Geo synthesis Engineering: in Theory and Practices
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Module - 05
Lecture - 25
Geo synthetics in Pavements

Dear student, welcome to NPTEL to video program on Geo synthetics Engineering in Theory And Practices, this is Lecture number 25, My name is Professor J N Mandal Department of Civil Engineering Indian Institute of Technology, Bombay, India, this Module 5, Lecture 25 Geo synthetics in Pavement.

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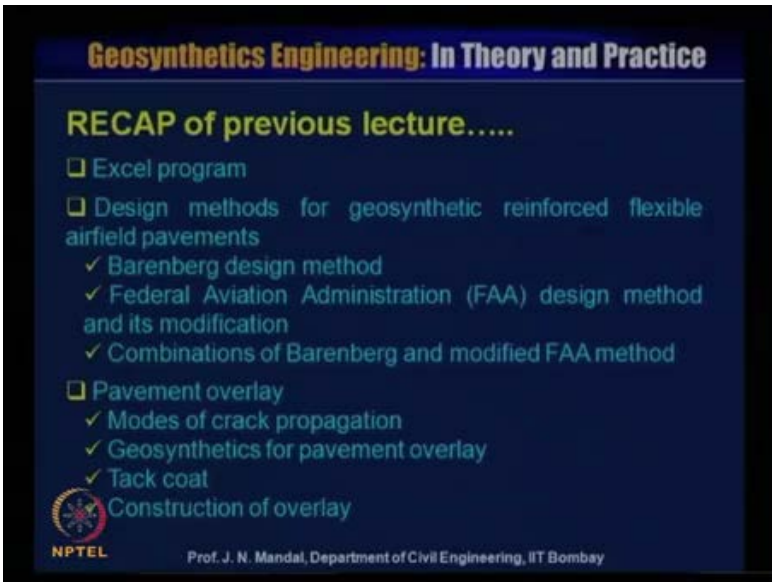

I will, now focus recap of the previous lecture we covered the excel program, design method of geo synthetics reinforced flexible airfield pavement, Bahrenberg design method, federal aviation administration FAA design method; and it is modification, combination of Bahrenberg and modified FAA method, then pavement overlay modes of crack propagation geo synthetics for pavement overlay, tack coat and construction of overlay.

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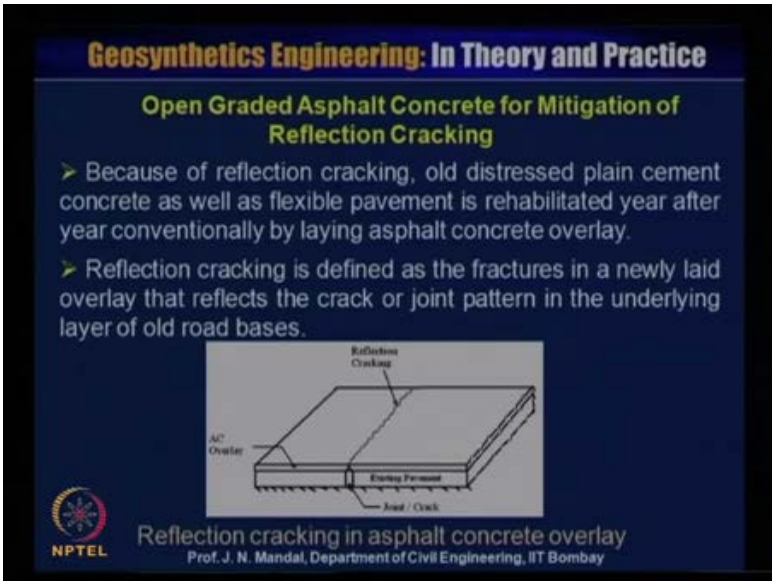

Now, I will address open Graded Asphalt Concrete for Mitigation of Reflection Cracking you know, because of reflection cracking the old distressed plain cement concrete as well as flexible pavement is rehabilitated year after year conventionally by laying asphalt concrete overlay. Reflection cracking is defined as the fracture in a newly laid overlay that reflect the crack or the joint pattern in the underlying soil of old road bases.

You can see here that reflection cracking is asphalt concrete overlay and this is the existing, the pavement and this is asphalt concrete overlay, on the top of the existing pavement and there is a formation of the crack, you can see reflection crack has occur here and this is the joint or the crack. So, this figure show reflection cracking is in asphalt concrete overlay most of the time you can observe the different types of the cracking pattern in a concrete overlay.

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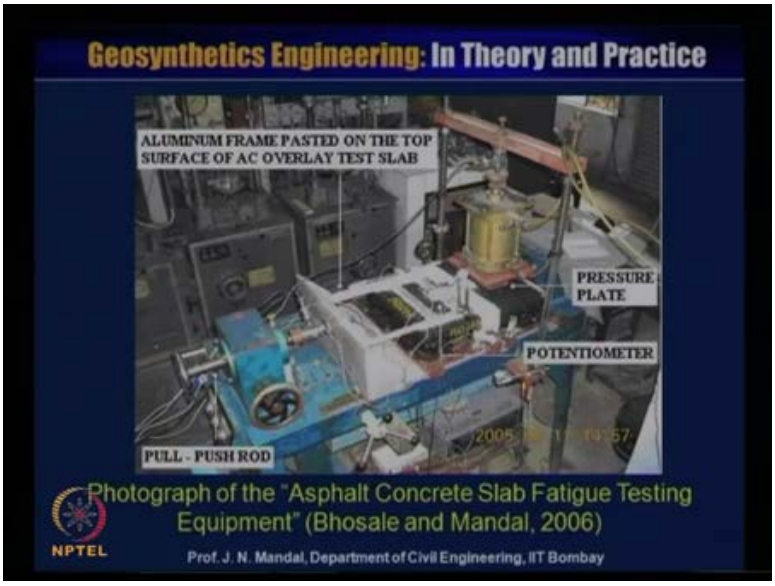

Now, Bhosale and Mandal 2006 developed this equipment for the asphalt concrete slab fatigue testing and this is the aluminum frame pasted on the top of the surface, as overlay as a test slab, this is the slab and there is a pressure plate and this is the cyclic loading is to be applied to this. And this is the potentiometer and here this machine act as a pull and the push, the rod you can see pull and the push the rod. So, this is this black one which is asphalt concrete slab and from this test, we have obtained some result which we will we will discuss in this course.

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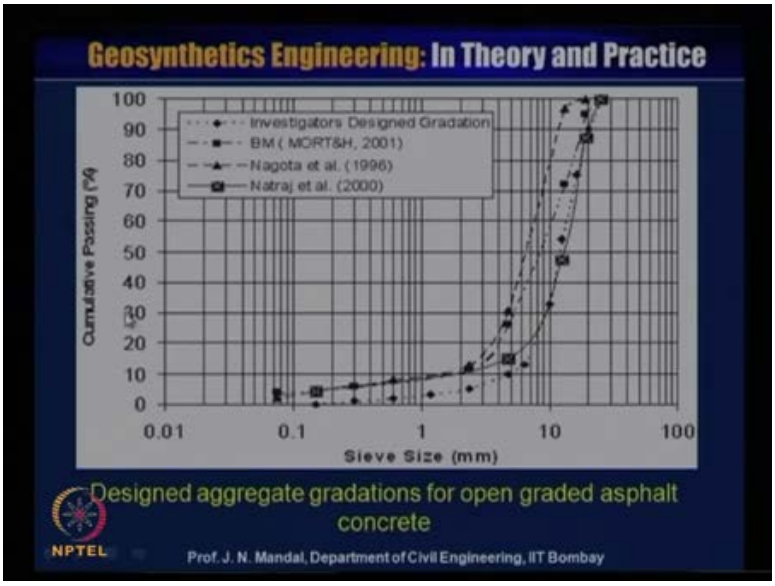

So, here is the figure which show the designated aggregate gradation for open graded asphalt concrete, this curve shows the cumulative passing in percentage versus the sieve size in millimeter. And you can see here that what is the investigator design gradation curve, which is matching almost with the m o r t and h 2001 and nagata et al 1996 and ((Refer Time: 05:15)) et al 2000. So, this gradation is very important that means, aggregate gradation for the open graded asphalt concrete is important it should be lies within this range, which we can see as for the morth 2 0 1 specification.

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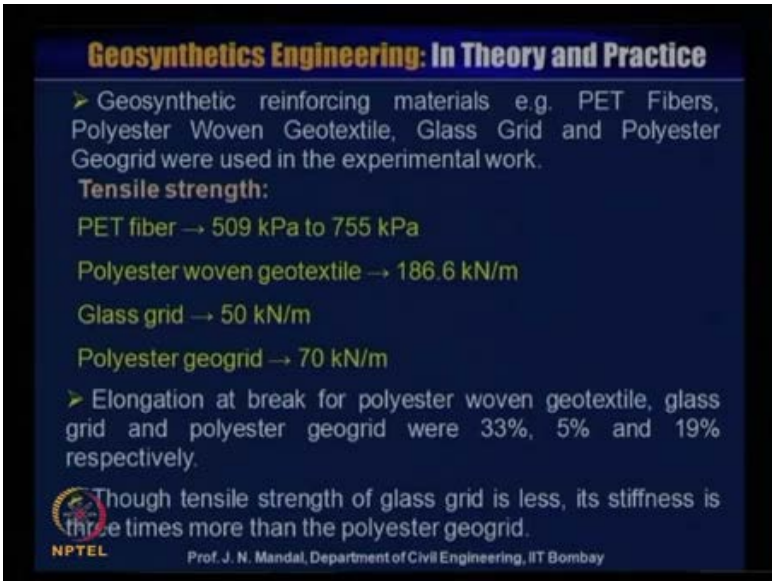

Now, geo synthetic reinforcing material, that is pet fiber polyester woven geo textile glass grid polyester geo grid were used in this experiment. So, in this experiment different types of the geo grid either in the form of the woven or in the form of geo grid or in the form of the fiber, have been introduced and then you have conducted the test, here we are focusing some of the behavior of the material, that is tensile strength of the pet fiber is in the range of 5 0 9 k P a to 755 k P a.

Polyester woven geo textile is 186 point 6 kilo Newton per meter glass grid 50 kilo Newton per meter polyester geo grid 70 kilo Newton per meter. The elongation at break for polyester woven geo textile glass grid and polyester geo grid were 33 percentage 5 percentage and 19 percentage respectively. You can see in case of the glass grid that elongation is very less its almost the 5 percentage, on the other hand polyester woven geo textile.

The elongation is more about 33 percentage and polyester geo grid about 19 percentage, which generally lies between the 10 to 15 percentage, though tensile strength of glass grid is less it is stiffness is three times more than the polyester geo grid material.

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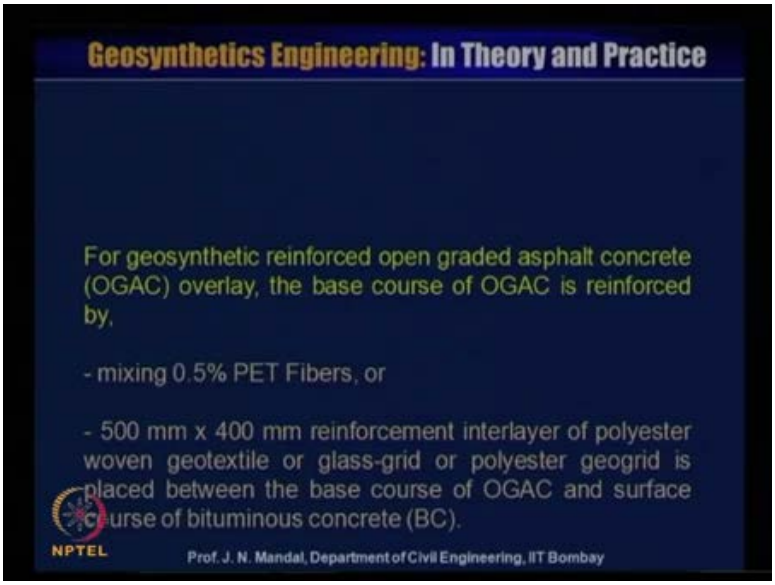

Now, for geo synthetics reinforced open graded asphalt concrete which we designated here OGAC overlay, the base course of the open graded asphalt concrete is reinforced by mixing. The point 5 percent pet fiber or 500 millimeter into 400 millimeter reinforce interlayer of polyester woven geo textile or glass grid or polyester geo grid is placed between the base course of the open graded asphalt concrete and surface course of bituminous concrete or which we call b c.

