Geo synthetics Engineering: In Theory and Practices
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Module - 1
Introduction to Reinforced Earth
Lecture – 2

Dear student warm welcome to NPTEL phase 2 program video course on Geo synthetics Engineering In Theory and Practice, My Name is Professor J. N, Mandal, Department of Civil Engineering, Indian Institute of Technology, Bombay, Mumbai, India, the name of the course Geo synthetics Engineering in Theory and Practice, this Lecture Number 2. Introduction, before entering into the geo synthetics one, one should understand the basic concept of the reinforced earth system.

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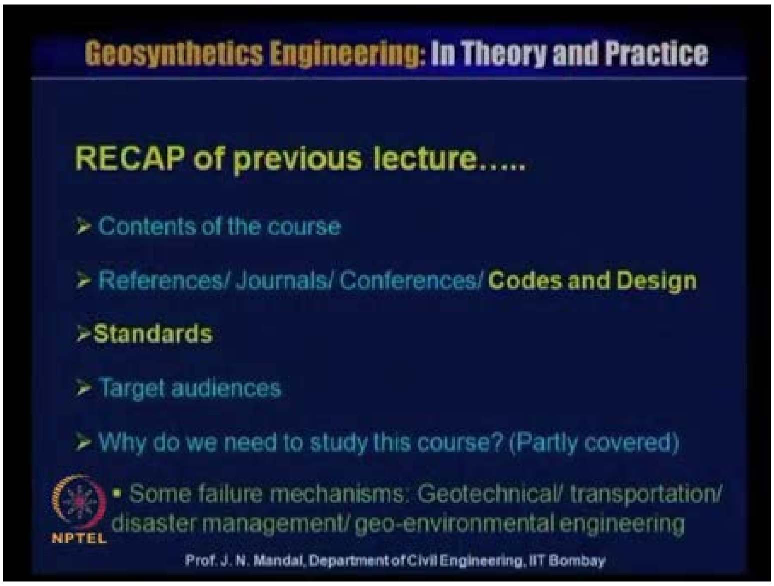

Here module number 1 introduction to Reinforced Earth, before we start this course lecture 2 I will address some recap of the previous lecture. In previous lecture I have covered the content of the course, references, journal, conference, code and design, and standard and the specification, and the target audiences. We have also partly covered the part of the course, why do we need to study the course that is some failure mechanism, geotechnical, transportation, disaster management, geo environmental engineering.

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Next we will begin the course on sustainability using geo synthetics, worldwide level of carbon dioxide have reached in highest level in 3 millions year US scientist, carbon dioxide was measured at 400 parts per million that is at Hawaii monitoring. Rise in a warning of large changes in climate and sea level, we have failed miserably in tackling this problem Pieter p Tans this times of India May 12, 2013, and that is the why there is global warming, and how we can control the global warming.

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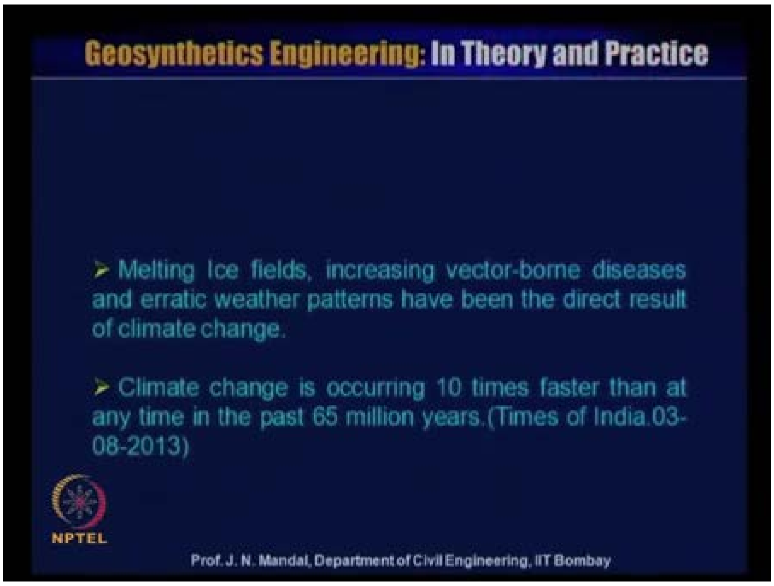

So, that sometimes we find that melting Ice field, increasing vector borne diseases and erratic weather pattern have been the direct result of climate change. Climate change is occurring 10 times higher than at any time in the past 65 millions year as per times of India 03 08 and 2013. So, this kind of the climate change what is happening, what will be the role of geo synthetics material in global warming or climate change. How we can generate the revenue, how we can sustain in a proper way, what is the role of the geo synthetics material, we are trying to address you the one of the example like the landfill.

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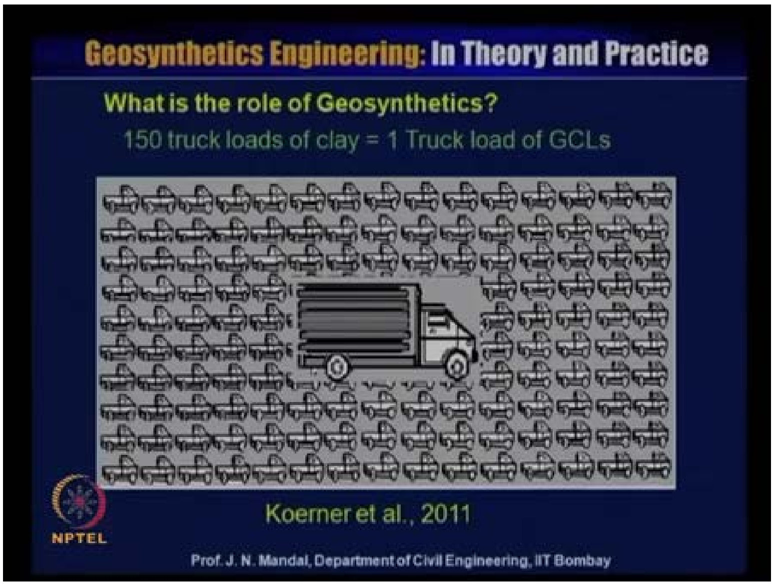

For example, loin you are constructing a landfill and whose thickness is varying from the 600 millimeter to 1200 millimeter. And it is compacted clay liner, you require huge quantity of the clay to be compacted, and you are constructing a landfill, so if you wanted to construct a landfill like this, you require the huge quantity of clay material from some other places.

And then you have to dump, you have to estimate, you have to compact the soil, and then after compacting the soil you are dumping all kind of the waste material for the formation of the landfill system. It require the transportation system to carry the clay from one side to the other side, and also is required lot of energy, lot of transportation, lot of petroleum cost it is everything if you take into account you can think in terms of energy it is a huge quantity of energy is lost.

So, alternative to that system we are adapting a innovative system and that what we call the geo synthetic system I am showing in my next slide that if we adapt the geo synthetics or the geo membrane material or geo synthetics clay liner material, for the construction of the landfill. Look at this picture there are 150 truck load of clay you have to collect these quantity of clay material from one side to the construction side is spend lot of money, lot of energy, lot of cost of the petrol. And alternative to this material we can use only one truck load of geo synthetics clay liner. So, you can see that how we can save the energy using this geo synthetics material is Koerner 2011.

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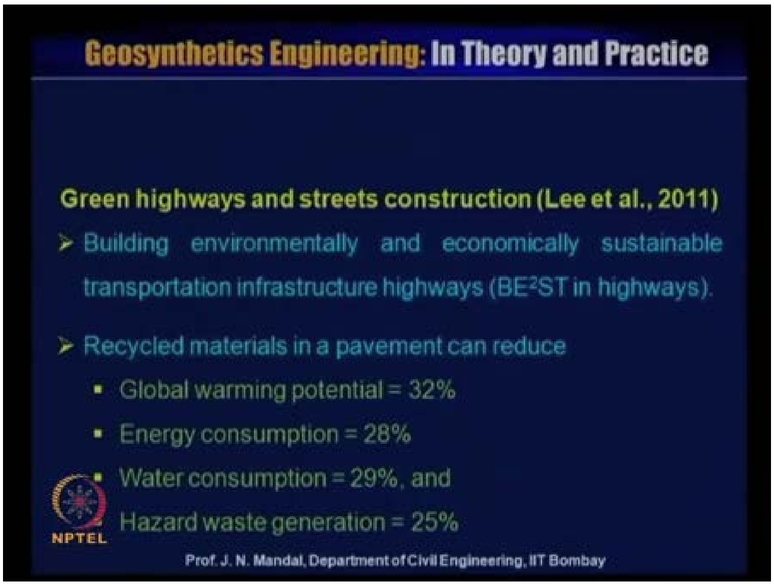

Now, we will talk about green highway and street construction Lee et al 2011, everybody is looking for green, green technology, green system, how you can make use the more greenery more sustainable construction road can be made of green. Building environmentally and economically sustainable transportation infrastructure highway, which is called BE square ST in the highway.

Recycling the material in a pavement can reduce drastically, you look at this global warming potential is about 32 percent, energy consumption saving about 28 percent, water consumption 29 percent and hazardous waste generation 25 percent, we can see that if we use the recycling material in a pavement how these can be reduced.

