temporary access roads and Terzaghi himself has used filter fabrics for construction of filters.

And in Japan, they used polyvinyl bags for construction of the sea walls, instead of the straw bags, the straw bags used to be very common traditional materials and they started using polyvinyl bags in the 1920's and 1930's. And of course, in Netherlands, which is below the sea level, they have been using geotextile tubes for construction of the dykes to keep the sea water away from their land.

And in Europe, they have been using a polymer meshes and membranes to contain industrial waste and so on, that has been going on for almost 50, 60 years, even before the advent of the modern geosynthetic materials. .

(Refer Slide Time: 22:03)



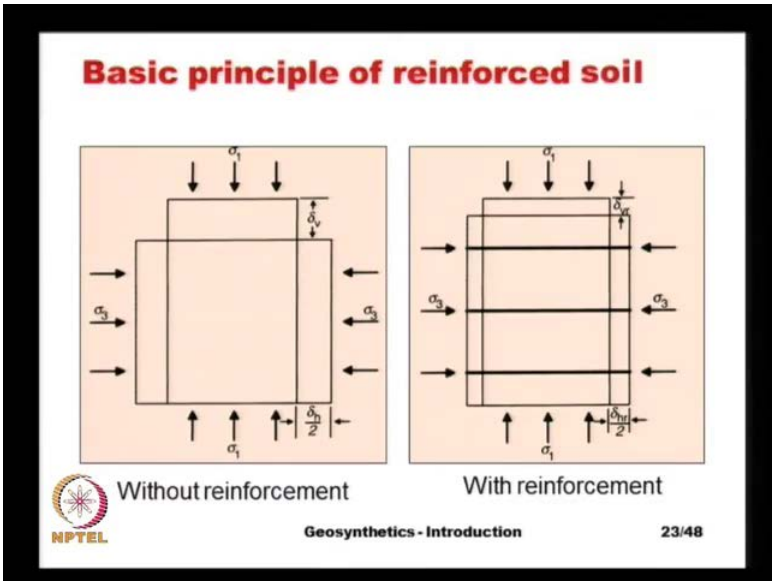
The concept of reinforced soil or the reinforced earth is attributed to one French engineer called Henri Vidal and I am calling it as reinvented because this concept is not new. Actually it has been used and somehow, we forgot about it and Henri Vidal is actually reinvented it and the manner of it is invention is very interesting. While playing with his

children on a beach, he had to construct some structures using sea sand and he notice that, when he put some small reeds and roots and other things, he able to build much higher structure using the beach sand.

And in suddenly, he got an idea while he was playing with his children that, we can put in more permanent materials for construction of very high soil structures. And he did lot of pioneering research work in his laboratory using a steel strips as reinforcement products and then some metallic sheets to contain the soil at the front. And he took out a patent and he called it as reinforced earth and he started his own company called reinforced earth, which is very popular in several countries.

So, this is how, the reinforced soil concept is come into engineering being and it is extensively used in all the countries and in almost all the countries in the world.

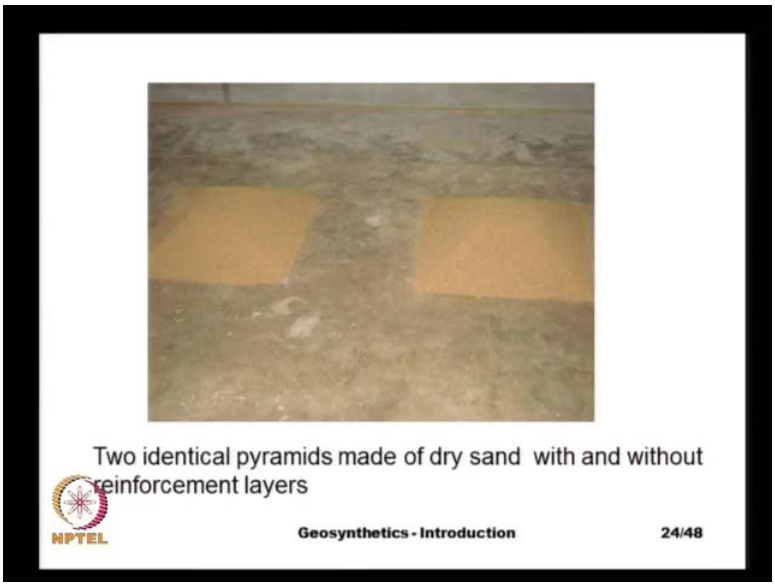
(Refer Slide Time: 23:48)



The basic principle of the reinforced soil is very simple, when the soil is not confined, if you apply some compression stress, the soil will strain will undergo tensile stress in the other direction. And if you put in some internal reinforcement layers, because of the tensile strength that is mobilized in the reinforcement layers. And then the frictional force that is mobilized along the surfaces of the reinforcement layers, the soil is confined and because of that, the soil exhibit higher strength.