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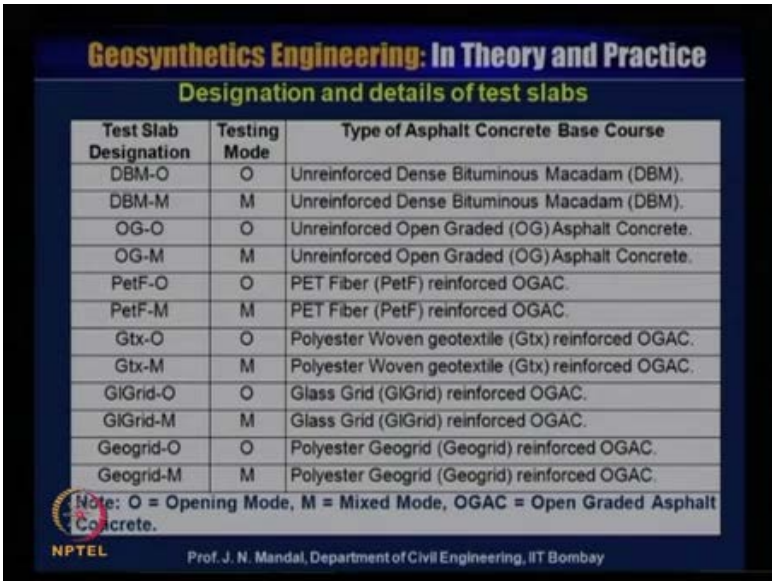

Now, here is shown the designation detail of the test slab, we have prepared the slab and that test slab designated as d b m. and that different types of the testing mode, it may be the o indicate the opening mode, m indicate the mixed mode. So, d b m that means, dense bituminous macadam here is the open mode and the type of the asphalt concrete, base course is unreinforced d b m, also d b m, m it is a mixed mode and testing mode is m and it also perform the test unreinforced dense bituminous macadam with the d b m.

And then that o g o this is the grid open graded and also the opening mode and open graded also the mixed mode, so this also open graded asphalt concrete either in the open mode and the opening mode or the mixed mode. Similarly, p e t f is the pet fiber, so pet fiber also in the open mode and also the mixed mode, so this is the reinforced with the o g a c open graded asphalt concrete.

Similarly, polyester woven geo textile grade reinforced with o g a c polyester woven geo textile grade reinforced with o g a c, either in the open graded or mixed mode, glass grid also reinforced with o g a c is the open grade glass grid reinforced with o g a c with the mix mode. So, polyester geo grid reinforced with o g a c in the open mode and polyester geo grid reinforced o g a c with the mixed mode, so these are the different types of the tests, different types of the mode and the different types of the geo synthetics material have been used and perform the test.

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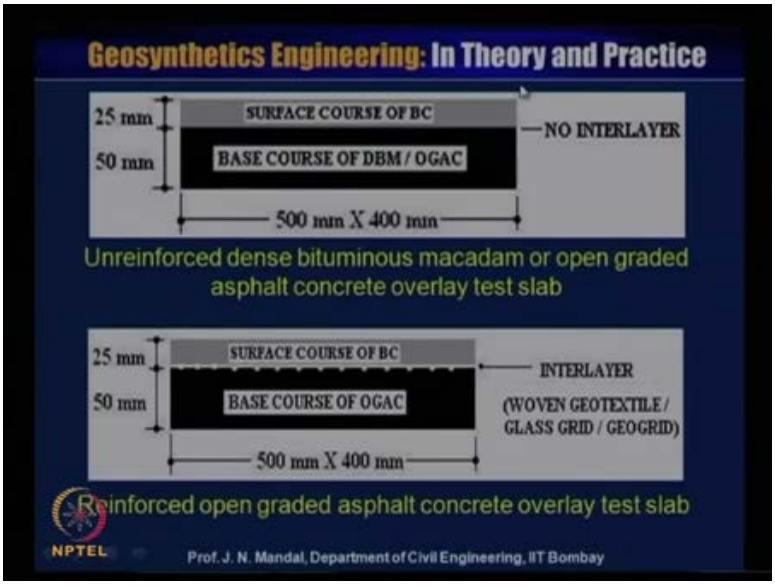

So, here you can see that unreinforced dense bitumen macadam or open graded asphalt concrete overlay test slab, this is about 500 millimeter to 400 millimeter and no interlayer, this is the base course of d b m and o g a c and this is the surface course of b c. And this thickness about 50 millimeter base course and surface course is 25 millimeter, so here unreinforced dense bitumen macadam or the open graded asphalt concrete overlay test slab.

Next the reinforced open graded asphalt concrete overlay test slab, the same one where you have used the woven geo textile and glass grid and the geo grid material this is also thickness 50 millimeter and this interlayer here. We have introduced the woven geo textile or glass grid or the geo grid whereas, here in case of unreinforced there is no interlayer and then we have performed the test.

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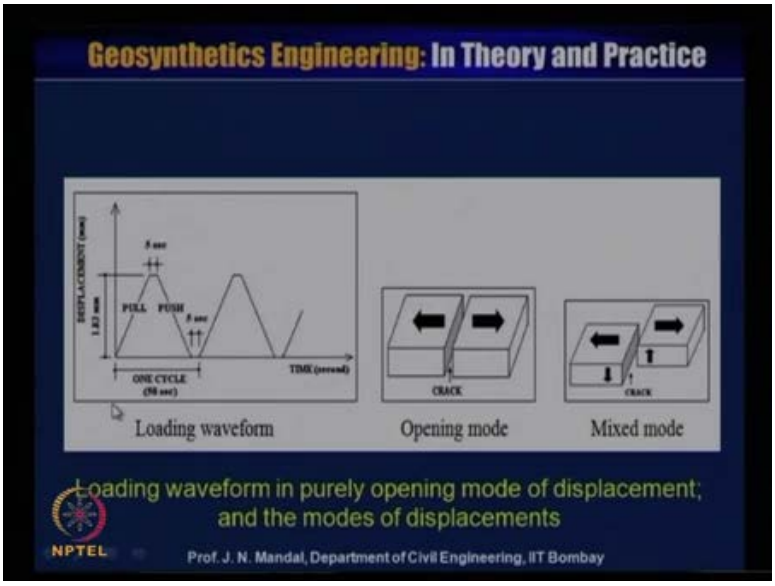

Now, you can observe that loading waveform in purely opening mode of displacement and mode of displacement, here you can see that loading in the waveform this is the displacement, this is millimeter and this is the one cycle this is a load waveform in time one cycle, this may be 58 second. So, it is what is happening it is like a pull and the push I have shown them shown the equipment, where there is a pull and the push.

So, you pull and then you can obtain the displacement about 1 8 3 millimeter and then you take the 5 second and then if you push it and then again you wait for 5 second. So, this will give you the one cycle and like that you can continue like, that with respect to the time to the with respect to the displacement, so this is what you call the loading waveform. And here it has been shown that this is the slab and you can see, when it opening mode you can see there is a open is moved away from this crack.

So, it is the opening mode and also here you can see the mixed mode that means, in the mixed mode, you can see there is a shear and then it moved out also that is this is the crack is here crack formation, due to the shear or it may move high this then it is called the mixed mode. So, you know that what do you mean by the opening mode and what do you mean by the mix mode.

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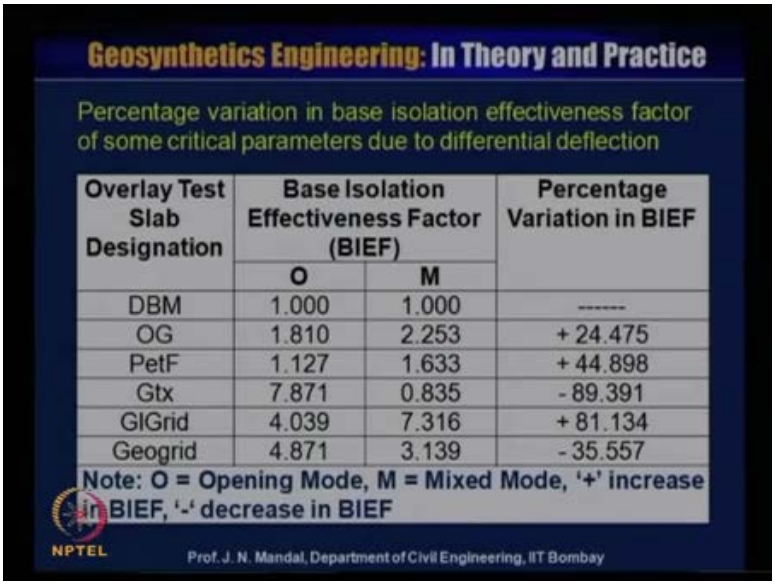

So, this is the percentage of variation in base isolation effectiveness factor of some critical parameter, due to the differential deflection. So, this is overlay test slab I mention that it is a d b m also that o g this is open graded and then pet this is the fiber this is the geo textile, this is the glass grid and this is the geo grid and this is open and the mixed mode.

So, here you have obtain the base isolation effectiveness factor, which is designated as b I e f and you can see that open mode and you can see the mixed mode in case of that, how the base isolation effecting pressure is increasing also is decreasing depending upon the type of the material, used you can see in the mixed mode the glass grid is very effective. But, in case of the geo textile it is not, so effective and this is the percentage of variation of the b I e f or base isolation effectiveness factor. So, here there is a some positive, there is also some negative, this positive which increase the b I e f value whereas, negative is shows the decrease in the b I e f value, so this value also will be the useful for the design.

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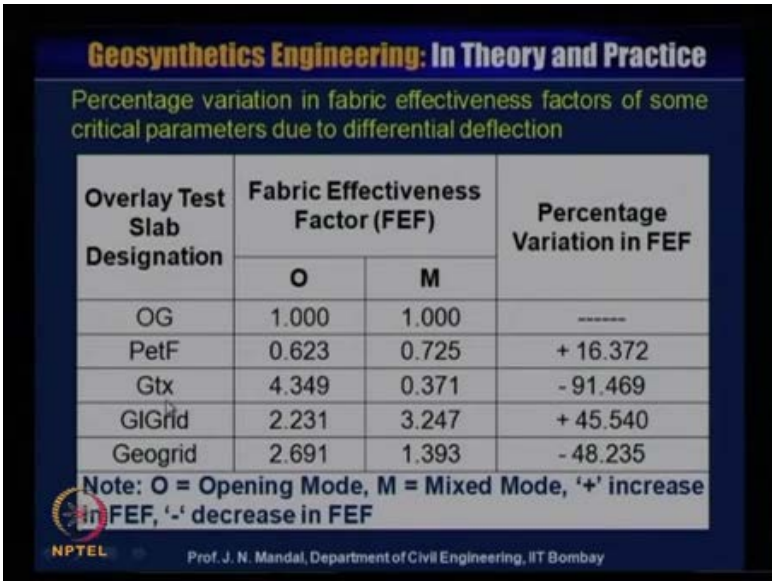

Now, percentage of variation in fabric effectiveness factor of some of the critical parameter, due to differential deflection here again that overlay test slab is designated here. And this is the fabric effectiveness factor which we call f e f this is again operating mode and the mixed mode and here the different types of the material, this is geo grid glass grid, geo textile polyester open graded.

And you can see, that fabric effectiveness factor also is glass grid and the geo grid a also in the mixed mode is variation is there also in geo textile, you can see that effecting factor opening mode greater, but in the mixed mode you can see it is on the lower side. So, overall in the glass grid you can see you have good got a good result in terms of the mixed mode and as well as in terms of the opening mode.

And this is you can see percentage of variation in f e f that positive that is increased then f e f value and negative, which increase that decrease of the f e f value.