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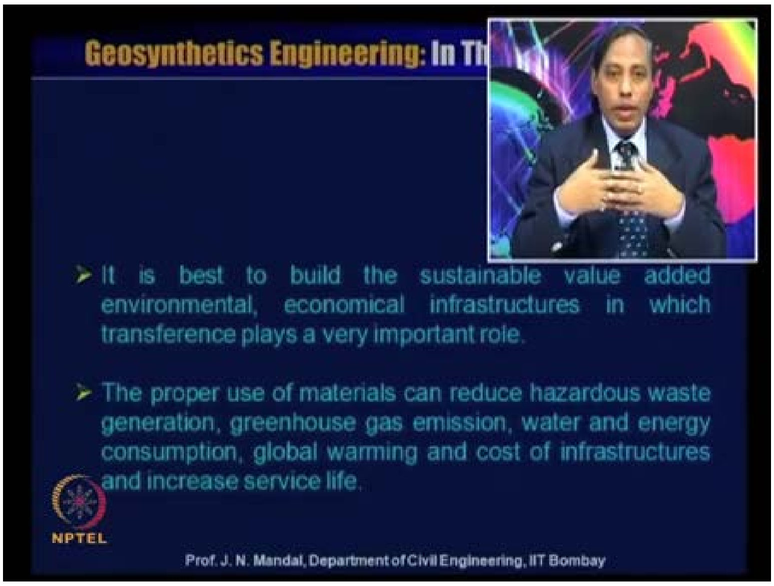

So, it is the best to build the sustainable value added environmental economical structure in which interference play a transference play a very important role. The proper use of the material can reduce hazardous waste generation, green house gas emission, water and energy consumption, global warming and cost of the infrastructure and increase the service life.

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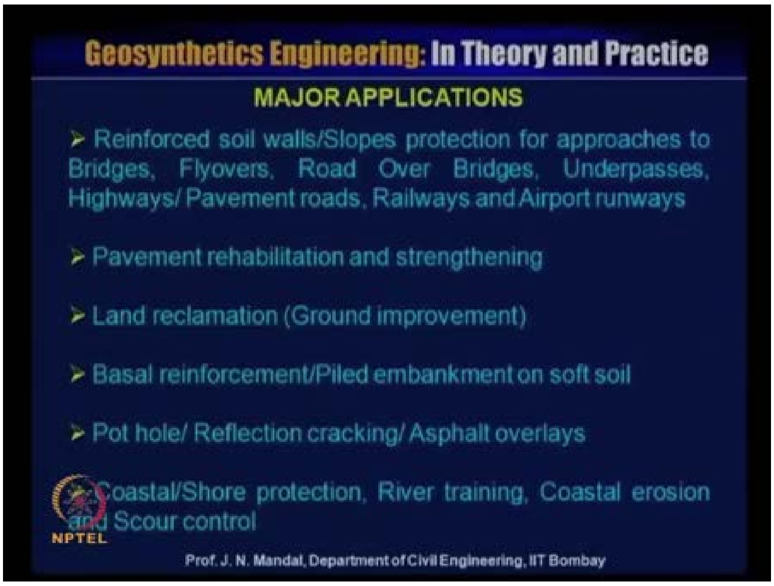

So, we can think that how we can save the energy, how we can use that alternative system using the innovative geo synthetics engineering material. Now, I will focus next slide what are the major application, it can be used for their inputs soil wall, slope protection for approaches to bridges, flyover, road over bridge which is now a day's going on in many structure in India., underpass highway a main road railway and airport runway.

We can do payment rehabilitation and strengthening, land reclamation, ground improvement what the soil is very soft is very difficult to construct any kind of the structure. And how you can improve the ground using this new material and what you call the geo synthetics, basal reinforcement piled embankment on the soft soil, if you go for the piling system it will be very expensive, and it will take lot of time. So, if you place on the top of the pile layer of the basal reinforcement, then you can reduce the diameter of the pile craft pacing also can be increased.

So, you can save lot of money and the geo synthetic material provided very good tensile strength. You know there are lot of pot hole, reflection, cracking an asphalt overlay this is regularly going on the after few month, again and again you keep on providing with the asphalt on the top of the existing pot hole. So, we can adopt the geo synthetics material to protect the cracking, to protect the pot hole, it depend upon that what will be the kind of the pot hole, what will be the kind of the cracking pattern whether it is a alligator cracking, whether it is a longitudinal cracking.

So, you have to be very carefully go to the depth and width of the cracking pattern and then you have to select the proper kind of the material to control the reflection cracking or pot hole. This material also can be used for the coastal shore protection, river training, coastal erosion and the scour control.

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These are some this major application can used for the rock fall protection control, landscaping, building, water harvesting, basement water proofing. Landfill and the capping municipal solid waste, industrial hazardous waste, and even then low level radioactive waste, it has been used also for the low level radioactive waste, and this longevity is about 500 years, dewatering, municipal and the industrial sludge, marine sediment and animal waste.

Separation, filtration, drainage erosion control and revegetation, so there are many, many application. Even then you can see the next slide you can cover the rock fall protection or the control, landscaping building, water harvesting, basement water proofing, landfill and capping municipal solid waste, industrial hazardous waste, low level radioactive waste. Dewatering municipal and industrial sludge, marine sediment, animal waste, separation, filtration, drainage, erosion control and revegetation.

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Apart from this application you can make use of this geo synthetic material in tunnel, dam, water reservoir, canal, ponds, tailing dam and mine rehabilitation. You can use for the sports field and the golf courses, land reclamation and remediation and land slide prevention.

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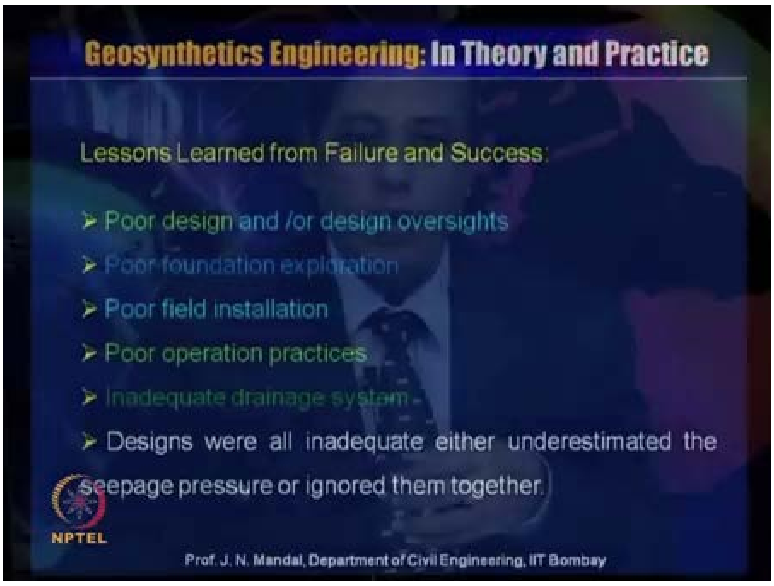

So, what we learn lesson learn from the failure and success what I have covered the some of the different types of the failure, in geotechnical engineering, transportation engineering, hydraulics engineering and the environmental engineering. So, from this failure and some if you go for good design, if you have the successful design, so there would be also success. So, what lesson we can learn from the failure and success, I am presenting that what the lesson learned from the failure and the success.

Most of the cases the failures occurs because, for poor design and or design oversight. So, one has to be take care for this, in a poor foundation exploration it has not been properly explore and find out the characteristics of the soil and their locality, so it is recalled the thoroughly explore the soil, and detail report of the soil investigation on that area.

You record the poor field installation, it happen due to poor operational practice it happen inadequate drainage, most of the cases there is a problem for the drainage, even then road construction, the input soil, retaining wall construction, slope construction there is no proper drainage system. So, then structure may fail due to inadequate drainage system, so we require proper kind of the drainage system, design were all inadequate under the underestimate the seepage pressure or ignore them together.

They do not some time consider the seepage pressure which is occurring at the back of the input soil retaining wall over the slope. So, that should take into consideration into the design, otherwise this structure most of the time this structure collapse, then no proper filling material, we require proper kind of the filling material from the proper kind of the problem. So, if you do not select the proper kind of the gradation of the material, then there is a possibility for the failure of the structure.

So, one has to be very careful that proper selection of the material both in terms of the soil, both in terms of the material also concerned. One material you should select why you want to select, how you will select, how will you design, so these are the some of the issue we will discuss.