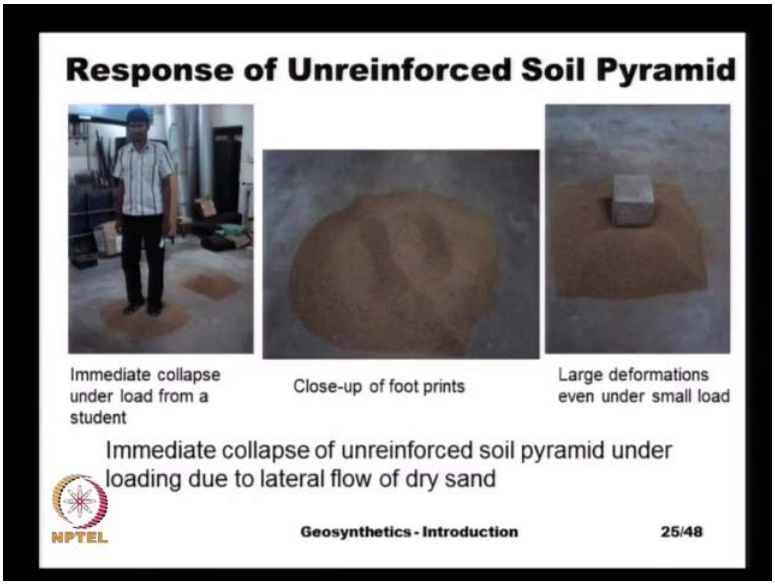
So, in the absence of this internal reinforcement, we need very stiff structure on the outside of the reinforced soil to provide some lateral confinement.

(Refer Slide Time: 24:39)



And here, I will show you some simple examples, some simple demonstration of the strength of the reinforced soil. And here, we have two identical soil pyramids, both are made of dry sand but the left side one is unreinforced and the right hand side pyramid is reinforced and let us see, how they perform.

(Refer Slide Time: 25:06)



Actually, here is my student who stood on the unreinforced pyramid and immediately, it has failed, here you can see the foot print of the student. And so we reconstructed this and reinforced pyramid, is actually this pyramid is hardly about 25 centimeter height, 250 millimeters. And we thought, student is too heavy, so we put only small cement block but even under the weight of the small cement block, the sand started moving.

So, this is the type of response, that a sand soil structure can give when there is no confinement. And so we see that, the unreinforced soil, it has undergone immediate collapse even under a very small load, because of the lack of lateral confinement and let us see, how the reinforced structured has performed.

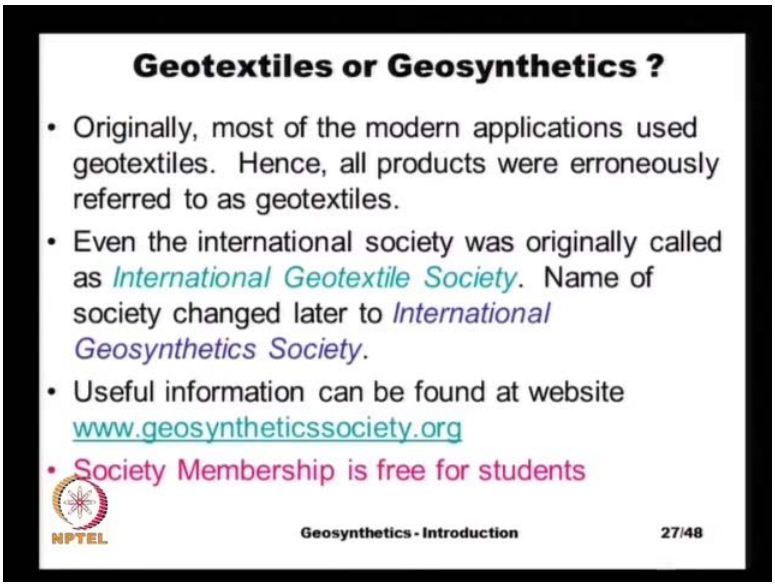
(Refer Slide Time: 26:07)

And because of the experience, that we gained with the unreinforced soil on the reinforced pyramid, we were very careful, we started loading it very, very carefully. We went on putting some weights and even after putting lot of weights, there was no failure and we were running out of the weights. So, we thought, why not we asks the same to student, who destroy the unreinforced pyramid to stand on this reinforced pyramid, with the help of two other people he stood on it.

And absolutely, to our amazement or it is actually not a surprise but then that is how, the reinforced soil performed, absolutely there was no failure, there was no visible lateral deformation, because of the reinforcement layers. There were two layers of geotextile reinforcement placed on this soil and there was no evidence of even foot print on this

structure. So, this small example, it illustrates the synergetic behavior of the reinforced soil and that can be employed for our own purposes.

(Refer Slide Time: 27:27)



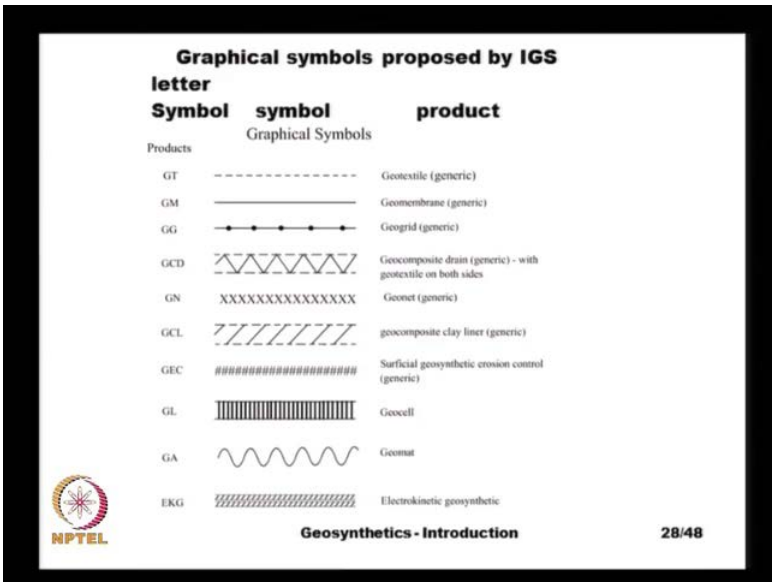
It is actually lot of a people have a misconception that, the geosynthetics are nothing but geotextiles, it is actually the I will not blame them because originally when it started, all the products are textile products and most of the applications are related to geotextiles. And so all the products whether they are geomembranes or geogrids, they were all bunched under geotextiles. And even the name of the international society was international geotextile society, when it started in the late 1970's and early 1980's to call as international geotextile society.