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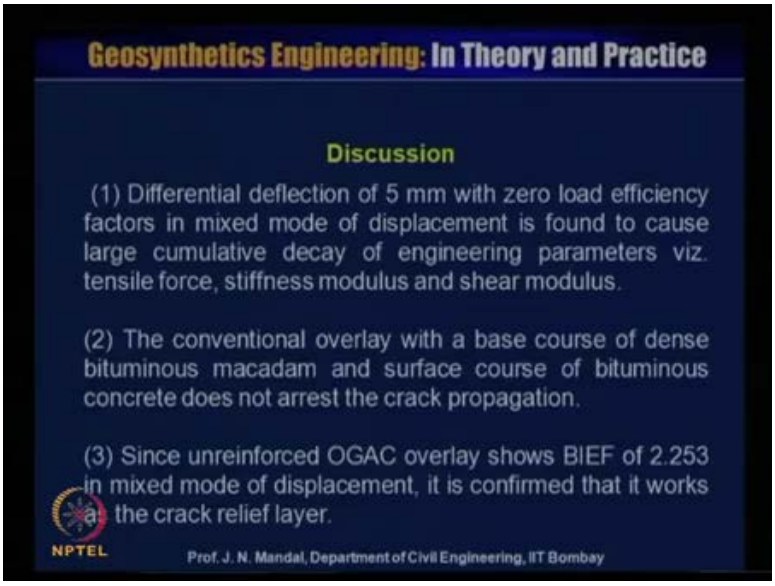

So, this factor also important, so from this what we can discuss, the differential deflection of 5 millimeter with 0, load efficiency factor in mixed mode of displacement is found to cause large cumulative decay of engineering parameters, that is tensile force stiffness modulus and shear modulus. Second, the conventional overlay with the base course or dense bituminous macadam and surface course of bituminous concrete does not arrest the crack propagation.

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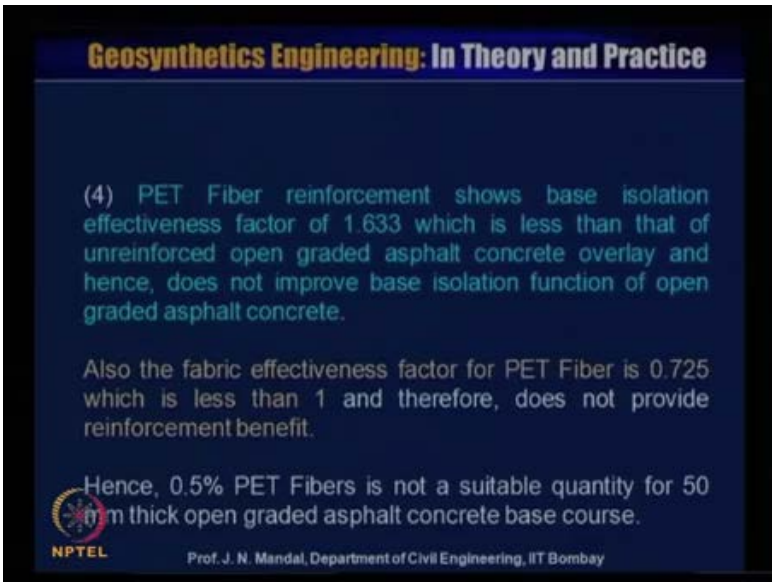

Three, since the unreinforced o g a c overlay show b I e f of 2 point 2 5 3 in mixed mode of displacement, it is confirmed that it work as a crack relief arrestor. Four, pet fiber reinforcement shows base isolation effectiveness factor of 1 point 6 3 3, which is less than that of the unreinforced open graded asphalt concrete overlay. And hence does not improve base isolation function of open graded asphalt concrete, also the fabric effectiveness factor for pet fiber is 0 point 7 2 5, which is less than the one and therefore, does not provide the reinforcement benefit.

So, you have to be careful that what kind of the material, you should select and for what purpose, you can see how the fabric effectiveness factor is less in case of the geo textile material. And which is should not be less than 1 therefore, it cannot be used as a reinforcing material. Hence point 5 percentage of pet fiber is not at all suitable quantity for 50 millimeter thick open graded asphalt concrete base course.

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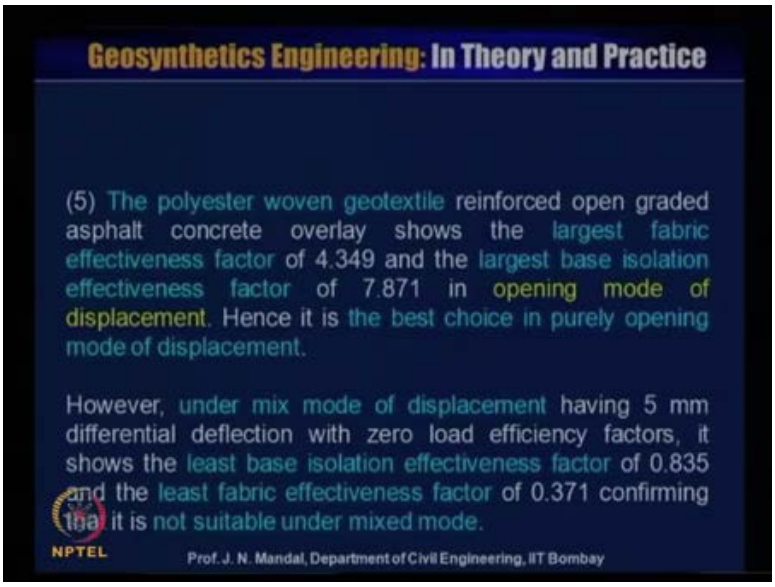

Five, the polyester woven geo textile reinforced open graded asphalt concrete overlay show, the largest fabric effectiveness factor of 4 point 3 4 9 and the largest base isolation effectiveness factor of 7 point 8 7 1 in opening mode of displacement. Hence it is the best choice in purely opening mode of displacement. However under mixed mode of displacement having 5 millimeter differential deflection with 0 load efficiency factor, it show the least base isolation effectiveness factor of 0 point 8 3 5 and the least fabric

effectiveness factor of 0 point 3 7 1 confirming that it is not suitable under the mixed mode.

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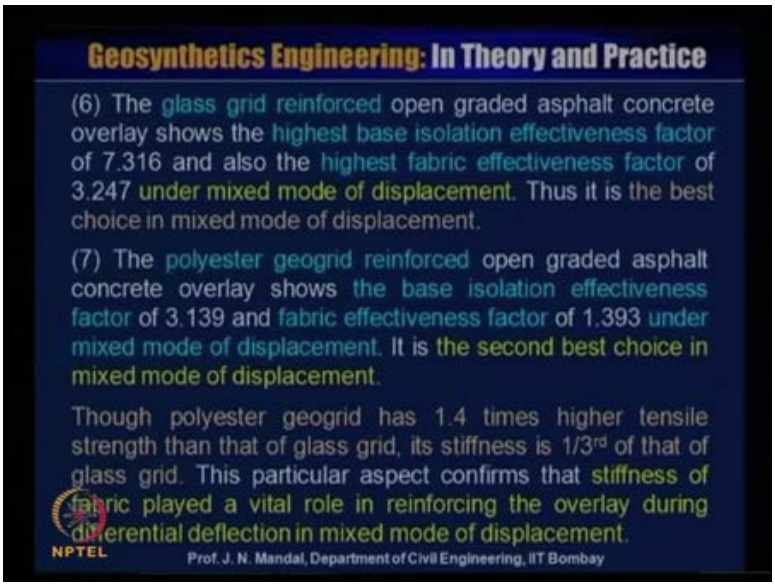

Six, the glass grid reinforced open graded asphalt concrete overlay show the highest base isolation effectiveness factor of 7 point 3 1 6 and also be the highest fabric effectiveness factor of 3 point 2 4 7 under mixed mode of displacement. Thus it is the best choice in the mixed mode of displacement, you can see that how the glass grid will be the more effective, because this isolation effectiveness factor is more compare to the other material.

Seven, the polyester geo grid reinforcement open graded asphalt concrete overlay, show the base isolation effectiveness factor of 3 point 1 3 9 and fabric effectiveness factor of 1 point 3 9 3 under mixed mode of displacement, it is the second best choice mixed mode of displacement. So, if the first choice is the glass grid then second choice will be the polyester geo grid.

Though polyester geo grid has 1 point 4 times higher tensile strength than that of the glass grid, it is stiffness is one third of the glass grid the particular aspect confirm that stiffness of the fabric played, a vital role in reinforcing the overlay during differential deflection in mixed mode of displacement, so we can also observe that what kind of the geo synthetics material should use.

So, we have performed with the different types of the geo synthetics material, either in the form of the fiber either in the form of glass grid, either in the polyester geo grid also in the woven geo textile material. And we find that what should be their what should be their isolation effecting factor and b I s f factor and what value, you should particularly select for the particular project, you can have more detail of this in one in a c paper that is also written by Bhosale and Mandal.

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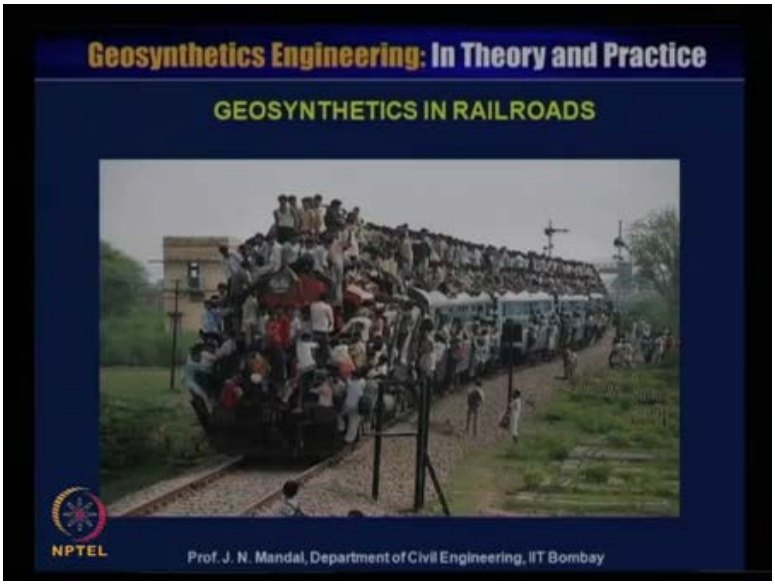

We will address the geo synthetics in the in the rail road, you know that that in the rail road how we can use the geo synthetics material, geo synthetics are used in the rail road beneath the stone ballast upon which the wooden or the concrete tie system is placed. Now, what will be the different function of the geo synthetics material, when you will use for the railway and where you can use, how you can solve the kind of the problem there is a possibility for the separation problem.

And that you can use for the new railway construction, where you can place the geo textile material between the in situ soil and the new ballast or the aggregate or in case of if it is required for the rehabilitation of the railway road that means, when the aggregate is all contamination. So, you can place the geo textile material between the contaminated ballast and the new aggregate or new ballast.

So, you can use that with the between the old and also the new ballast, where you can use the geo textile material, so where the geo synthetics material will act as a separation.

So, geo synthetics material can be used for the new railway construction also geo synthetic material can be used for the rehabilitated, the any railway or geo textile material act as a separation, also it has a confinement effect as a reinforcement.

Because, it can prevent the lateral that movement and there is a possibility for any filtration, that what time this is a there is a development of the pore water pressure, where there is a upward rising of the water, where you can use this geo synthetics material which will act as a filtration and also there will be a lateral drainage.

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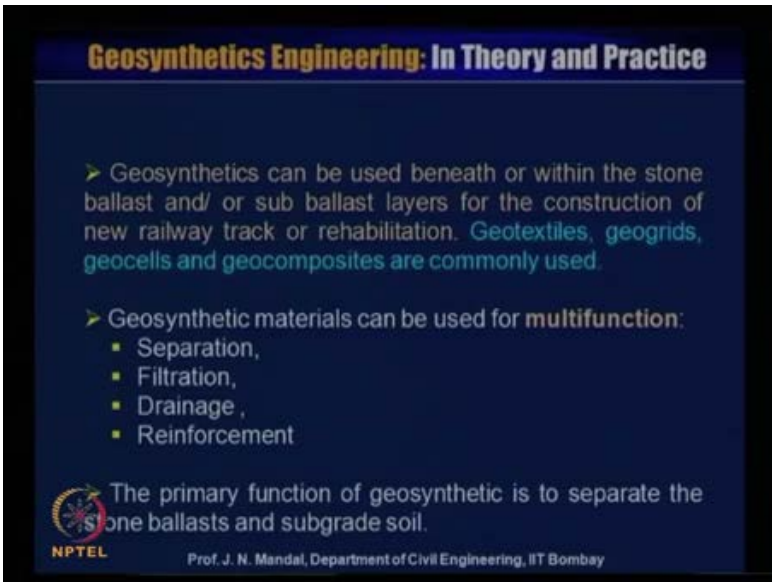

So, we will show that some of the side what geo synthetics can be used beneath or within the stone ballast and or the sub ballast layer for, the construction of the new railway track or rehabilitation. You can use geo textile, geo grid, geo cell, geo composite and also the gabion are commonly used, geo synthetic material can be used for multifunction it can act as a separation, it can act as a filtration, it can act as a drainage, also it can act as a reinforcement. The primary function of the geo synthetic is to separate the stone ballast and the sub grade soil. So, that is the primary function.