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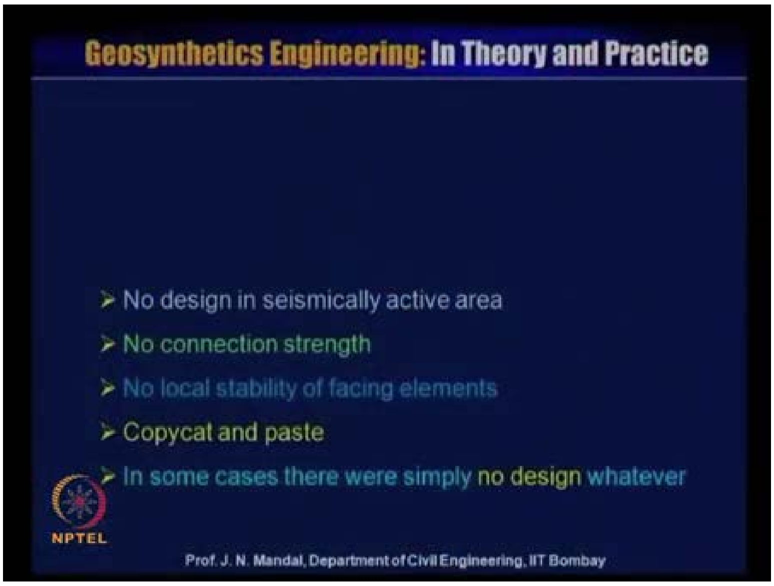

Next slide no design in seismically active area, even then there is a seismically zone area, so design has not been made. No connection strength, when you are using a reinforced soil retaining wall, this should be properly connected with the facing element if it is not been properly connected with the facing element, then structure may collapse. And also each and every facing element you require for local stability, so sometimes you can see there is no local stability of the facing element.

And many cases designer whether he is professional or non professional are providing with the design, they just do copycat and paste it which is designed cheaper than 30 percent, then what will do from the other sources. But, they do not know what will be the problem in future, what will be the time of the failure may occur due to this kind of the design. So, one has to be very cautious about that design it require proper kind of the design, proper kind of the selection of the material, proper kind of the placement of the material in some cases there are simply no design whatever.

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So, you have to be very careful, so Dr J. P. Giroud mentioned geo synthetics do not make miracle, and should not be expected to be miracle. The geo synthetics should not automatically be consider it as the main culprit if failure occurs, the geo synthetics should not be used as a scapegoat when the design is flawed. A failure may provide an opportunity to improve a flaw design, so this we have to keep it mind.

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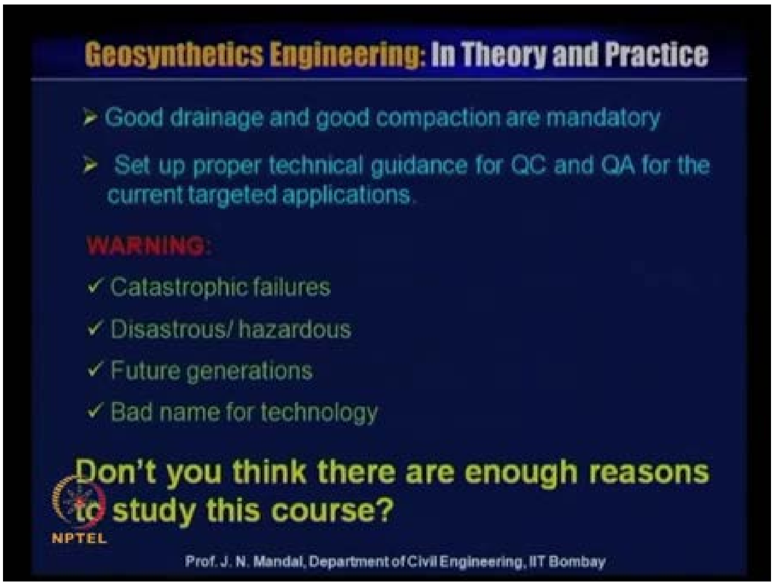

So, what we require for the good design, we have to be very careful about the good drainage, good compaction are mandatory. We need to set up the proper technical guidance for quality control and quality assurance for the current target application, otherwise what will happen. Look at what kind of the warning system, there will be a catastrophic value, there will be the disaster, hazardous you think about our future generation, what they will learn ultimately we will set the bad name for the technology. So, what I have covered from lecture 1 and lecture 2 do not you think there are enough reason to study this course.

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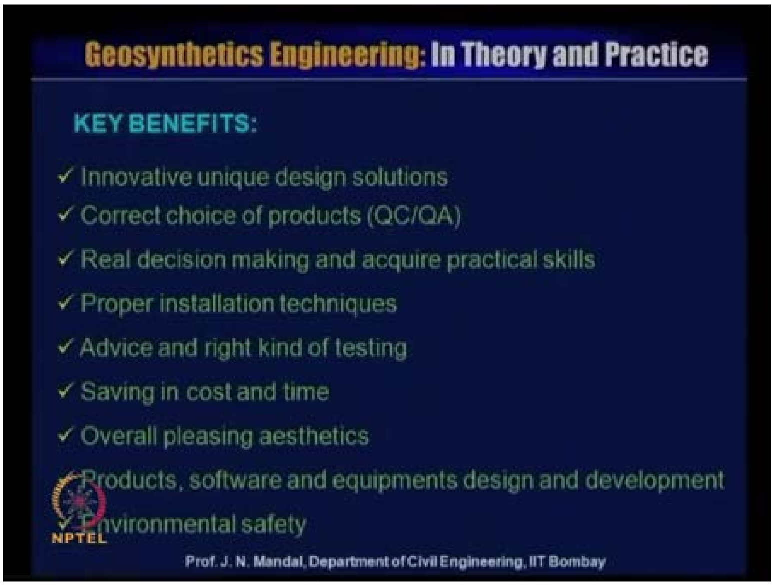

So, if you study this course geo synthetics engineering in theory and practice, what key benefit we can achieve, we can have a innovative unique design solution. Correct choice of the product is very important correct choice of the product because, there are various types of the products, and various types of the material. So, you have to be carefully select the material, and at the same time you require proper kind of the quality control, and the quality assurance.

You have to take real decision making and acquire practical skill, you require the proper installation technique you cannot randomly place any direction as you like it you have to be careful. For an example, that a geo synthetics material has a machine direction or cross machine direction or the rap direction or the wave direction or the longitudinal direction or transverse direction. So, you should know the which direction load should be transferred, which direction the tensile strength is more or less, you have to be very careful to proper selection of the geo synthetic material installation system.

You can advice and right kind of the testing, most of the cases you have to give the proper kind of the testing, as per certain standard and the code. Not just as usual we can use any kind of the code, which will not satisfy the criteria and then there will be a problem. So, you can be benefitted learning about the testing of the material, and what kind of the test has to be conducted, there may be the different types of the tensile strength for the geo synthetics material. So, one has to be careful that which set to should be the recommended for this particular application.

If you do you can saving in cost and time both cost and also time, and overall pleasing aesthetic. Whatever structure you wanted to construct whether it is a road way, whether it is a facing element, you can have over all pleasing aesthetic it looks beautiful, it looks greenery because, now a day's also green technology. So, you can have a good grid, so it is the environmental friendly sustainable infrastructure can be constructed, there are different product and the software and equipment, design and the development.

We have developed certain kind of the software which we will focus giving our course and you will be benefited, hence for the LSS model for the landfill system. We have also developed a kind of the slope stability, software and also for the reinforced soil littering or soft soil, we will focus during I presentation. And what are all that we have to think that it is environmental safety, it is very important that environmental safety these are the some of the key benefit which you can learn from this course.

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Now, before entering into this geo synthetics one should understand the basic concept and mechanism of reinforced earth system, there is no reinforced earth system, there is no geo synthetic system. So, we should learn first of all what is reinforced earth, who is the pioneer for the reinforced earth, we should give credit to the person who is the pioneer for this reinforced earth, I say if there is no reinforced earth, there is no geo synthetic engineering system.

So, how the geo synthetic system come from the reinforced earth, so this I want you to focus that basic mechanism, and mechanics how the reinforced earth system and it is from the French, it is from the mister Henry biggle, who is the architect, and the civil engineer and you will be wondered to hear how he had obtained this idea from what he has got this idea, it is very interesting to us to know about this reinforced earth system and his idea.

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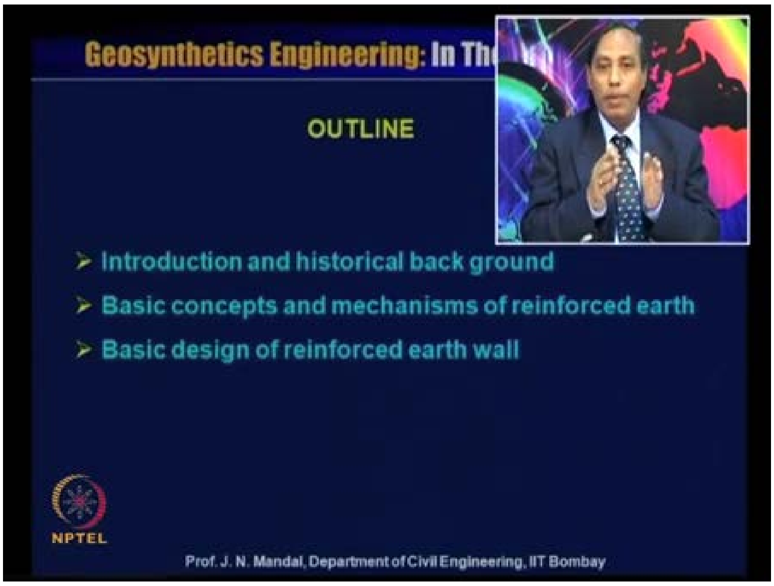

So, with this I will now begin with the outline of the reinforced earth system I will focus on the introduction and historical background. Basic concept and mechanism of reinforced earth, which in the French language he is called the terry army and it is patented, and basic design of the reinforced earth wall. When you talk about the reinforced earth wall, we use this kind of the metallic reinforcement this is a kind of the metallic reinforcement, in the form of the strip we use also in the form of the strip like this also.