But then only towards the late 1980's and early 1990's, people started questioning, why not we have a more generic name because we have number of products like the geotextiles, geogrids, geonets, geomembranes and so on. Why not we have a more genetic name so the society name is changed to international geosynthetic society and and so now, the generic name is geosynthetics. We do not call them as geotextiles, unless they are textile products and here, I have listed the website address of the international geosynthetic society.

And there is quite a lot of useful technical information on the website and there is a good news for the students, you can become members of the society free of cost without

paying any money. But, you have to go through your respective chapter or your respective country chapters.

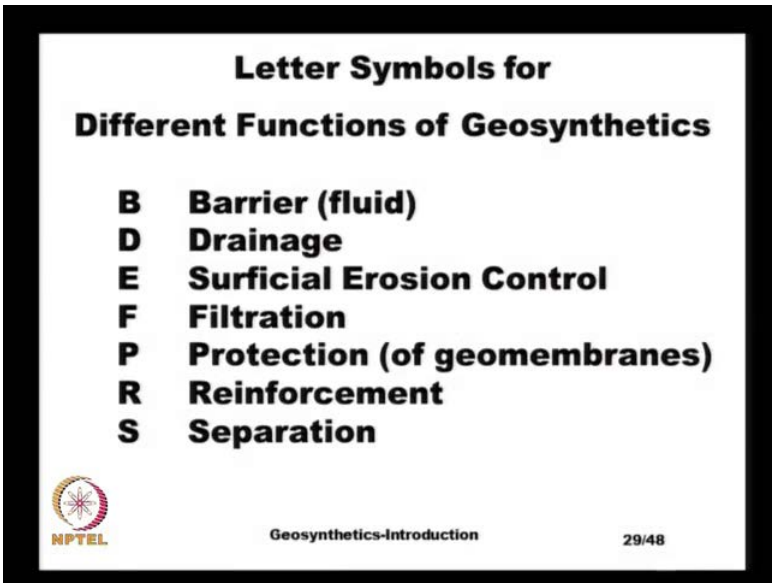
(Refer Slide Time: 29:18)



So, here is the list of the different type of geosynthetics, it is actually these are the graphical symbols proposed by the international geosynthetic society starting from geotextiles at the top. The geotextiles are indicated by dashed lines and geomembranes by a solid line and the geogrid with a solid line with number of dots and the GCD that is, the GeoComposite Drain is actually it is with two lines and with hexagons all over. And the geonet with number of x marks and the GCL that is, the GeoComposite clay Liner with a with two parallel dashed lines and with hatches.

And the geosynthetic erosion control mat, it has a trimped surface like this and the geocell that provides the three dimensional confinement with number of vertical lines and then the geomat with a surface like this. And then more recently, we have the electro kinetic geosynthetics wherein, we pass some electrical current to change the properties of the soil and they are denoted like this. And the product symbols are shown on the left hand side and the graphical symbols are shown like this and it becomes easy when we use the symbols and then for identifying any product.

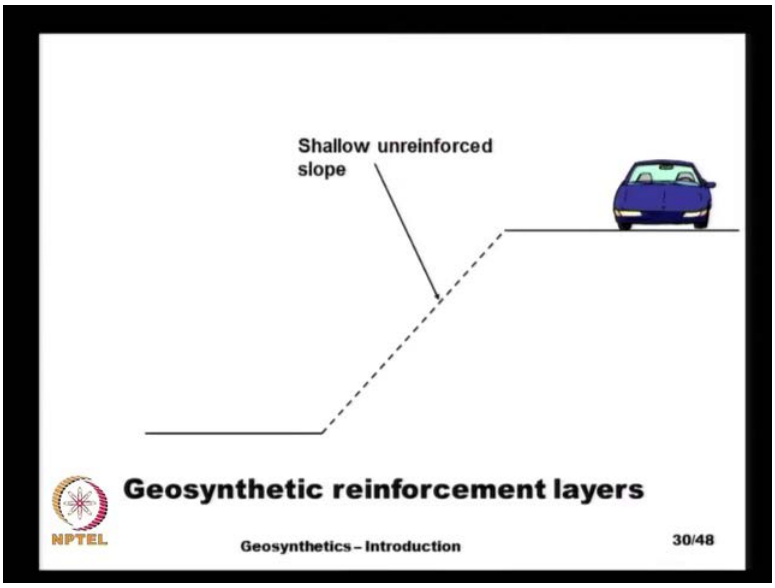
(Refer Slide Time: 30:53)



And the letter symbols for different functions so actually these geosynthetics are applied for several purposes and the left hand side, once again the letter symbols. The B stands for barrier against the fluid flow, the D drainage that allows free flow of water through the geotextile material or geosynthetic material. And the E is stands for surfiical erosion control product, F for filtration that is, filtration is we allow the water to flow but we do not allow the fine soil particles to escape.