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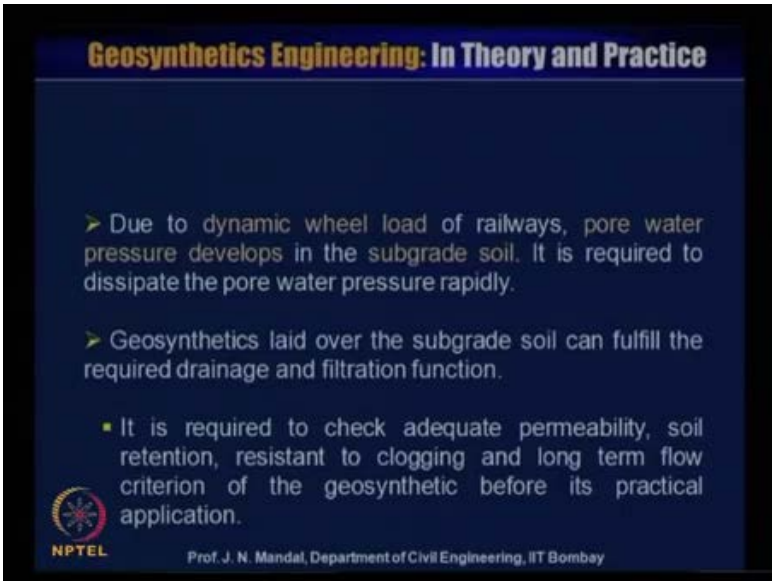

Now, due to the dynamic wheel load of the railway pore water pressure developed in the sub grade soil, it is required to dissipate the pore water pressure rapidly the pore water pressure may be moved upward or due to the dynamic wheel load of the railway then there will also a development of the pore water pressure on the sub grade. So, it is very much essential that how you can dissipate the pore water pressure rapidly.

So, how the geo synthetics can help you to act as a filtration as well as drainage, so geo synthetic laid over the sub grade soil can fulfill, the required drainage and the filtration function. It is required to check adequate permeability of the soil retention resistance to clogging and long term flow criteria of the geo synthetics, before it is practical application. We have already discussed about the flow related problem that it should solve, that certain criteria what should be the adequate permeability what should be their retention criteria of the soil, what should be the resistance or the clogging criteria also long term flow criteria.

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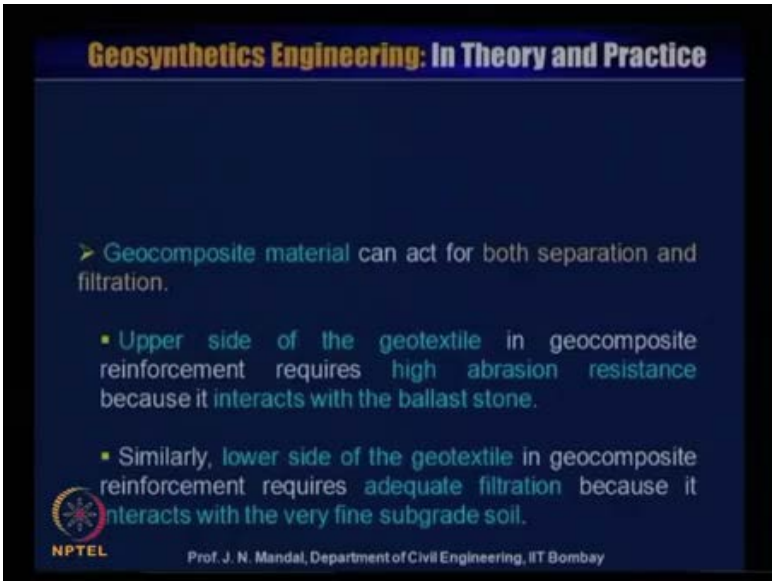

Now, geo composite material can act both separation and the filtration, upper side of the geo textile in a composite reinforcement require high abrasion resistance. Because, it interact with the ballast stone on the other hand, similarly lower side of the geo textile in a geo composite reinforcement require adequate filtration, because it interact with the very fine sub grade soil you can see here.

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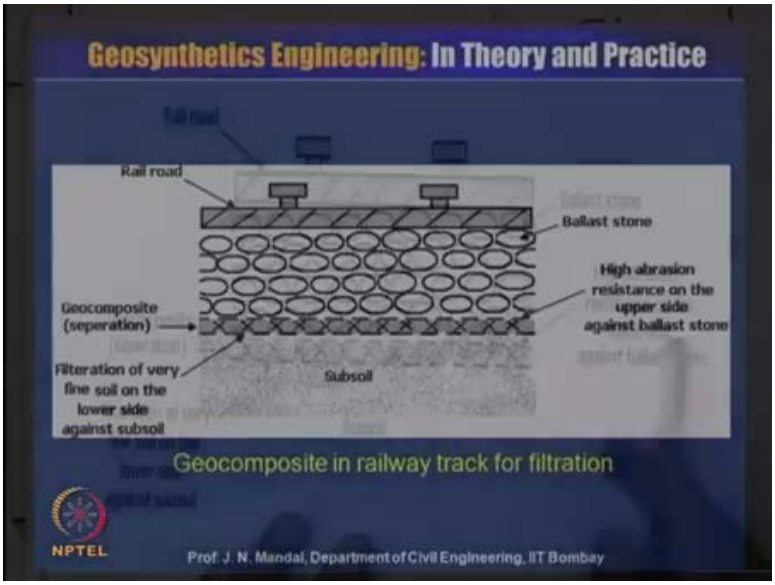

I can show you this is the rail road and this is the tie and this may be made of the concrete or the wood and this is the ballast and this is the subsoil this soil is soft. So, you

can provide a layer of the geo composite material in between the subsoil and the ballast stone. So, here you can see this is a geo composite material, now this is one material and the top and the bottom is the geo textile material.

So, that is why this is combination of the geo grid or the geo net or the woven or nonwoven geo textile material at the top and the bottom, that is why it is a geo composite material and this geo composite material act as a separation. Now, you can see that upper side of the geo textile in the geo composite reinforcement require high abrasion resistant, because it interact with the ballast. So, it should satisfy the observation criteria, similarly in the bottom one you can see there is a filtration of very fine soil on the lower side against the subsoil.

So, lower side of the geo textile in the geo composite reinforcement require for adequate filtration, because the subsoil is here and because it is interact with the very fine sub grade soil. So, here also in case of the filtration that pore water pressure rising up from the soil beneath, the geo textile, due to rising water or there is a possibility any dynamic pumping action of the individual wheel load. So, this geo composite material will act as a filtration as well as the drainage, also there is a requirement something lateral drainage, when the water entering from above or below the geo composite material.

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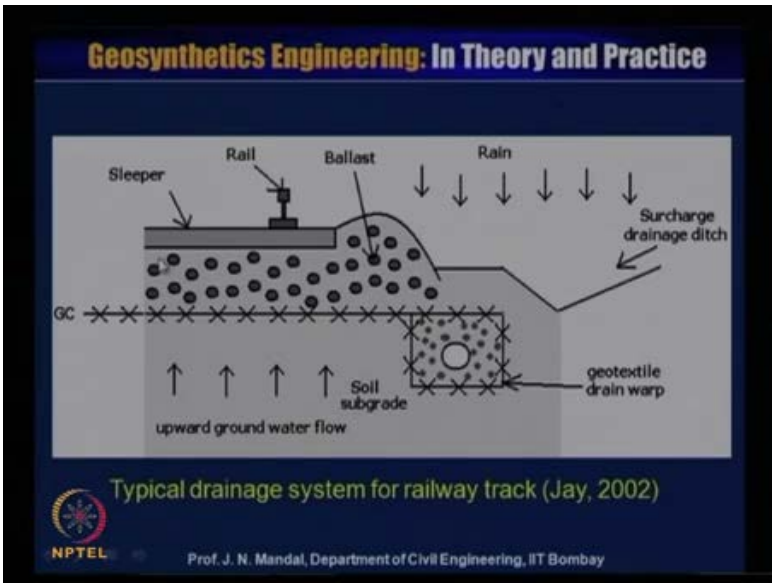

So, here is another typical drainage system for railway track, this is jay 2002 and you can see this is the railway, this is the sleeper and this is the ballast and you can provide with

the geo composite material. And there is a trench geo textile drain with the wrap, with ((Refer Time: 31:11)) then when there is a subsoil or is here and there is a upward ground water flow, then you require proper kind of the geo synthetics material and this water can be drained it out through the strain or there is a rain or there is a surcharge drainage or ditch, the what can pass through this trench material.

So, this is a kind of the typical drainage system also can be used for any railway track, so here also sometimes, if you only provide with the geo textile material then below the subsoil, you can provide also with the some sand drain, because the geo textile material directly will not come in contact with the subsoil. If you can put with a another separate layer here in below the subsoil sub grade, then three layer of the sand. And then the geo textile material and on the top of that also you can provide with the some sand drain, because the ballast should not directly come in contact with the geo textile material or alternatively, you can provide with the geo composite material. So, this kind of the also the drainage system is used for the railway track. So, geo synthetics reinforcement also provide lateral confinement, you can also use some kind of the gabion on the side near to the slope.

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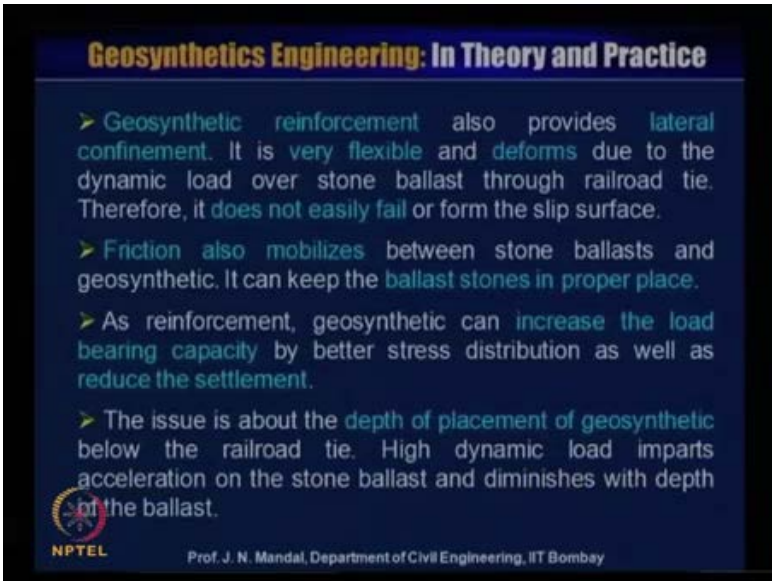

Which can provide you the confinement effect lateral confinement effect and it is very flexible and deform due to the dynamic load, over the stone ballast through rail road tie therefore, it does not easily fail to or from the slip surface, filtration also mobilize

between the stone ballast and the geo synthetics, it can keep the ballast stone in proper place as reinforcement geo synthetics can increase, the load bearing capacity by better stress distribution as well as reduce the settlement. The issue is about the depth of the placement of geo synthetics below, the railroad tie high dynamic load imparts, acceleration on the stone ballast and diminishes with the depth of the ballast.

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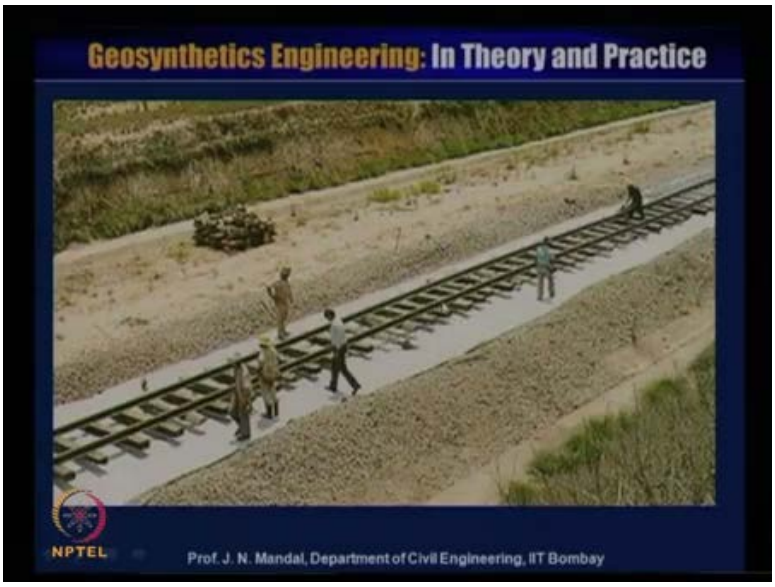

You can see here that, how the geo synthetics material this white color has been used this below the this railway track.