So, you can have the different type of the strip material, initially lot of the research work have been carried out using the metallic strip, which is made of galvanized mild steel, aluminum, either it is in the form of strip or it is in the form of fiber, and lot of research work have been carried out in this area using the metallic reinforcement based on the Vidal design.

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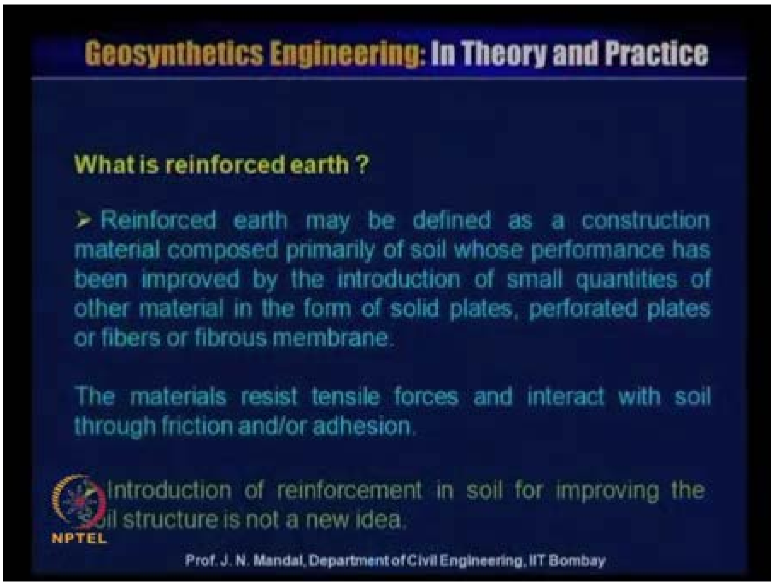

Now, let us know what is reinforced earth, reinforced earth may be defined as a construction material composed primarily of soil which performance has been improved by the introduction of small quantity of other material in the form of solid plate, perforated plate or fiber or fibrous membrane.

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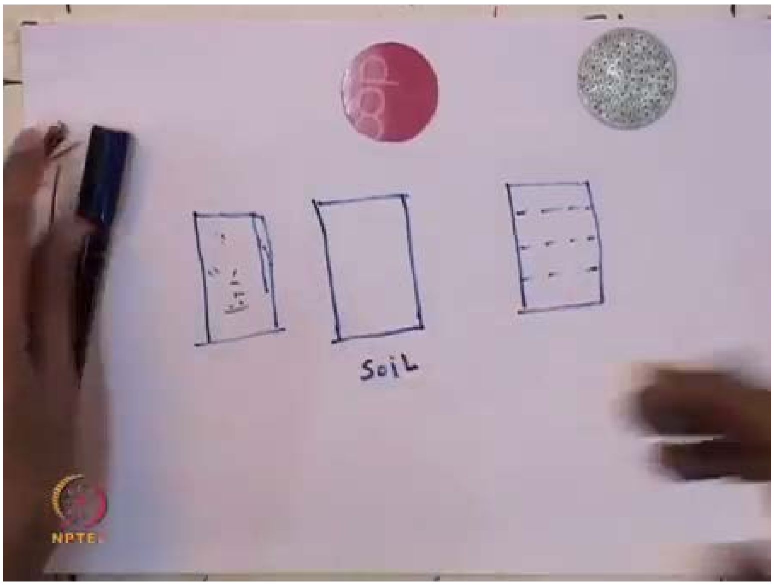

Just like this kind of the material, this is the perforated material, but we can use also the solid material like this, you can also use in the form of the fiber element like this. So, you can make a tri-axial sample, so you can make a tri axial sample like this know that, that is in cylindrical in shape this one is only with the soil. So, this is the soil and other case you can make the same sample tri-axial soil sample.

And you can place the number of the layer of this plate either in the form of perforated plate or in the form of solid plate, you can place and you can see that what will be their behavior how they are changing. And sometimes also you can mix up with the certain kind of the fiber element like this, and you can see that what is happening and how it interact with the soil. So, these are the material which resist the tensile forces and interact with the soil through friction and the adhesion. The introduction of the reinforcement in soil for improving the soil structure is not a new idea, it is a well known to everybody there is nothing new I will show some of the slide.

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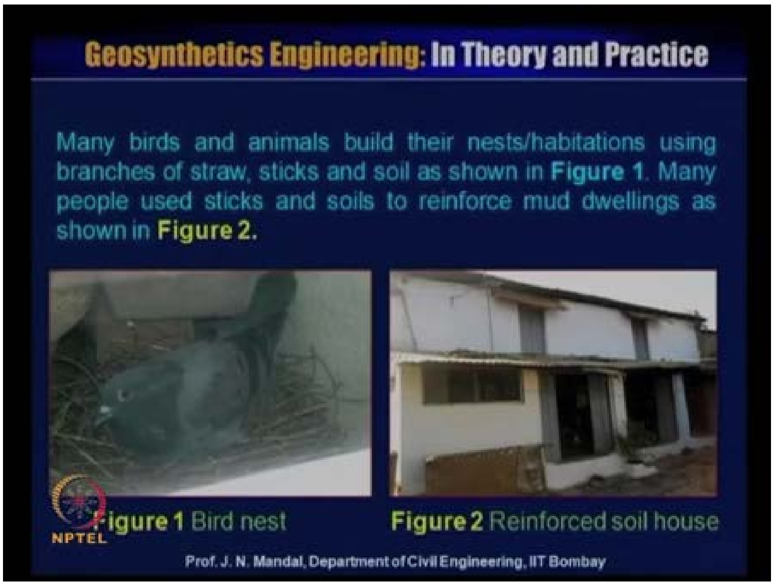

You can see many birds and animal build their nests and habitant using the branches of the straw, stick and the soil as shown in figure here. Many people use the stick and the soil to reinforce the mud dwelling, you can see something mud house there are many mud house you can have it in the villages. So, this is nothing new, so how this concept came.

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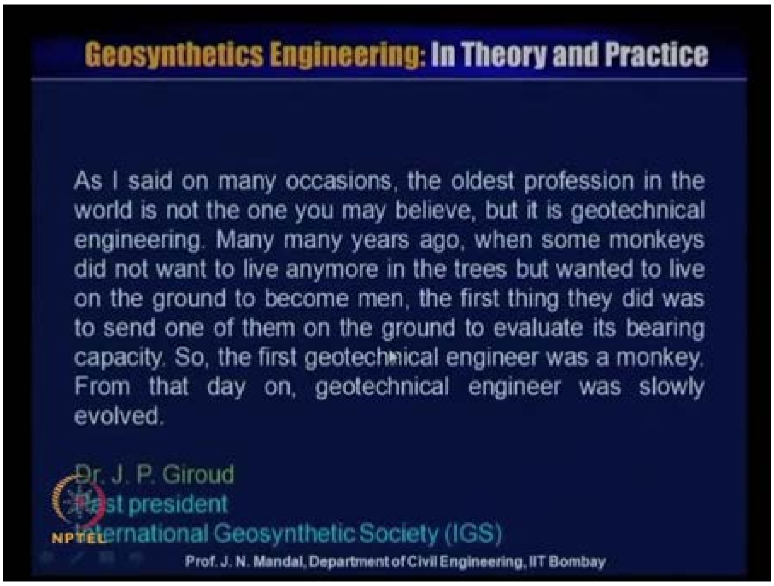

I am just mentioning one doctor J. P. Giroud who is the past president for international geo synthetic society, he quoted. As I said on many occasion, the oldest profession in the world is not the one you may believe, but it is geotechnical engineering many, many years ago, when some monkeys did not want to live anymore in the tree. But, wanted to live on the ground to become men, the first thing they did was to send one of them on the ground to evaluate the bearing capacity. So, the first geotechnical engineers was a monkey, from that day on geotechnical engineer was slowly evolved.

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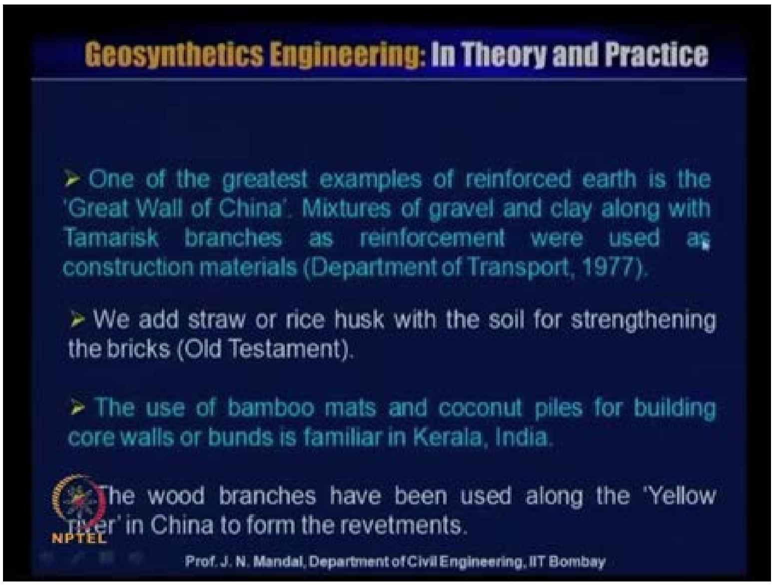

I will focus some of the example, one of the greatest example of reinforced earth is the great wall of china. And this is mixture of the gravel and clay along with the tamarisk branches as a reinforcement were used as a construction of the material this department of transport 1977. We add straw, rice husk with the soil for strengthening the brick it is old testament, the use of bamboo mat and the coconut pile for building the core wall or bund is very familiar in Kerala India. The wood branches have been used along the yellow river in china to form the revetment.