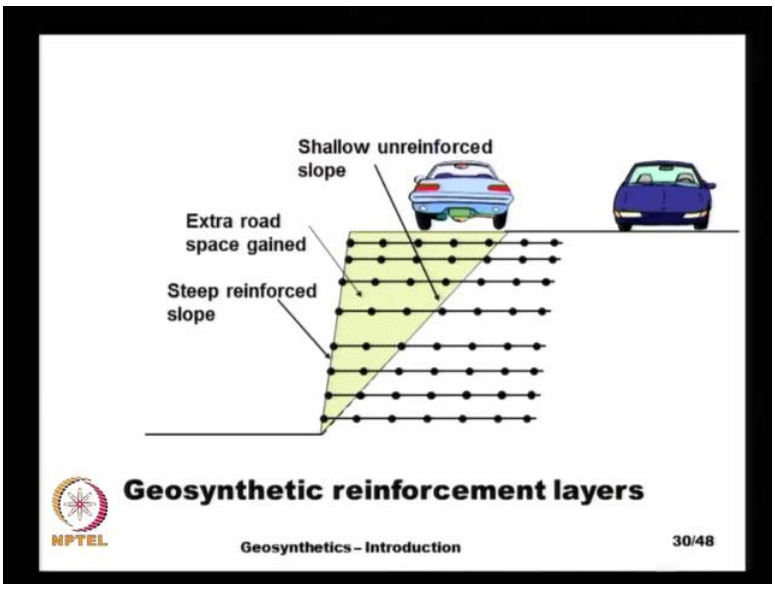
The P is protection of a geomembranes or some other materials and then R is for reinforcement and S is for separation, separation means to separate out or the different materials inside a geotechnical structure.

(Refer Slide Time: 31:52)



So, some simple examples, I will just show through some sketches let say that, we have a highway like this and we want to widen this road. And if you want to maintain the same shallow slope, you need to obtain extra land and then move the road wider. Or other possibilities, you can make this shallow slopes steeper by putting a some reinforcements and add extra road on the space that we gain and concept is like this.

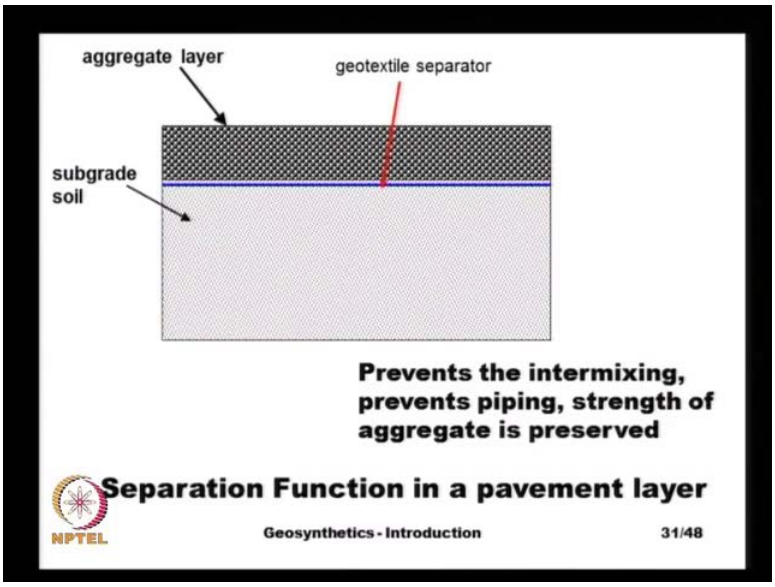
(Refer Slide Time: 32:33)



So, we just simply make the slope as much steeper slope and then we get some extra space for our construction purpose. And this type of applications are possible, because of

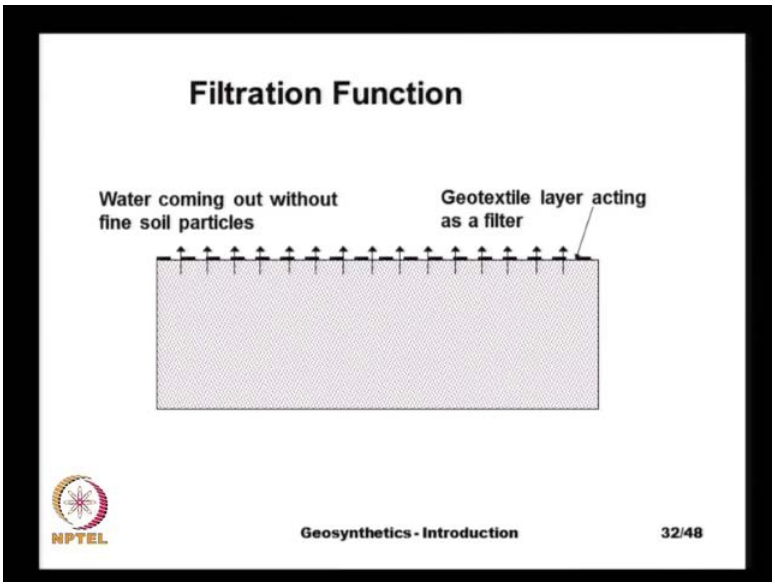
the geosynthetic reinforcements that we can place inside the soil. And so that the soil even at a very steep slope, it is stable.