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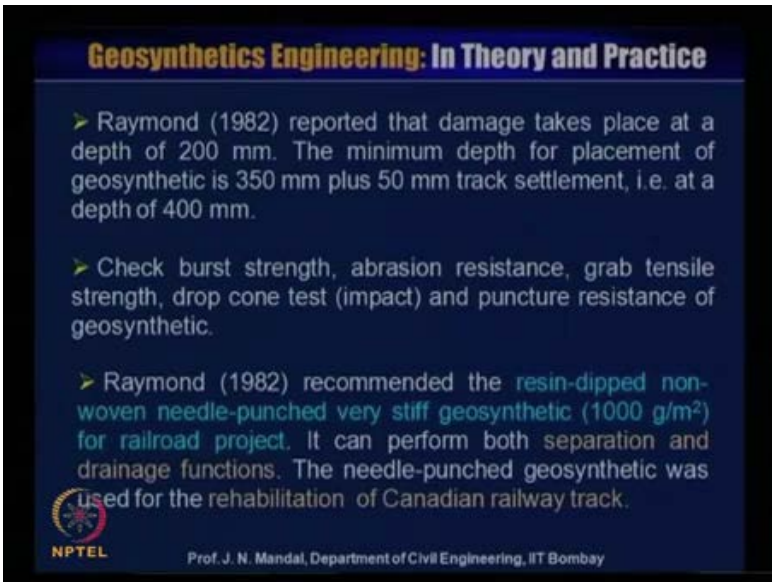

Raymond 1982 reported that damage take place at a depth of 200 millimeter, the minimum depth of for placement of the geo synthetics is 350 millimeter plus 50 millimeter track settlement, that is at a depth of 400 millimeter, check burst strength, abrasion resistance, grab tensile, strength drop cone test impact and puncture resistance of geo synthetics. Raymond 1982 recommended the resin dipped nonwoven needle punched very stiff geo synthetics, 1000 gram per meter square for railroad project, it can perform both separation and drainage function, the needle punched geo synthetics was used for the rehabilitation of canadian railway track.

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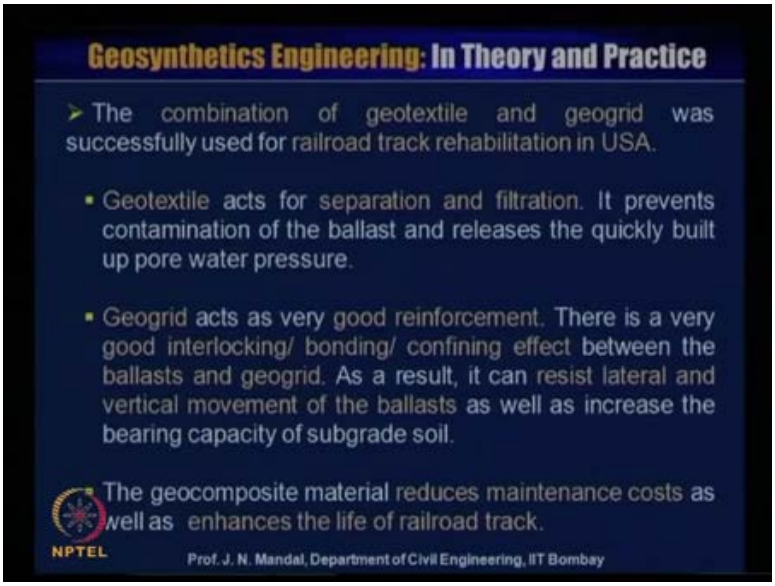

The combination of geo textile and the geo grid was successfully used for the railroad track rehabilitation in USA geo textile acts a separation and filtration. It prevent contamination of the ballast and release the quickly built up pore water pressure, geo grid act as a very good reinforcement there is a very good interlocking, bonding or confinement effect between the ballasts and the geo grid as a result it can resist the lateral and the vertical movement of the ballasts as well as increase the bearing capacity of sub grade soil. The geo composite material reduces the maintenance cost as well as the enhance the life of the railway track.

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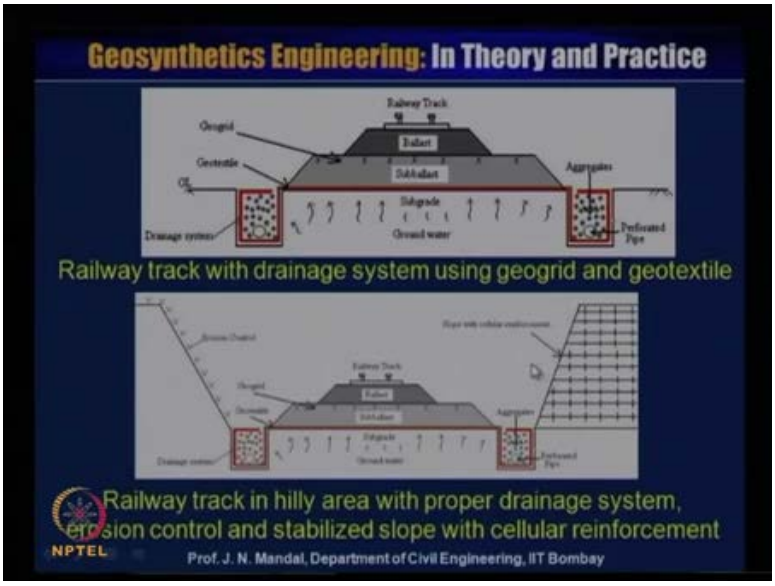

You can see some railway track in the hilly area, here is the hilly area with the proper drainage system and you can see one side, that it is a hill you can provide with the kind of the cellular reinforcement. And if the space is a shortage, so you can length can also be reduced or if there is any mountain and space is not enough, so we can provide with the cellular reinforcement.

So, this is the railway track in hill area where you can use the cellular reinforcement or if there is a erosion on the other side, then you can provide with the geo textile material when the natural material and also the grass can grow here. And this is a railway track with the drainage system using the geo grid and the geo textile material, you can place the geo grid in between the sub base and sub grade and there is a proper kind of the drainage system this is the red one is the geo textile material.

And which will act as a separation filtration as well as the drainage and also it act as sometimes, as combination of the geo grid and the geo textile material which it can be provided between the sub base and sub grade, where this geo grid can act as a separation and as well as reinforcement, similarly the geo textile can act as a separation as well as the filtration and the drainage.

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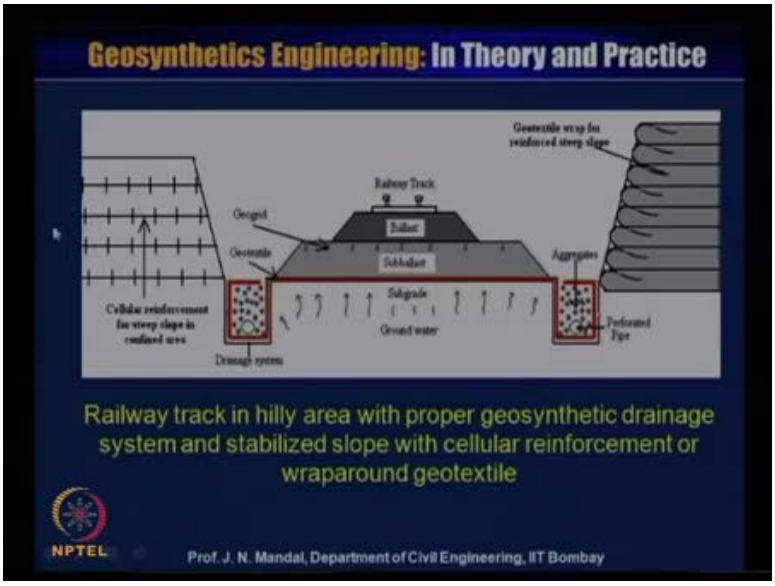

This is another this railway track in the hilly area with proper geo synthetics drainage system and stabilized slope with cellular reinforcement, one side you can go for the cellular reinforcement, you can also provide with the wrap around geo textile. So, we will discuss later how we will design the wrap around geo synthetics material here, so this is another system where you can use the different system.

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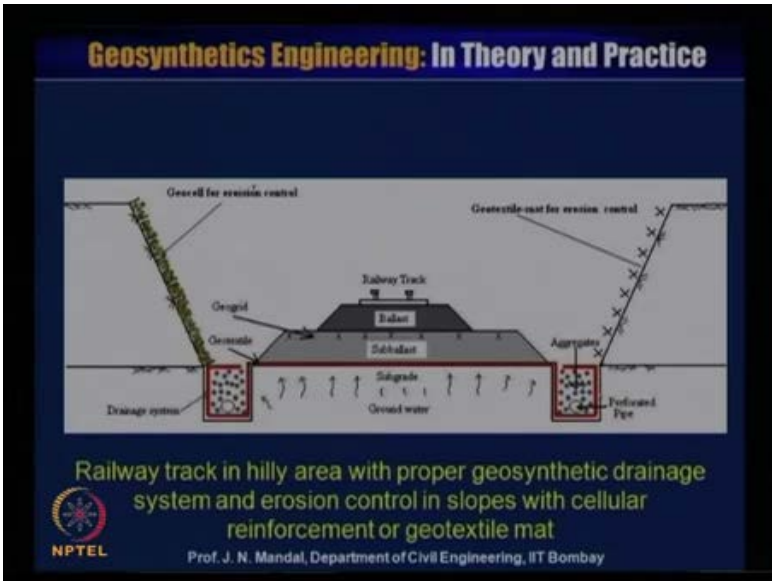

This railway track in the hilly area with proper geo synthetic, the drainage system and erosion control in slope and with the cellular reinforcement, you can provide the cellular

reinforcement and then grass can grow here also, you can place only the geo textile material and this is the geo textile mat for the erosion control, where also the grass can grow.

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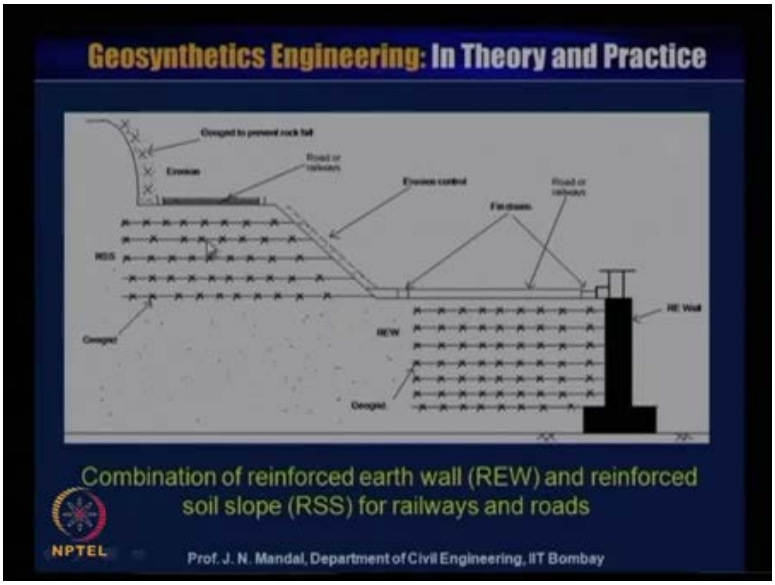

So, you can make it more greenery this is combination of the reinforced earth wall and the reinforced soil slope for the any railway track, if this is a railway any the railway track. And this is a railway track, if there is a erosion then you can provide with the geo synthetics material to control it, you can place the slope then number of the layer of the reinforcement can be placed and it can make a more stable.

And also you can make a make a road or the roadway here, where you can place this r e wall reinforced soil wall this is the number of the layer of geo grid material has been placed. So, you can construct, the r e wall what you call reinforced earth wall or you can make a steep slope, using the geo grid material and where you can build up the also the railway, so it is possible that any angle any shape you can.