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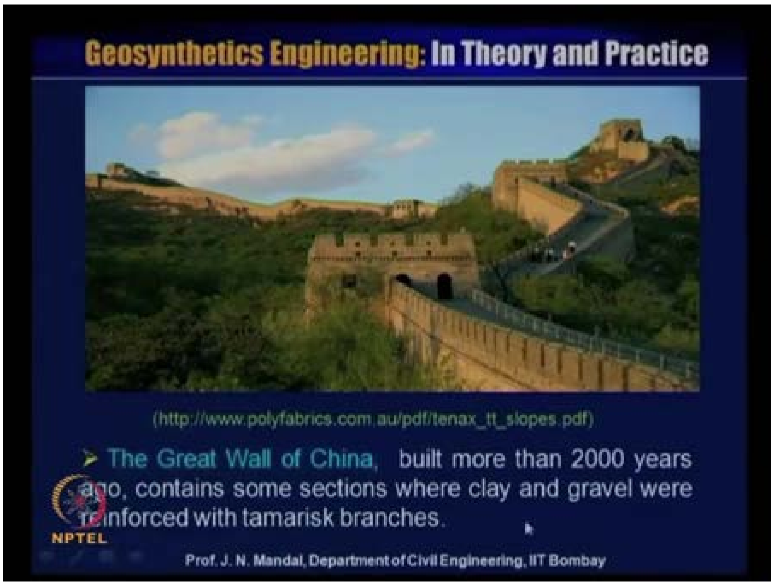

I am showing you some great wall of china, it is built more than 2000's year ago, and contain some section where the clay and the gravel were reinforced with the tamarisk branches, you can see this is one of the old structure, where the reinforcement system have already been used and that is we can see more than 2000 years ago.

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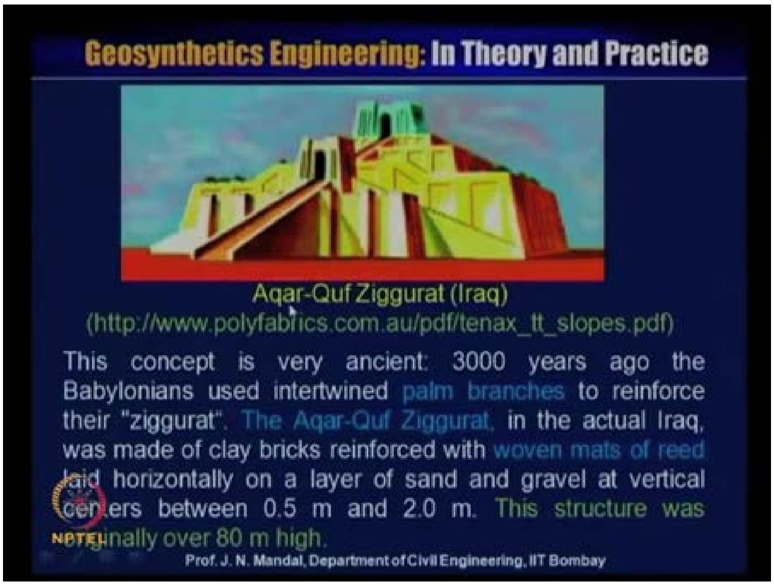

This is another structure Aqar-Quf ziggurat in Iraq, the concept is very ancient 3000 year ago the Babylonian used the intertwined palm branches to reinforce their ziggurat. The Aqar-Quf ziggurat, in the actual Iraq, was made of clay brick reinforced with the woven mat of reeds laid horizontally on a layer of sand and gravel at vertical center between 0.5 meter to 2 meter, this structure was originally over 80 meter height. You can see this kind of the old structure, which is constructed 3000's years ago and this height of the structure is about 80 meter.

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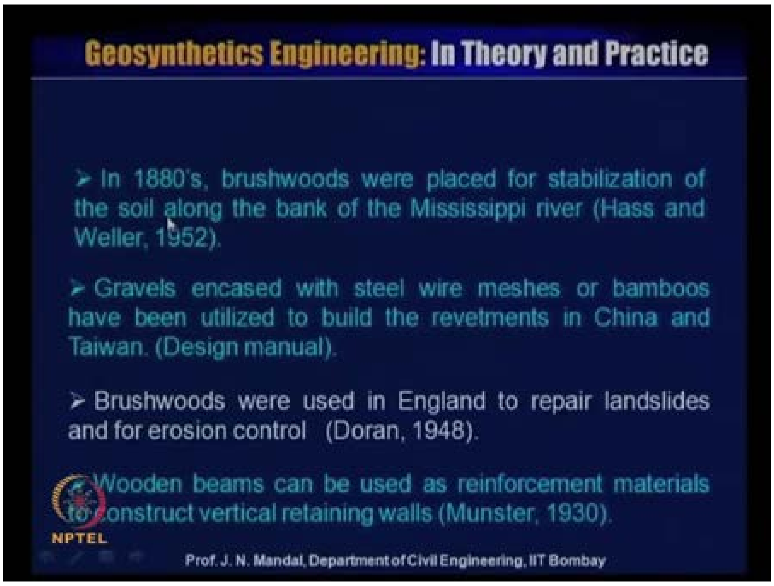

In 1880 brushwood were placed for stabilization of the soil along the bank of Mississippi river, Hass and Weller 1952. Gravel encased with the steel wire meshes or bamboo have been utilized to build the revetments in china and Taiwan, this is on design manual. Brushwood were used in England to repair the landslide and erosion control Doran 1948, wooden beams can be used as a reinforcement material to construct the vertical retaining wall Munster 1930. So, there are many, many example where we have used these kind of the material, but we did not know that time, that what is called the reinforced earth today.

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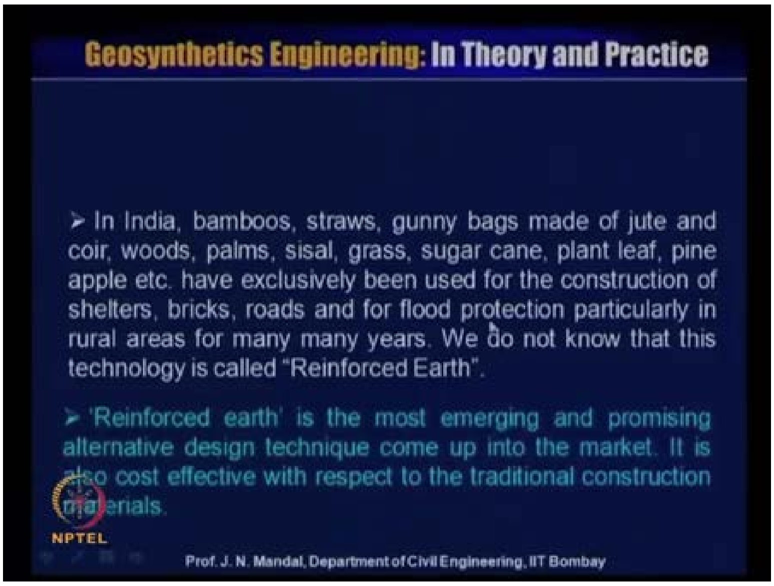

In India, bamboo, straw, gunny bag made of jute and coir, wood, palm, sisal, grass, sugar, cane, plant leaf, pineapple etcetera, have exclusively been used for the construction of shelter, brick, road and for flood protection particularly in the rural area for many, many years, we do not know that this technology is called reinforced earth. Reinforced earth is the most emerging and promising alternative design technique come up into the market, it is also cost effective with respect to the traditional construction material.

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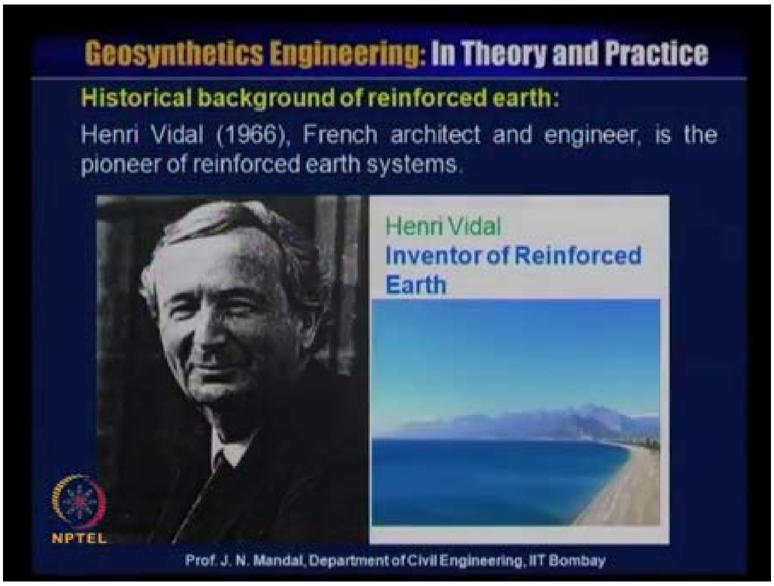

And the next slide shows that from where we had got this idea, what is the concept and mechanism. This is Henry Vidal 1966 a French engineer and architect, is the pioneer of reinforced earth system, and this is the beach Mediterranean beach, this Henry Vidal 1966 named a French architect and engineer is the pioneer, and investigated the concept of mechanism of reinforced earth system. He got the idea when he was playing with his small beautiful daughter in a white sandy beach of Mediterranean.