(Refer Slide Time: 33:00)



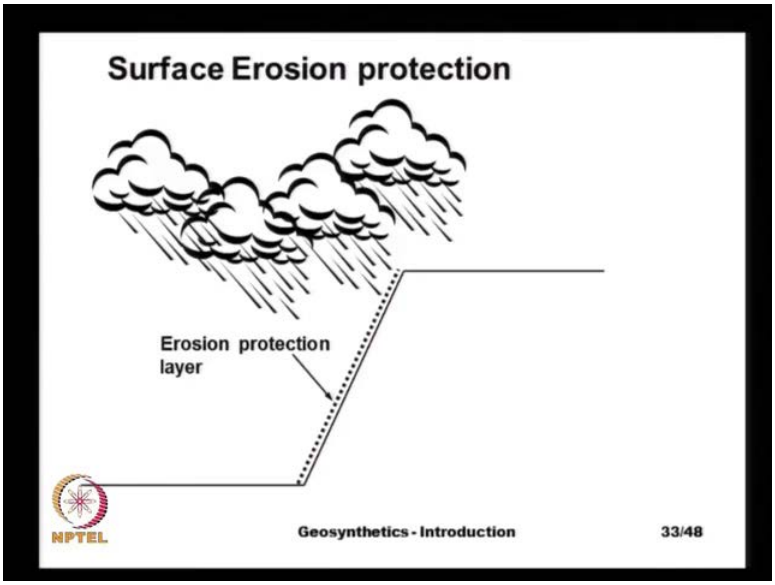
So, this is typical separation function in a pavement layer, the blue line is geotextile separator and the aggregate layer is separated from the subgrades soil by a geotextile separator. And the purpose of this separator is to prevent the intermixing of the aggregate material with the soft soil below and to prevent the piping. And because of this these two aspects, the strength of the aggregate is preserved for a much longer time.

(Refer Slide Time: 33:37)



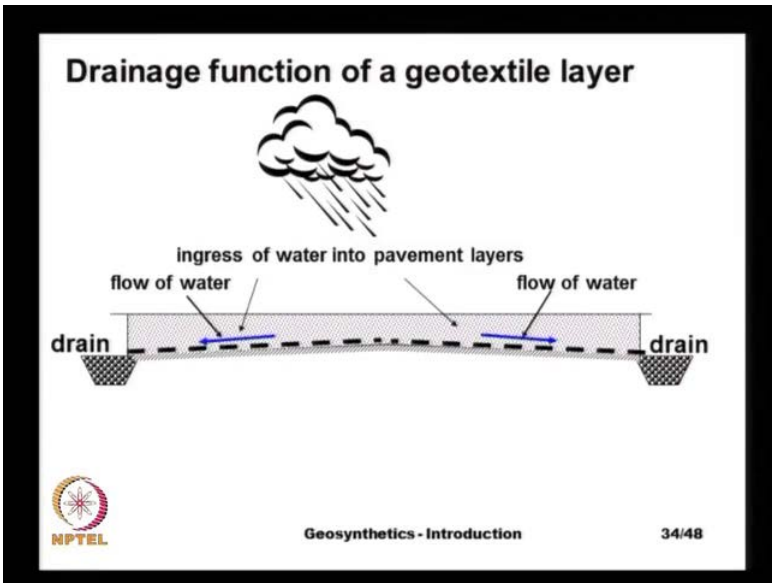
And the filtration function is shown here, because of the placement of a geotextile which has some specific opening in them, it allows the water to come out from the ground. But, it does not allow the fine soil particles to escape from the ground and so it prevents the piping of the some fine soil particles. And because of this, the subgrade can retain the strength for a very long time, even if there is lot of moisture in the ground, like in the form of rain or the surface water and so on.

(Refer Slide Time: 34:23)



And surface erosion protection is illustrated here, wherever we have a slope and when there is a rainfall, the surface soil starts getting eroded. And we can prevent that erosion by slowing down the water and by reinforcing the soil by using some surface erosion protection mats.

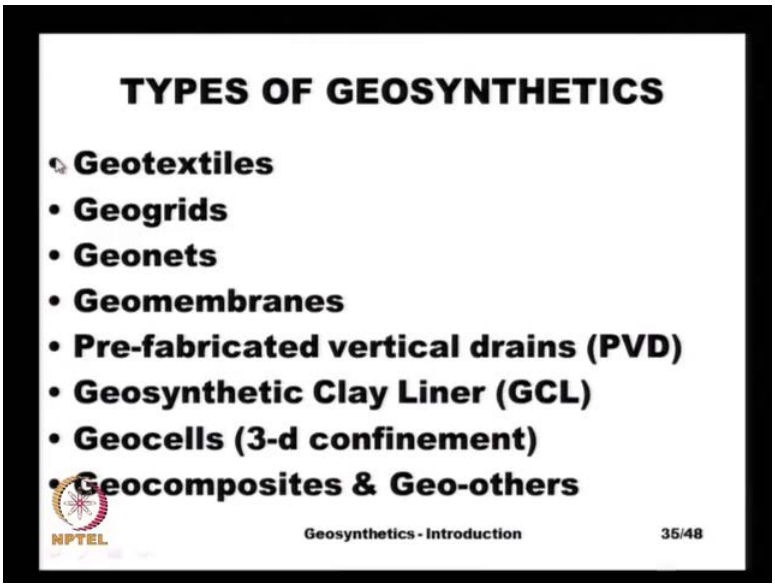
(Refer Slide Time: 34:47)



And another major function that we have is the drainage, drainage is the flow of water along the length of the geotextile or a geogrid or a geo product or through the thickness of a thick geosynthetic product like a geonet or a geotextile. And if we do that, if we are able to do that, the rain water whatever enters into the pavement, it can smoothly flow into the side drains without entering the subgrade.