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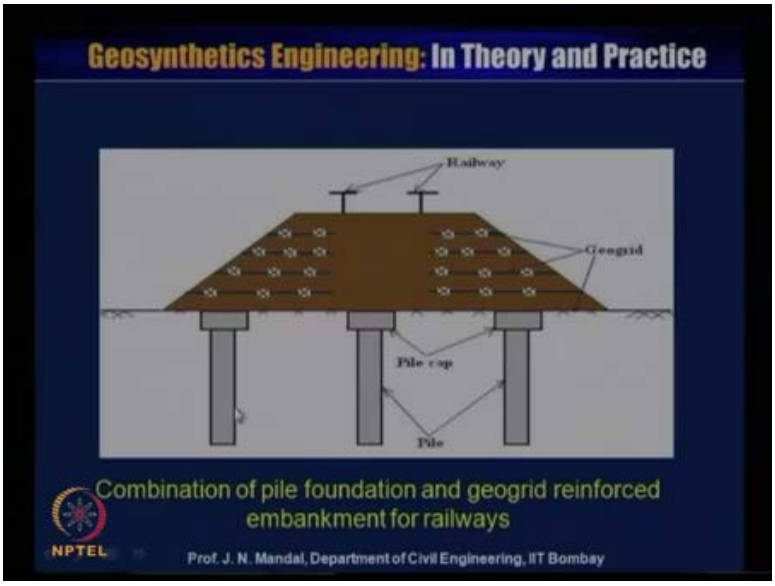

This is another very useful it has been used also in the Germany for the railway, where the pile this is combination of pile foundation and the geo grid reinforce embankment for the railway. So, this is the pile and pile cap and you can provide with the geo grid material in between the pile cap and also the embankment fill material. And this will reduce the diameter of the cap and also, it can reduce the space it can it can increase the spacing of the pile. So, because the geo grid material will act as a reinforcement, so it can take the tension, so on the top of this also you can construct the railway and it is very useful and it has been used also in many country including the Germany.

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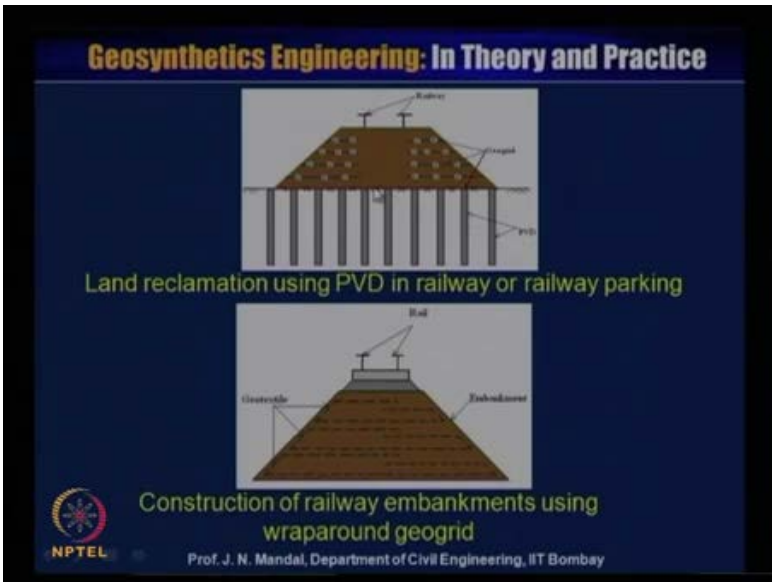

This is land reclamation using the p v d in railway, so where this is the p v d has been installed and then on the top of the then embankment has been constructed and railway can be pass through, this kind of the embankment. This construction for the railway embankment using the wrap around geo grid, you can wrap around the geo grid and construct the slope and the railway line can be passed through this.

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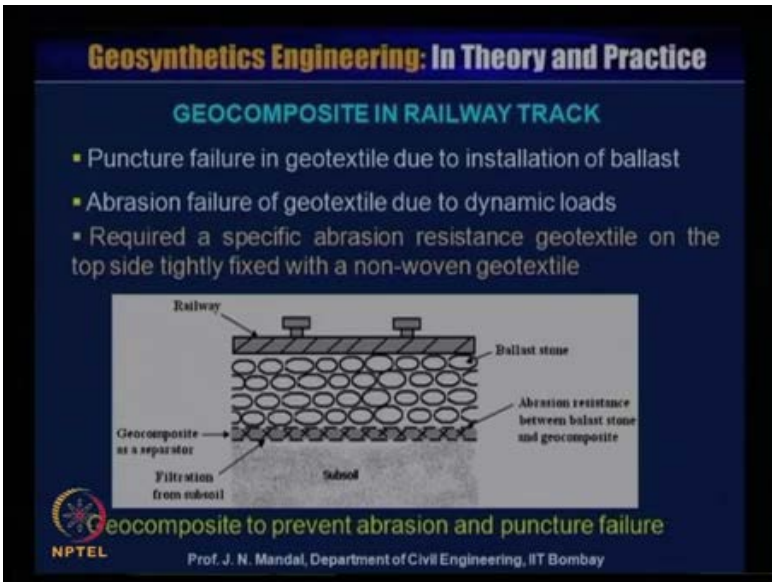

Now, geo composite in railway track, puncture failure in geo textile due to installation of the ballast, abrasion failure of geo textile due to dynamic load. Require a specific abrasion resistance geo textile on the top side of the tightly fixed with the nonwoven geo textile material. So, this is I mentioned that how also the geo composite material also can be prevent the abrasion and the puncture failure.

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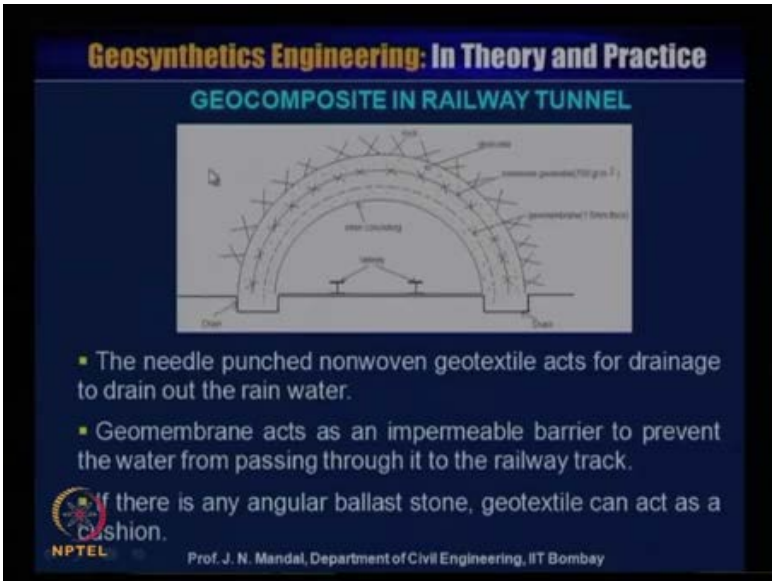

This geo composite also in the railway track, this is a kind of the tunnel where inside the tunnel these this is a railway line, so needle punched nonwoven geo textile here act as a drainage to drain it out, the water and geo membrane you are placing here, where geo membrane will act as a impermeable barrier to prevent, the water from passing through it to the railway track. So, it is therefore, that any angular ballast stone with geo textile can act as a cushion.

So, this geo cushion this geo textile material will act as a cushion it can prevent that angular stone to damage this geo membrane material, if geo membrane material damage the water can penetrated into the tunnel and then there will be a problem in the railway. So, on the top of this when the geo textile material is placed, it should be drained it out through this drain here, so geo textile material act as a good drainage material and geo membrane material, it is a impermeable material then water cannot penetrated into this railway track and geo textile also act as a cushion for the geo membrane.

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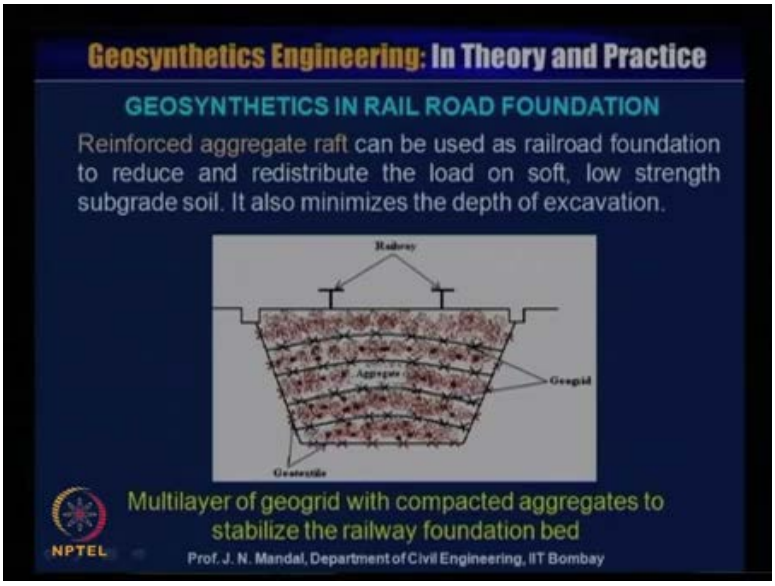

Now, geo synthetics railroad foundation you can see that this is a multi layer of the geo textile with compacted aggregate to stabilize the railway foundation, where reinforcement aggregate raft can be used as a railway foundation to reduce. And the redistribute, the load on the soft low strength sub grade soil, you go for the mat which is very expensive, alternative to that you can provide with the multilayer of geo grid with compacted that aggregate to stabilize the railway foundation bed.

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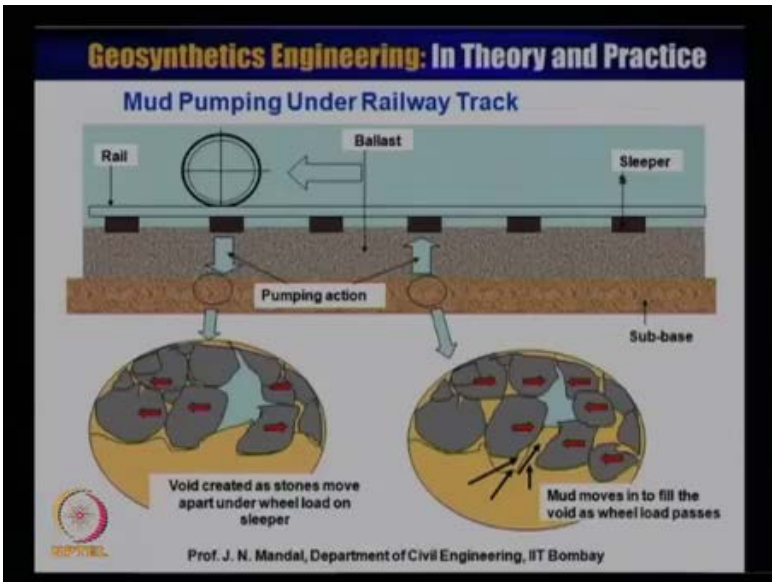

Now, another greatest problem with the mud pumping under the railway track you can see here that this is the mud pumping under the railway track, at the time of the railway wheel this is the railway wheel is over the sleeper. So, this is the this is the sleeper, this is the ballast, this is the railway track and this is the sub base. So, at the time the rail wheel is over, the sleeper this is the sleeper the load act downward on the sub base, this is the sub base, load act downward on the sub base. As a result the stone you can see here these are the stone the stone moved apart, stone these are the stone which moved apart, as a result the stone moves apart both direction and created a void here is a void.

So, void created as stone moved apart, under the wheel load on sleeper and second case when the wheel passes one sleeper to the other, the later sleeper this sleeper moves upward it moves upward that means, here pumping action it is move upward due to the pumping action. As a result this stone will try to close each other, and mud pumping occurs in the upward direction to fill this void. So, that is why the mud move into the fill the void as wheel load passes, so this is what is called the mud pumping under the railway track, so this happen and most of the time there will be a kinds of the problem.

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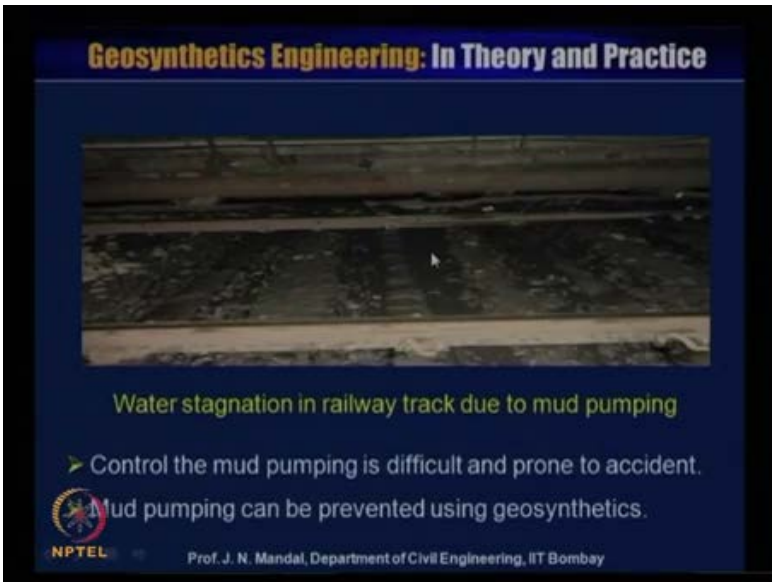

So, water you can see here water stagnation in the railway track due to the mud pumping., so you need control the mud pumping is difficult and prone to accident mud pumping can be prevented using the geo synthetics material.