He formed the flatter pond with the help of a mount of sand, and this pond what we call today an unreinforced soil. He noticed some pine needle near to the sea shore, he picked it up and inserted into the cone, the cone with the reinforcement is called today reinforced earth. He stand on the top of the two cone, one unreinforced and other is the reinforced soil, and found the difference in the sediment this reinforced soil cone is also steeper angle, the combination of soil and the reinforcement is called the composite construction material that called reinforced earth.

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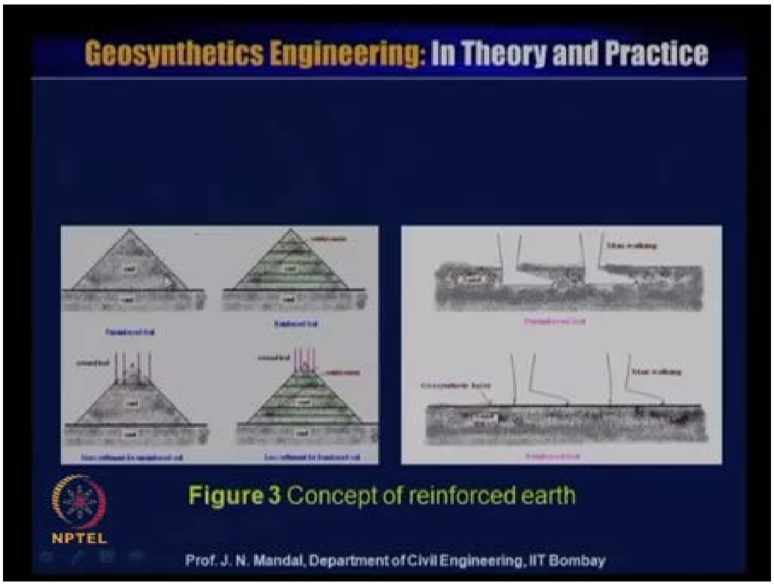

So, first laboratory on the reinforced earth is in the sandy beach of Mediterranean, he came back and wrote the basic concept and mechanism of reinforced earth. He investigated, how the forces are transmitted between the soil and the reinforcement the friction, and inter locking and the radiation to improve the mechanical properties of the composite material. His invention on the reinforced earth system has adapted in many country throughout the world.

We look at when we walk along the sandy beach which is poor material, it is difficult to walk, but if you place one layer of the geo synthetic material on the top of the same sand layer it is easy to walk. It means that fabric can resist the weight of the person without failure, we can conclude that the granular soil and the pine needle or the fabric having tensile strength combine produce a composite material, which is stronger than the soil alone.

Reinforced earth can be analogue to the reinforce concrete, granular soil is weak in tension and good in compression, and reinforcement is weak in compression and good in tension. So, with this idea we came to know about the reinforced earth system, and this reinforced earth system is the Vidal vision how the Vidal has developed the basic mechanism and concept of the reinforced earth, which has been exclusively used throughout the world. What he has used metal as a reinforcement, galvanized mild steel as a reinforcing material for the construction of the reinforced earth.

Look at this also this figure this is a cone, this one is the unreinforced and you can place the number of the layer of the reinforcement, if you put the load on this you can see that how the formation of cone after the application of the load. But, when you are introducing the layer of the reinforcement, you can see the difference in the settlement, and also you can see the difference in the load carrying capacity of the soil. You can see the right hand side picture a man on a loose sand it is very difficult to walk.

On the other hand if you can place a one layer of the geo synthetic material then it is easy to walk you can easily can walk. That means, this geo synthetic material can resist the weight of a person, and there will be a development of fixed between the soil and the reinforcement, now this is the basic concept of the reinforced earth.

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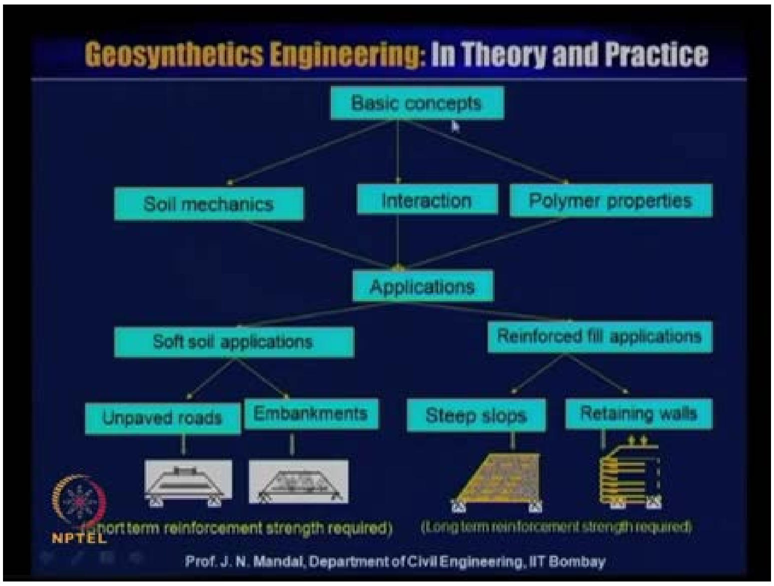

Now, based on the basic concept of the reinforced earth, this basic concept is the two thing one is the soil mechanics. Another is the interaction with the polymer material, two one is the soil you should know the what will be the characteristics of the soil material, another you should know what will be the characteristics of the polymer material, both interact with the soil and polymer you can make a reinforced earth system.

Now, what is that interaction the reinforcement interact with the soil to develop the axial forces, through the bond and compatibility between the deformation to the soil and the reinforcement. So, this interaction is very helpful for this basic concept and mechanism of reinforced earth system, and various kind of the application we can apply to the soft soil application like a unpaved road or if you want to construct the embankment.

And these are the short term reinforced strength requirement, and other application is the reinforced fill application that is steep slope or the retaining wall. And this is the long term reinforcement strength system, we will study all these aspect and we will focus how you will design the unpaved road or the embankment construction on the soft soil, how you can use the geo synthetics material for the short term stability. And we can use for the soap stability problem, as well as for the mechanically stabilized input soil wall system this is for long term stability basis.

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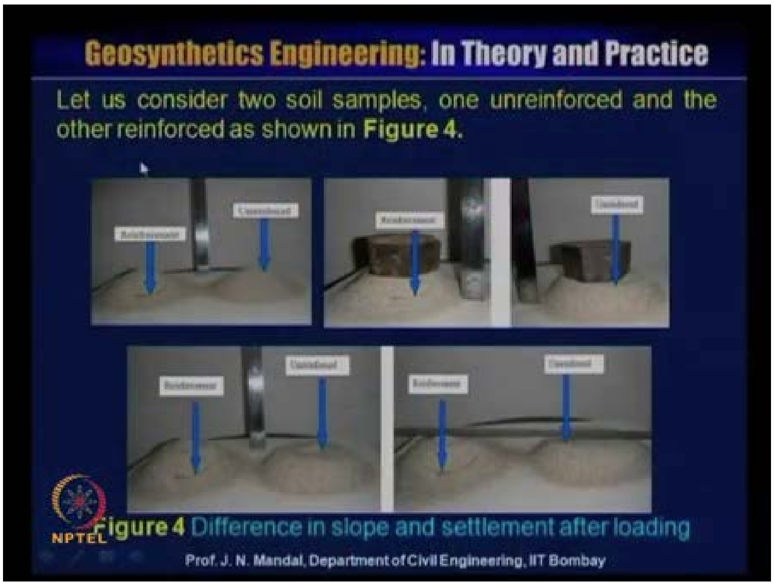

Now, let us consider these two soil sample, one unreinforced and other is the reinforced sample. You can see this side is the unreinforced sample, and this side is the unreinforced sample, this side is the reinforced sample, you can apply the load reinforced case, you can apply the load in the unreinforced case. After applying the load you can see that what is the difference in the slope, and what will be the difference in the settlement. You can see the difference in the settlement in case of unreinforced and the reinforce case, you can see that what will be the pattern of the slope pattern, you can see the much more steeper slope in case of the reinforcement.