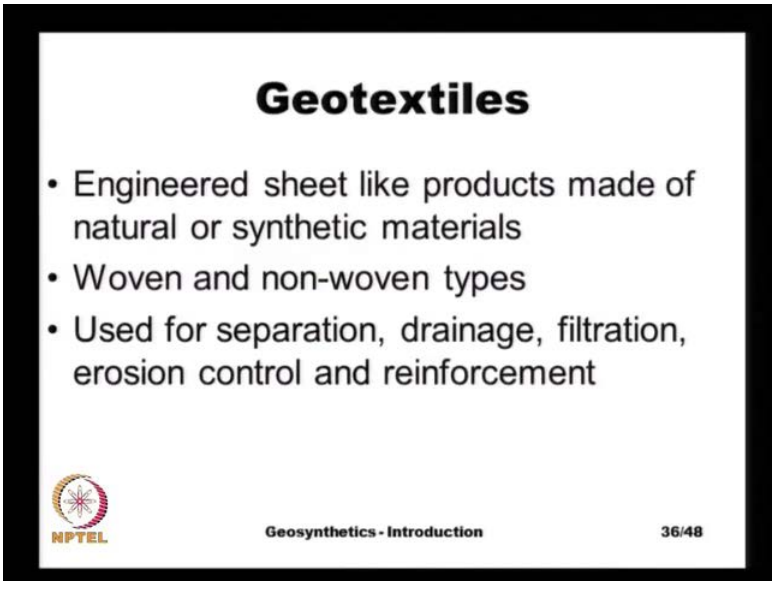
Because, the problem with the soil is as long as the soil is dry, it will have a very good strength but once it is mixed with water, you have the problem of the pore pressure and then the reduced effective stresses. Then once the effective stress is reduced, the strength of the soil we know that, it reduces. And say, if you are able to somehow drained water out from the pavement without the water entering into the subgrade, we can have a stronger subgrade and a good road surface for a very long time.

(Refer Slide Time: 36:00)



So, let us look at different types of geosynthetic products, once again I am listing the geotextiles first because they were the first ones, the first engineering products that were introduced into the civil engineering. Geotextiles and geogrids and geonets, geomembranes, prefabricated vertical drains, geosynthetic clay liners and geocells, all the previous products they are all planar products whereas, the geocells they are three dimensional in nature. They have some surface area and some depth and then of course, there are several varieties of geocomposites and geo others and so on.

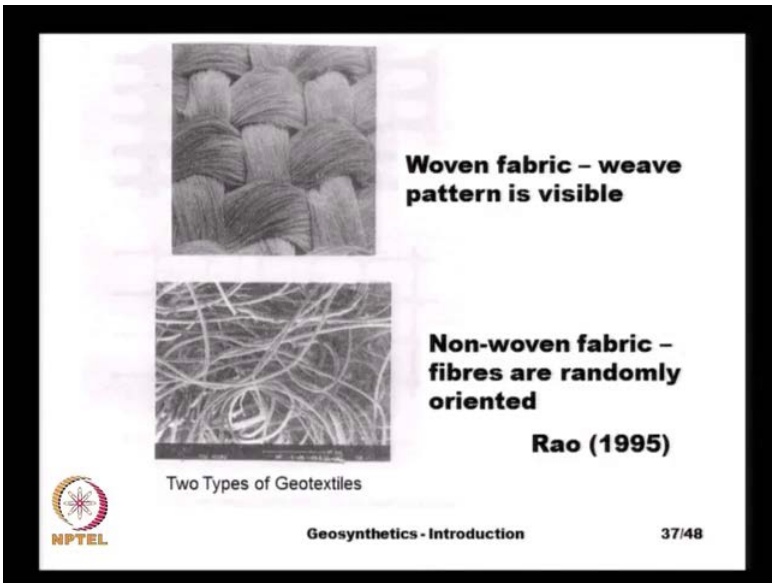
(Refer Slide Time: 36:45)



The geotextiles is actually they are the first ones to be introduced into the engineering used along with the soils and these geotextiles, these are engineered sheet like products made of natural or synthetic materials. And there are two types of materials like there is a woven product and non woven product and the woven product is similar to the textiles that we wear like for example, the shirt is made of a woven textile. And similarly, there are some other varieties, which are known as non woven products, one good example is the carpet.

The carpet that we have in the houses, it is basically a number of fibers are woven together to form a thick mat like a carpet. And some of the applications for the geotextile are separation, the drainage, filtration, erosion control and also, we can use it as a reinforcement. And now a days, the geotextiles they are also made with very high strengths, some of them has a high as 700 kilo Newton per meter. That is, a meter wide as geotextile product can support a weight of 700 kilo Newton or 70 tons that is how, strong they could be.

(Refer Slide Time: 38:10)



And here, you see the microscope photographs of a woven product and non woven fabric, in the woven fabric, we can see the view pattern clearly like in the length and width direction. Whereas, non woven fabric, are the fibers are randomly oriented and they do not have any preferential direction.