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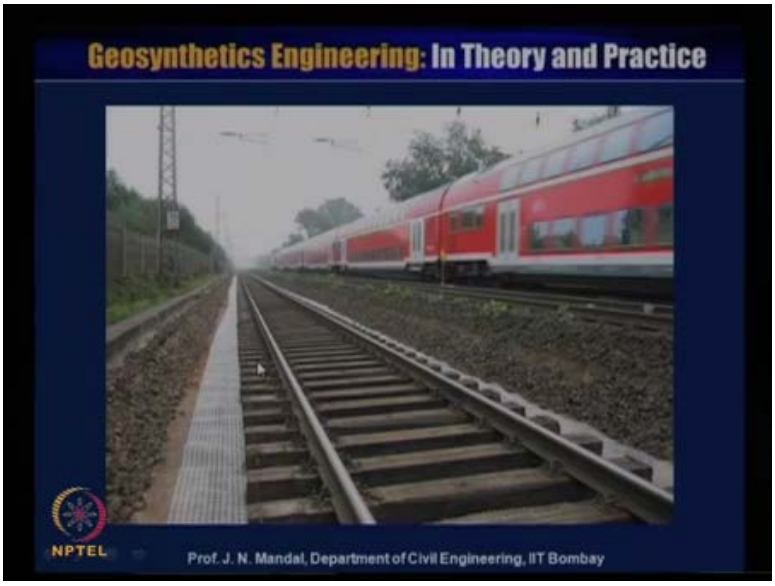

You can see you can place the geo synthetics material here and then mud pumping can be controlled also.

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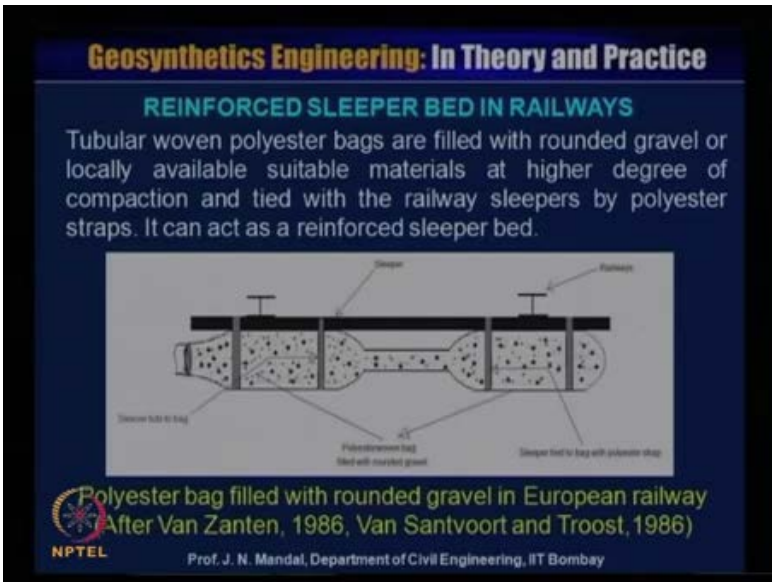

Here that reinforcement sleeper bed in the railway tubular this is the polyester bag filled with the rounded gravel in European railway, after van zanten 1986 van santvoort and troost 1986, this is tubular woven polyester bag are filled with the rounded gravel or locally available suitable material at a higher degree of compaction and tied with the railway sleeper by polyester strap.

It can act as a reinforced sleeper bed, it has also been used this is the polyester bag the silt with the rounded gravel and this you can say kind of the bag sleeper, bed to bag with the polypropylene geo textile material.

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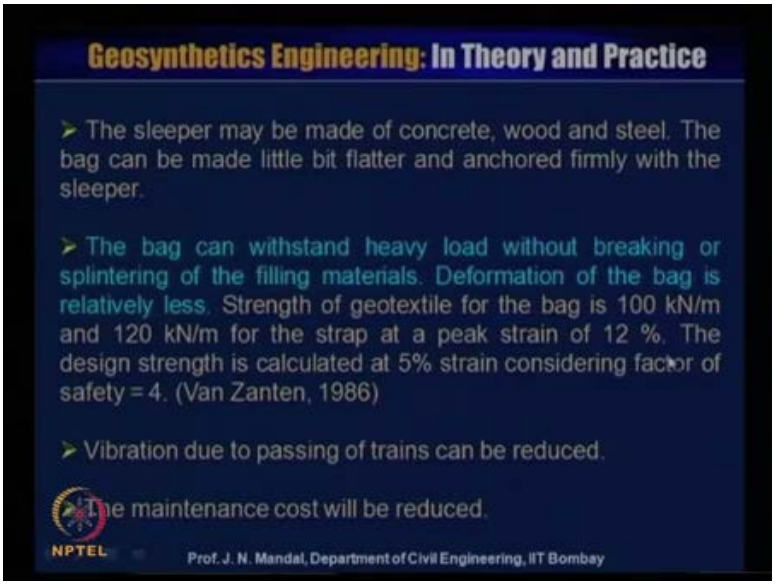

So, sleeper may be made of concrete, wood and steel the bag can be made little bit flatter and anchored firmly with the sleeper, the bag can withstand heavy load without breaking or splintering of the filling material. Deformation of the bag is relatively less, the strength of the geo textile for the bag is 100 kilo Newton per meter and 120 kilo Newton per meter for the strap at a peak strain of 12 percentage. The design strength is calculated at 5 percent strain considering the factor of safety 4 that is given van zanten 1986 vibration due to passing of the train can be reduced the maintenance cost will be also reduced.

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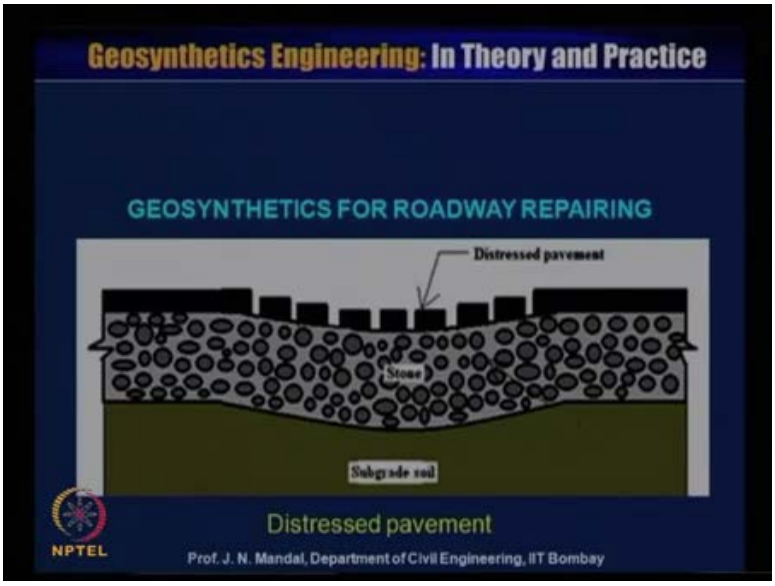

So, here this geo synthetics for the roadway repairing, you can see this is a distressed pavement this is the stone, this is the distressed pavement and how you can rectify this distressed pavement.

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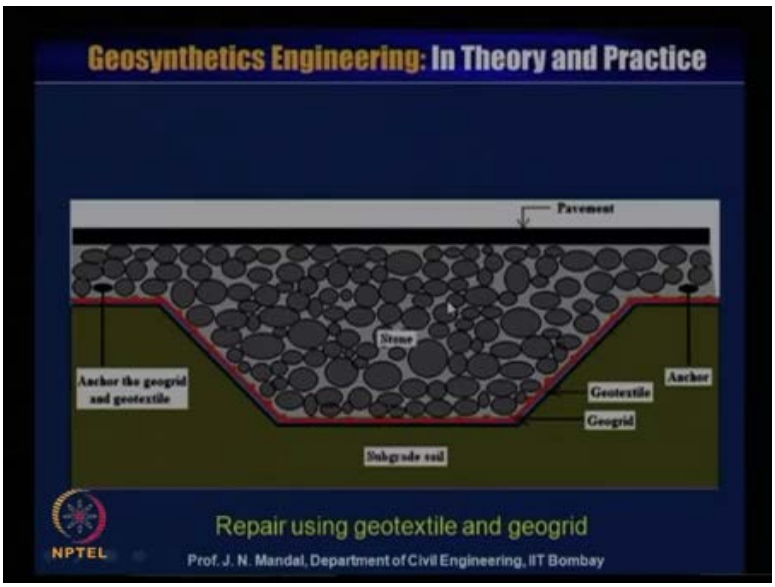

You can excavate and you can provide with the geo grid or the geo textile material and you can anchor, the geo grid and geo textile and then you filled up with the stone and then you can provide with the pavement on the top.

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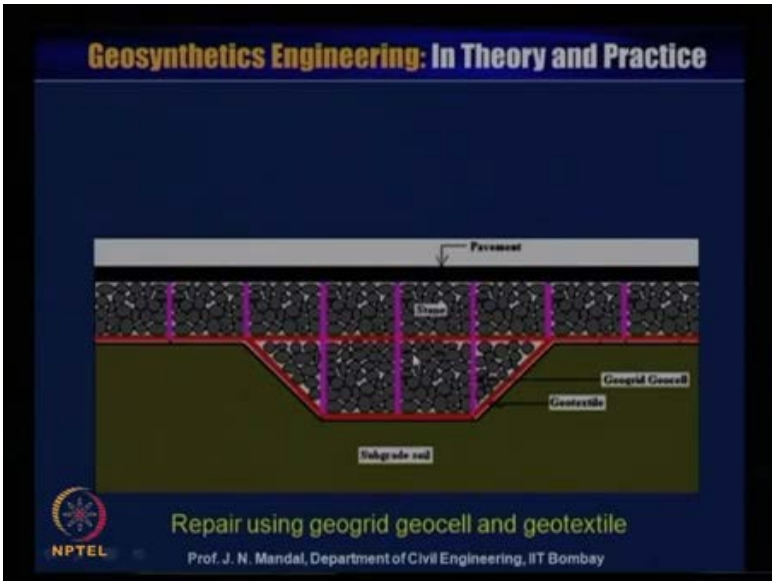

Also you can repair using the geo grid, geo cell this is the geo grid geo cell and this is made of the geo grid or it may be the geo cell all combination, you can see this is the geo cell and this filled up with the stone. And there will be there will be no lateral also the deformation, it very give very good confinement effect or you can repair this kind of the problem using the geo grid, geo cell or geo textile.

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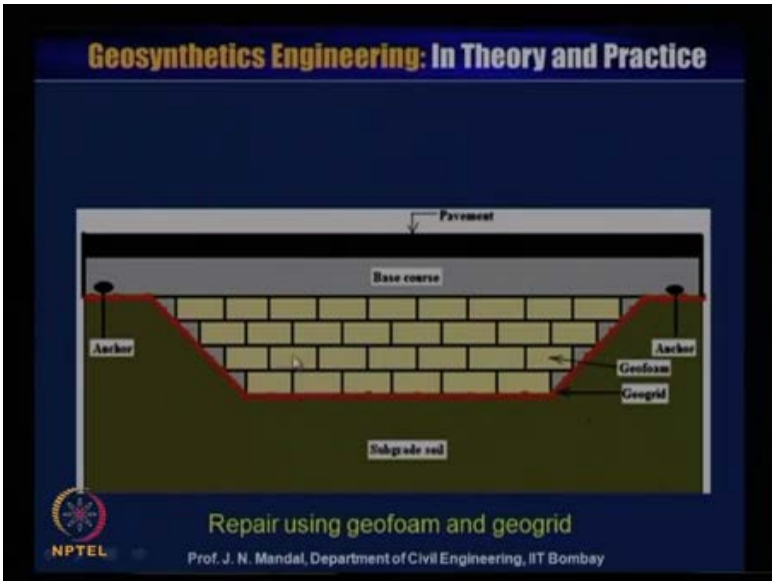

You can also use the geo textile, which can be anchored and then you can place this geo foam material on the top of this is as a base course drain and then the pavement.