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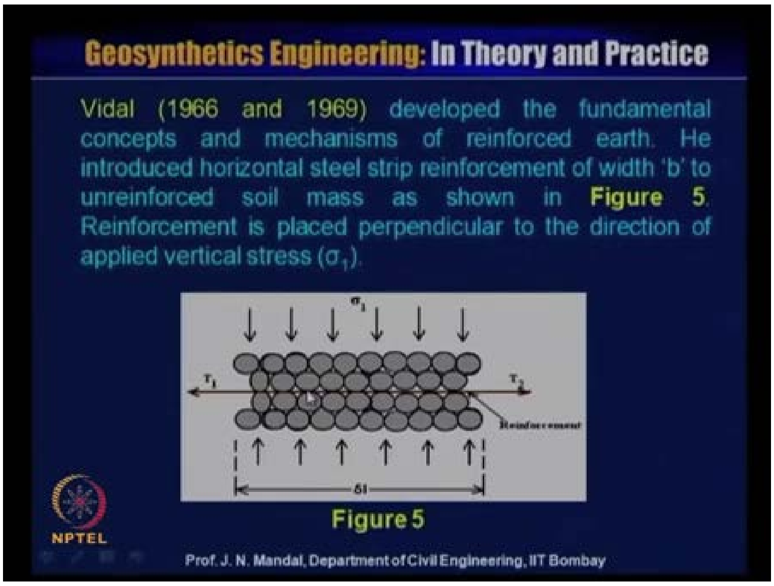

So, now Vidal 1966, 1969 developed the fundamental concept and mechanism of reinforced earth. He introduced the horizontal steel strip reinforcement, this is the horizontal steel strip reinforcement and it is width is b to unreinforced soil mass, as shown in this figure 5. The reinforcement is placed perpendicular to the direction of the applied vertical stress sigma 1, and this is the T 1, this is the T 2 and this is the delta of l, now if we apply the load there will be deformation about the delta of l.

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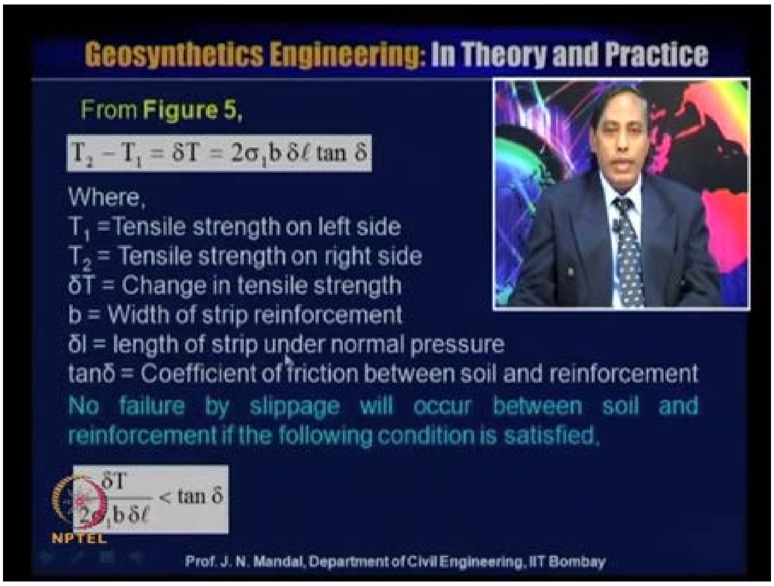

And you can see we can write the T 1 what will be the tensile strength on the left hand side. That means, this is T 1 is the tensile strength on the left hand side, T 2 is the tensile strength on the right hand side, and this delta T is the change of the tensile strength, this is the delta l is the delta l is the change of the tensile strength. And b the width of the strip material this b this is the width of the strip material is b this is the reinforcing material here that width of the strip is b.

And delta is the length of the strip under the normal pressure, and tan delta is the coefficient of friction between the soil and the reinforcement. So, in such cases there will be no failure by the slippage will occur between the soil and the reinforcement if this following condition is satisfied that is delta T divided by twice sigma b delta l it should be less than tan delta, if this condition satisfied then no failure will occur by the slippage.

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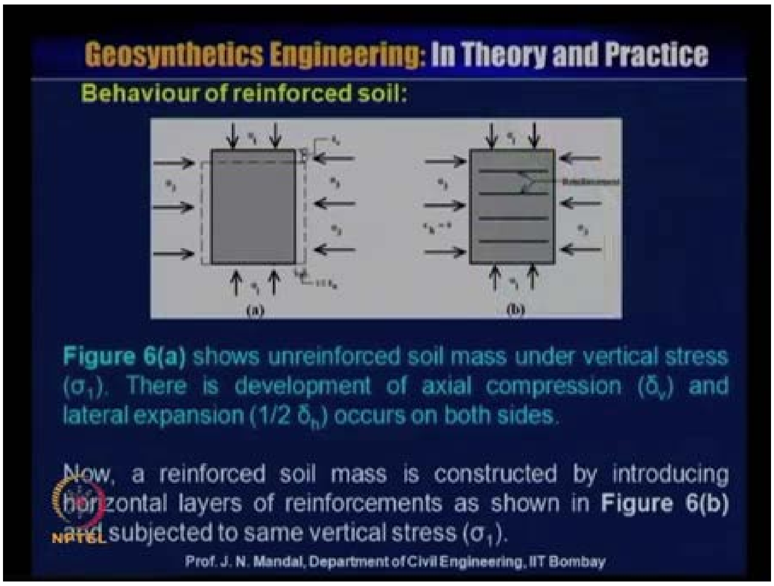

So, this is one of the basic concept what it has been observed, now what will be the behavior of the reinforced soil. You can see that left hand side is unreinforced soil mass under the vertical stress that is sigma 1, and there is a development of axial compression that is delta of v, and the lateral expansion it is lateral expansion that is half delta of h occur in the both the side. That means, when you are applying the load let us say on a tri-axial sample when you are applying the load, in unreinforced case there will be development of the axial compression which is designated here as delta b.

And also there is a lateral expansion which is designated by half delta h, and which occur on the both side of this sample. Now, we introduce the layer of number of the reinforcement this is all the layer of the reinforcement at a particular placing, now the reinforce soil was constructed by introducing the horizontal layer of reinforcement as shown in figure 6 b. And then subjected to the vertical stress that sigma 1 is the major principle stage, and sigma 3 is the minor principle stage, we can see there is no lateral deformation almost the lateral deformation is 0.

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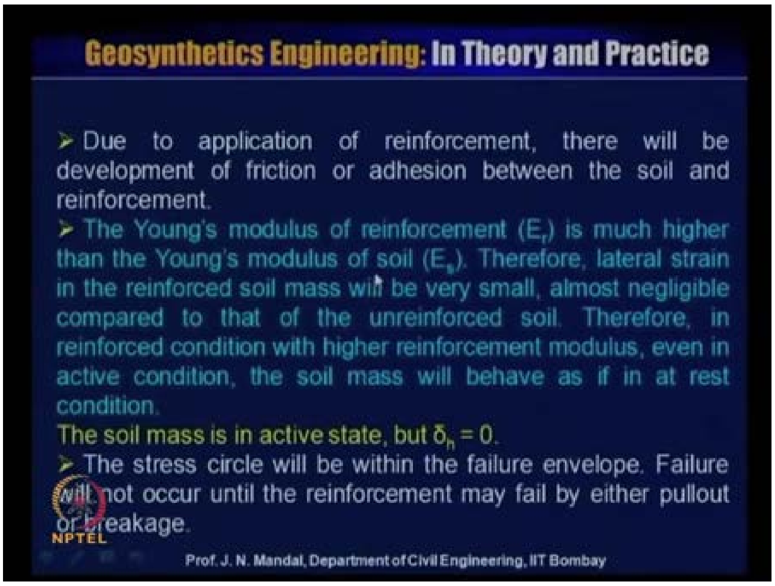

So, we wanted to study why it is 0, so due to application of the reinforcement, there will be development of friction or the adhesion between the soil and the reinforcement. Now, every material has a young modulus of the reinforcement, the young modulus of the reinforcement here is much higher than the young modulus of soil E s. Therefore, lateral strain in the reinforced soil mass will be very small, almost negligible compared to that of the unreinforced soil.

Therefore, in the reinforced condition with a higher reinforcement modulus, even in the active condition, this soil mass will behave as if in at rest condition. So, therefore, the soil mass in the active state that is delta h is equal to 0, the stress circle will be within the failure envelope failure will not occur until the reinforcement may fail by either pullout or the breakage.