(Refer Slide Time: 38:34)

Some pictures of the geotextiles are shown here, we could have a very thin geotextiles which could be used as a separator or as a filter and we can also have thick geotextiles. Some of these thick geotextiles are as thicker as 10 millimeters to even 15 millimeters and the thick geotextiles, they are used for a drainage purpose like especially, if we want the water to flow away from the pavement, we can provide a very thick geotextile. So that, the water can flow along the thickness of the geotextile and these thick geotextiles, they also used as cushion especially, when we construct a land fill with geomembranes.

Geomembranes are nothing but plastic sheets and these landfills are to contain let us say, some has a industrial ways or chemical ways and so on. And we do not want this plastic geomembrane to get punctured and so below that geomembrane, we may put a thick geotextile so that, there is some cushion.

(Refer Slide Time: 39:43)

And here, are the examples of two coir products and the left hand side, we see a woven coir mat and the right hand side, we have a non woven coir mat. And in the woven coir mat, we can see the view pattern whereas, in the non woven coir mat, all the fibers are randomly aligned so there is no preferential direction.

(Refer Slide Time: 40:09)

And here, we see one example of woven geotextile fabric, it is actually there are different varieties of geotextile fabrics, even within woven ones. And here, we see all these yawns

that are coming out and this has a definite view pattern, length direction and transverse direction.

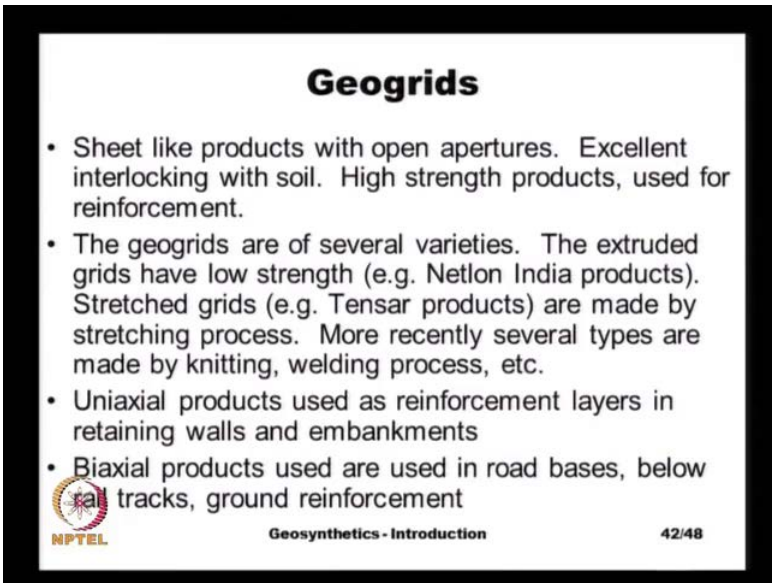
(Refer Slide Time: 40:35)

And here, we see the application of a geotextile below a railway track, these geotextiles they are excellent separators and also excellent filter materials. And this particular track is in the Konkan railway and because of the heavy rainfall, the tracks they used to sink into the ground, because of the soft soil below the track and because of the pumping action.

When the trains got a very high speed, they develop lot of pore pressures and once the pore pressure builts up in the soil, it comes out at a very high speed. And when it comes out it, it brings along with all the fine soil particles and if you line this soil surface with a geotextile, it not only provides some strength to the track. But also, prevents all the fine soil particles from coming out of the ground and because of that, we prevent the piping action.

And in fact, after the use of geotextile, the train speed could be increased in this particular section, in one particular season the trains they were run at a very low speed of 10 to 20 kilo meters per hour, because of the problems of the track. But, once this stretch was reinforced, the speed was brought back to the reasonal design speed of about nearly 100 kilo meters per hour.

(Refer Slide Time: 42:11)



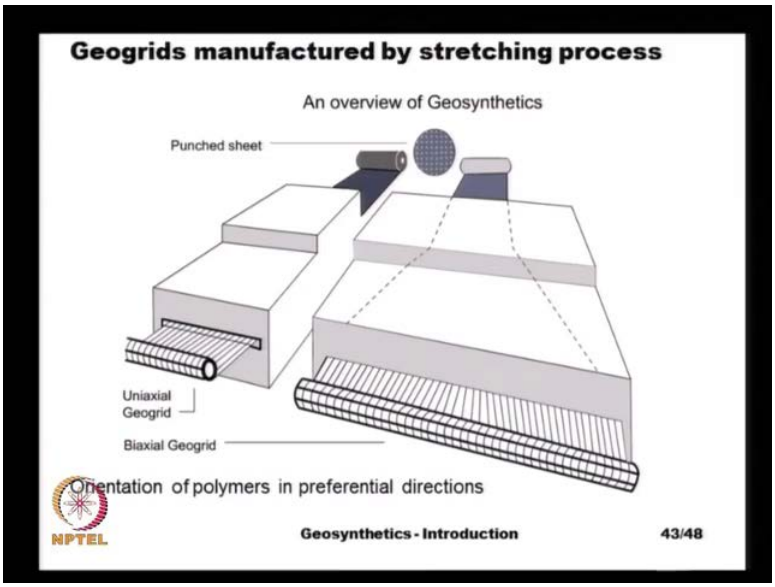
And the next product that is very popular, the geosynthetic product is the geogrid, these geogrids they also planar products. But, unlike the geotextiles, they have very large openings, they have large openings or apertures and these have excellent interlocking with soil and aggregate. And typically, they can be made with very high tensile strength and they are mainly used for geo for reinforcement. Because of the open nature of this geogrids, they cannot be used as filter layer or directly as a separator.

And they are mostly used as a reinforcement products below the pavements or below the railway tracks or for construction of a steep slopes and high retaining walls and so on. And these geogrids, they are of several varieties, they could be excluded geogrids having very low strength like the Netlon India products, that were made in the 1980's or stretched geogrids. One good example is the Tensar UK where, the pioneered, the polymeric technology and the manufacture of geogrids, which very high strength geogrids, which are highly durable and these are made by stretching product.

So, they are called as Tensar products basically, these are all tensioned elements and more recently, there are other varieties of geogrids made by knitting process or welding process and so on. And there are in terms of the preferential strength directions, there are uniaxial products, which are used as reinforcement layers where, we need reinforcement only in one direction like for example, behind the retaining walls or for construction of steep, soil slopes.

And the biaxial products, the biaxial products they have strength in almost equal strength in both the predominant directions that is, longitudinal and transverse directions. And these biaxial products, they are used below the road bases or below the railway tracks or for general ground improvement also, we use the biaxial products.

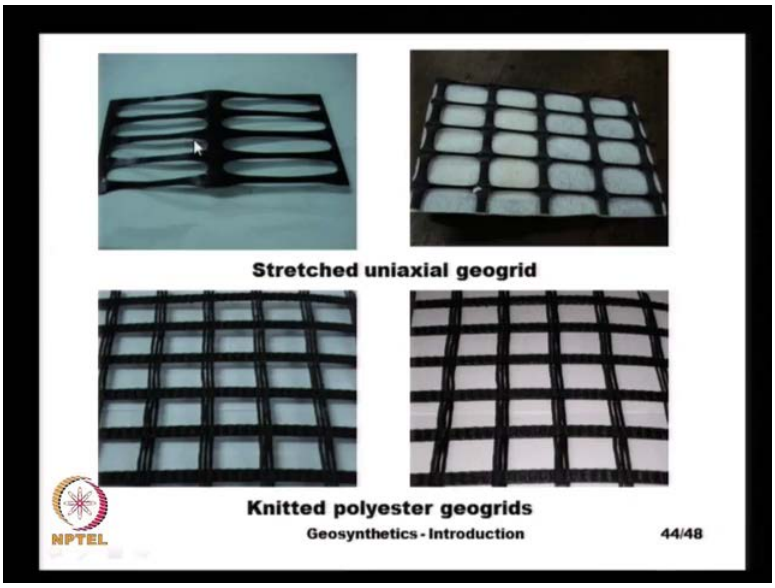
(Refer Slide Time: 44:43)



And in this slide, you see the manufacturing procedure of the uniaxial products and the biaxial products. Basically, the stretching process what we do is, we take a plastic sheet, we punch some holes in it and then stretch them in one direction to produce uniaxial grids or in two directions to produce biaxial geogrids. And in these patented processes where, the polymeric sheet is heated to some temperature and stretched.

We orient the polymers in preferential directions, either in the one direction or in both the directions and once the polymers are oriented, the strength becomes very high. And most of these products, they are also mixed with some stabilizers like carbon black and other things so that, they can last for a very long time.

(Refer Slide Time: 45:46)



And these are some examples of the different types of geogrids, here we see on the top left hand side, we see an example of a stretched uniaxial geogrid. And here, we see a composite of two materials, geotextile combined with a geogrid and that can serve two different purposes, one is reinforcement and the other is separator as a filter layer. And at the bottom, we have the knitted polyester geogrids, they are made by wieving process and knitting process.

(Refer Slide Time: 46:28)

And here, we see the application of a geogrid for construction at the land fill at Hindustan Zink factory in Visakh.

(Refer Slide Time: 46:43)

And here, we see the geogrid being applied for construction of a pavement and this particular product is biaxial product because below the pavements the load is applied in all the directions. So, we need strength in both the directions so we have a biaxial product. And now, we have a new product, that is just introduced into the market that is called as a triaxial, which has strength in all the radial directions.

Because, in these biaxial products, there are only two preferential directions, one is longitudinal and lateral. Whereas, the load may be distributed in some other directions and to take care of that type of situations, we have the triaxial grids, which are just introduced into the market.

(Refer Slide Time: 47:42)

And here, we see a very innovative application of a very low strength geogrids for costal protection and this particular application was in Navi Mumbai near the Vashi railway station. Here, because of the ocean currents and then the tidal actions, the land was subject to erosion and most of the new Mumbai was constructed by reclaiming the land from the sea. And once you take something from the sea, it would like to get it back and slowly, whatever islands that were constructed, there were severe erosion.

And these islands or these reclaimed lands, they are lined with water known as manufactured geocells, made of geogrids like this. And these geogrids, they are filled with stones in the portion that is closed to the water and then behind that, all this pockets are filled with sand and the result is that, the entire network is actually, all these networks of the geocells, they are knitted together by some process. So that, the entire structure is one single unit and we can easily control the action of the sea to prevent the sea erosion or the coastal erosion.

And this is one of the early applications of geosynthetics in India using very, very low strength geogrids. So, in this lecture, we have basically try to give basic introduction to the topic of geosynthetics. We have seen historical applications of the geosynthetics and then more recent applications and we have discussed about two varieties of geosynthetics that is, the geotextiles and the geogrids. We have seen, what they are and for what

applications, they can be employed. And in the next lectures, we will see the other geosynthetic products.

Thank you.