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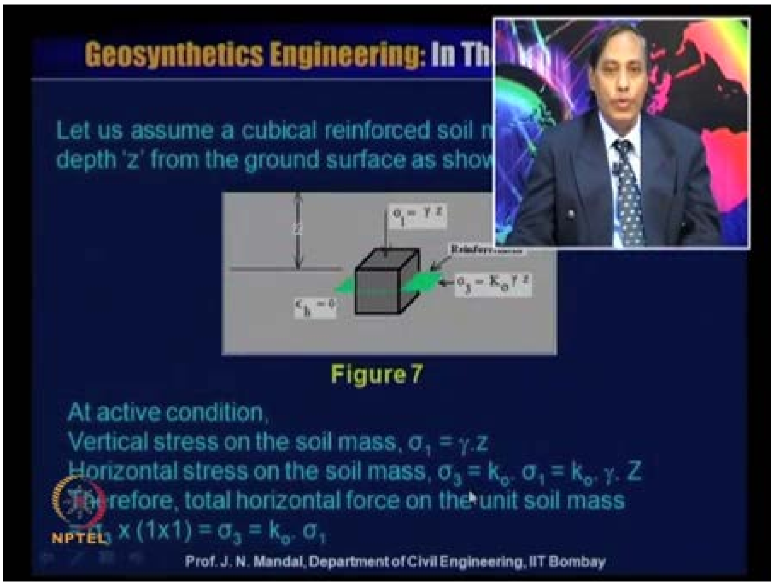

Now, let us assume a cubical reinforced soil mass, this is the cubical reinforced soil mass of unit volume at a depth z from the ground surface as shown in figure 7. At active condition the vertical stress on the soil sigma 1 is equal to gamma z, horizontal stress on the soil mass is sigma 3 is equal to K 0 into sigma 1. That means, K 0 into sigma 1 is equal to gamma z, so sigma 3 is equal to K 0 into gamma z therefore, total horizontal force on the unit of soil mass sigma 3 into one into one; that means, sigma 3 is equal to K 0 into sigma of 1.

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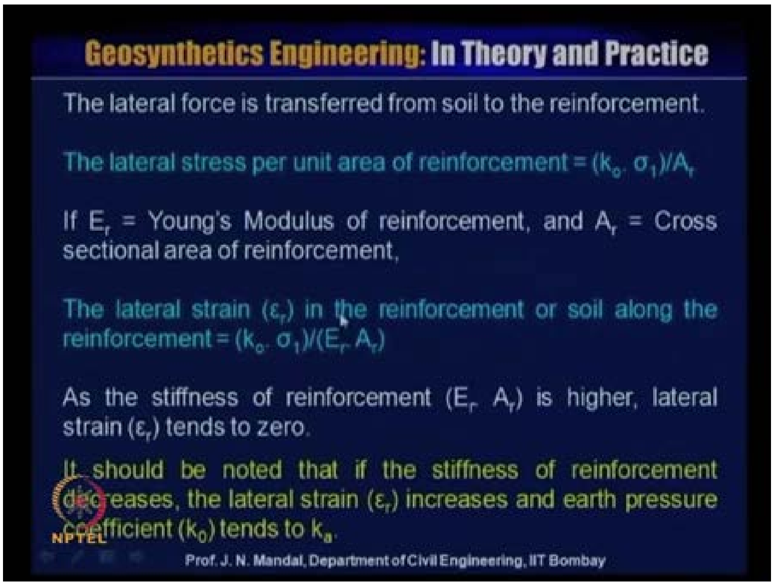

The lateral force is transferred from soil to the reinforcement, the lateral stress per unit area of the reinforcement is equal to k 0 sigma one by A r, where E r is the young modulus of the reinforcement, and A r is the cross sectional area of the reinforcement. So, lateral strain in the reinforcement or the soil along the reinforcement can be expressed as k 0 sigma one divided by E r into A r.

As the stiffness of the reinforcement E r into A r is higher, the lateral strain epsilon r tends to 0, it should be noted that if the stiffness of the reinforcement decreases, the lateral strain epsilon r increases and earth pressure coefficient k 0 tends to k a.

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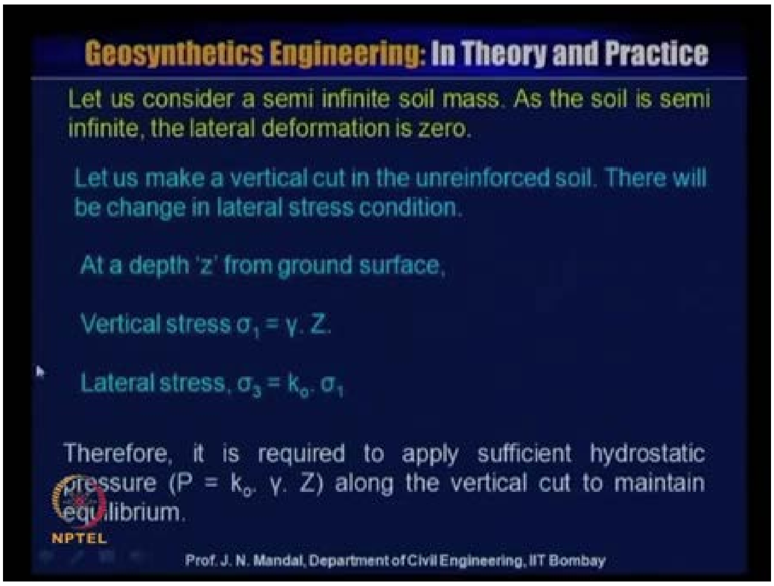

Let us consider a semi infinite soil mass, as the soil is semi infinite, the lateral deformation is zero. Let us make a vertical cut in the unreinforced soil, there will be change in the lateral stress condition, at a depth z from the ground surface you can determine the vertical stress sigma 1 is equal to gamma Z. Lateral stress sigma 3 is equal to k 0 into sigma 1 therefore, it is required to apply sufficient hydrostatic pressure that is p is equal to k 0 gamma Z along the vertical cut to maintain the equilibrium.

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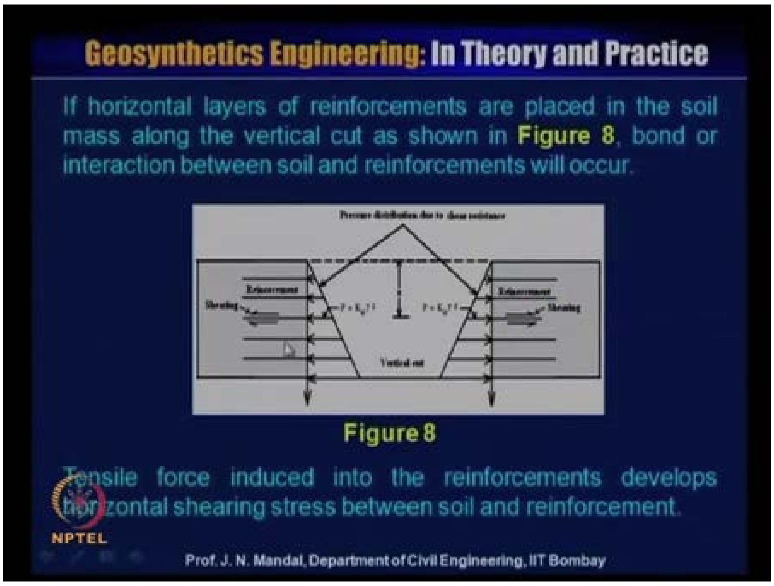

You can see this slide if the horizontal this is the vertical cut, and this is the layer of the reinforcement has been placed. And if the horizontal layer of the reinforcement placed in the soil mass, along the vertical class as shown in this figure 8, so there will be a bond or interaction between the soil and reinforcement will occur in both the sides, you can see the here p is equal to k 0 into gamma Z. So, tensile force in the reinforcement develop the horizontal shearing stress between the soil and the reinforcement.

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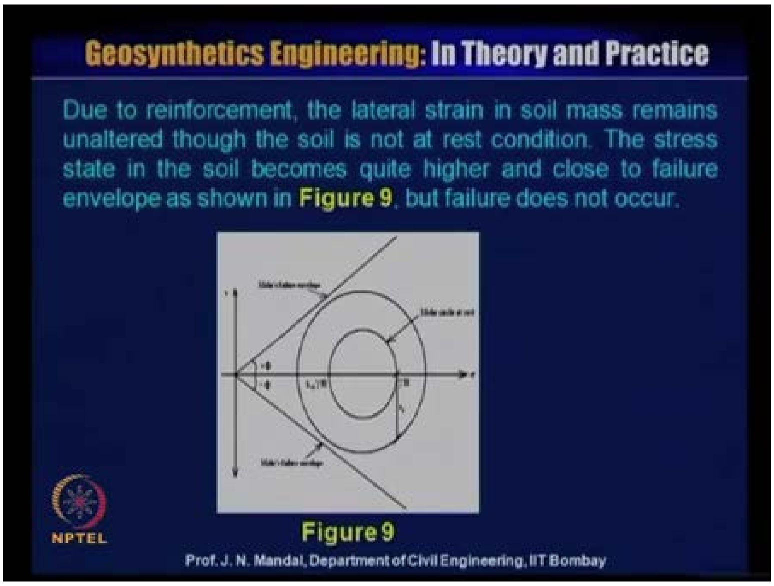

Look at this figure unreinforced soil obey the more column failure criterion, the corrosion less soil may simply defined by two linear failure envelope, inclined at an angle of plus pi and minus pi to the normal stress axis. But, pi is equal to internal angle of shearing resistance of the soil, this molar circle this is the mode circle at rest condition, this is sigma 1 is gamma h, this is sigma 3 is k 0 gamma h, this is in stable condition at rest, and that is why this circle is lies inside the more column failure envelope.

Now, due to the reinforcement the lateral strain in the soil mass remain unaltered though the soil is not at rest condition. The stress state in the soil become quite higher and closer to the failure envelope as shown in this figure, but failure does not occur, you can see that due to the introduction of the reinforcement there will be no lateral strain. But, this bigger size mode circle also lies inside the mode circle envelope, and that is why reason the failure does not occur. So, with this please let us here from you any question.

Thank you very much.