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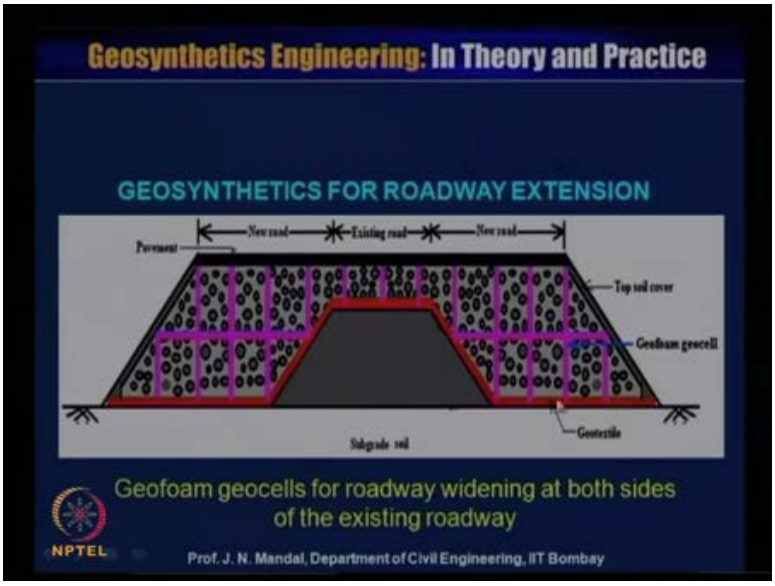

so you can see different types of the material can be used this is geo synthetics for the road way extension, if it is required for the extension any road this is the suppose existing road and you wanted to extend the road. Where you can provide with the geo foam or the geo cell for the road roadway widening, as both side of the existing road you can if this is the existing road here, you can extend it with the new road by the inclination of the geo foam geo cell or the geo grid geo cell material. So, you can extend the road like this.

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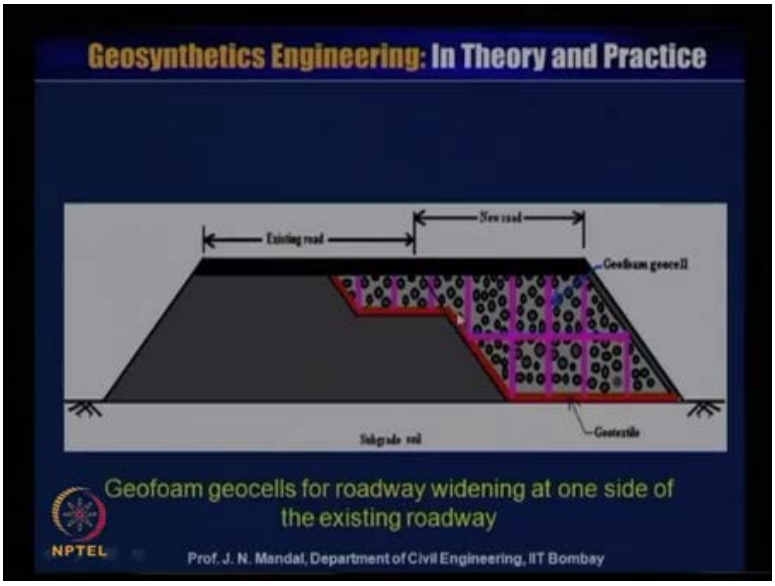

also the geo foam or geo cell for roadway widening on one side if you want this is the existing road and if you want it to widening on the other side of the road. So, this is the new road by you can include the geo cell or the geo foam material.

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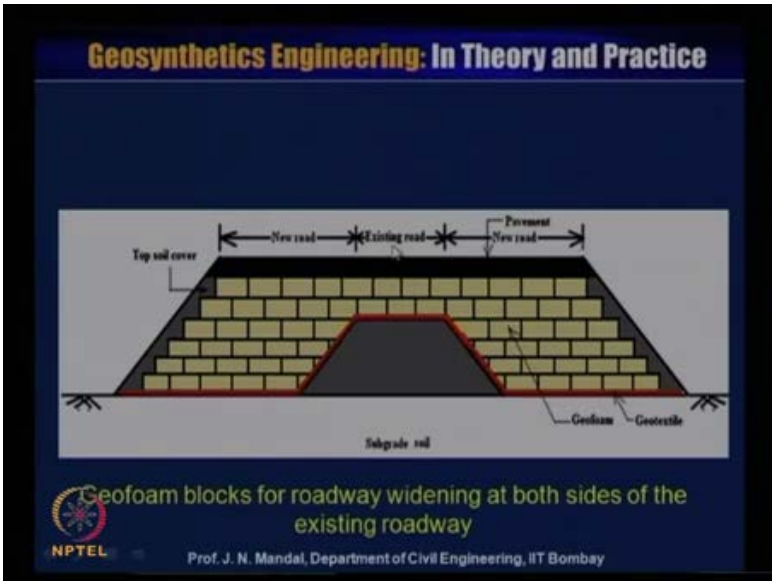

Also geo foam block on the roadway widening at both the side of the existing with existing road, then you can road the new road you can provide with this here like this, so you can use it.

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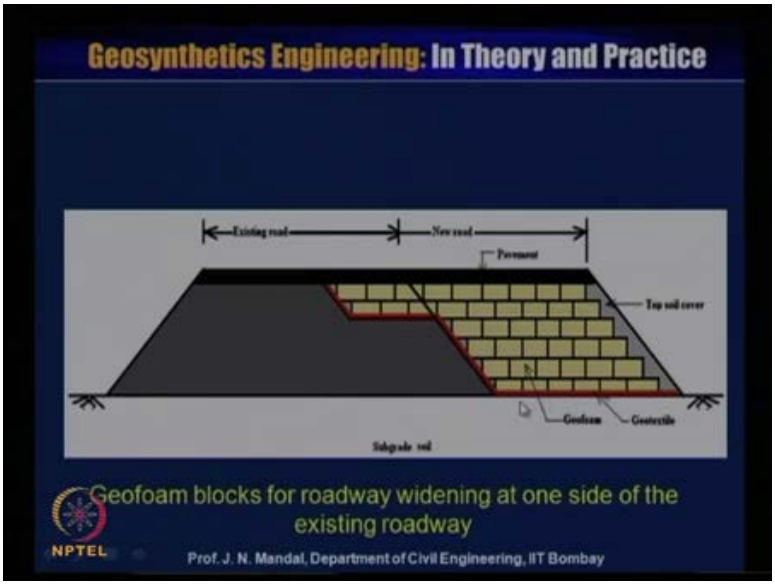

And geo foam block roadway widening at one side of the existing road, if the situation is like this where you can place the geo foam, it is very easy to place the geo foam and you can widening and then you fill up with the soil and the grass can grow. So, you can make a new road.

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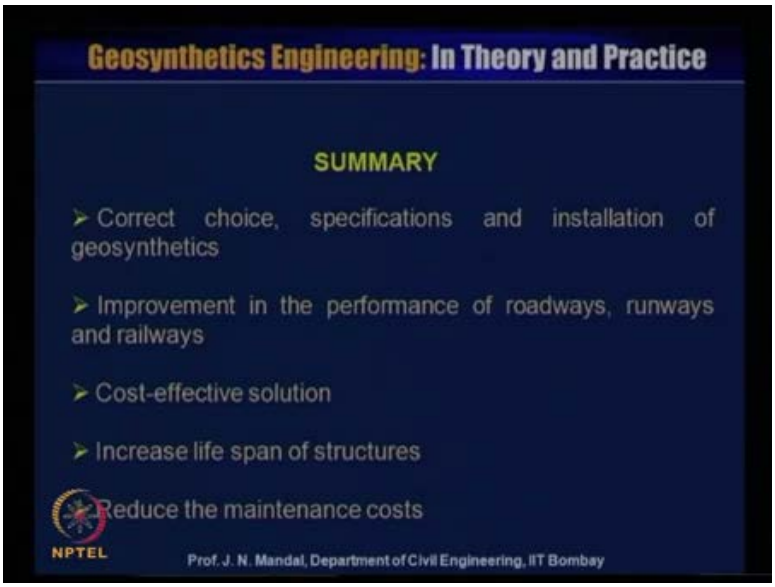

So, summary is the correct choice specification and installation of geo synthetics, improvement in performance of the roadway, runway and the railway, it is a cost effective solution, increase the life span of the structure reduce the maintenance cost.

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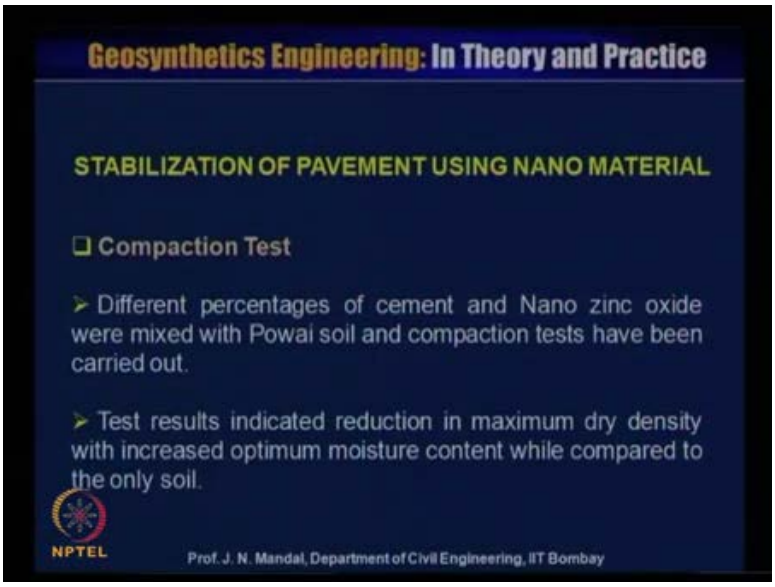

Now, stabilization of pavement using NANO material, this is a you have done the number of the compaction test and different percentage of the cement and the NANO zinc oxide were mixed with the powai soil. And compaction test have been carried out test result indicated, the reduction in maximum dry density with increase of the optimum water content while compare the only soil.

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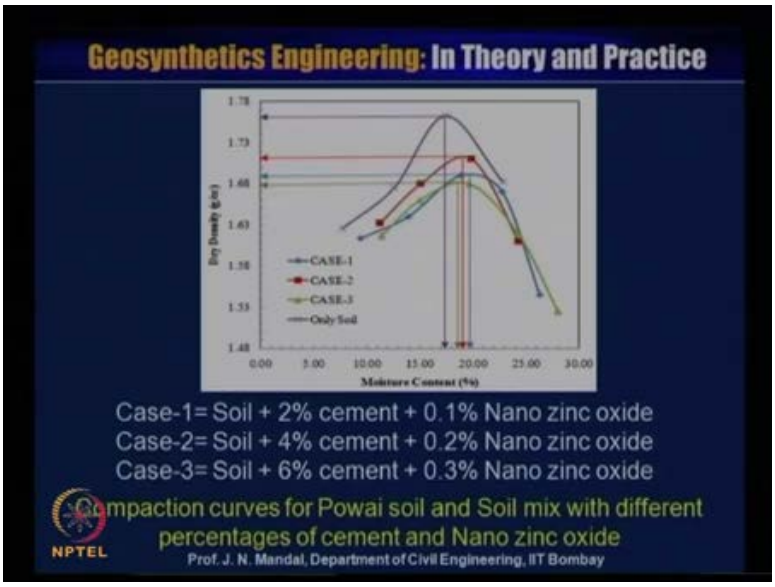

You can you can see here that you can see the here this is the c b r c b r mold and which we are performed the test this is the NANO zinc, NANO zinc oxide material also has been included. And we find that different types of the fly ash and also cement which has been used. So, in case one that soil and 2 percent cement and point 1 percent, NANO zinc oxide material has been used and case two, also soil 4 percent cement and point 2 percent NANO zinc oxide has been used and case three, soil plus 6 percent cement plus point 3 percent NANO zinc oxide has been used.

So, this is one of the sample they were the test has been performed and you can see it is a very hard, so I will show you some of the compaction test result if you draw the dry density versus, the moisture content and what is happening in case of the conventional soil and in case of when you are introducing this cement and the NANO zinc oxide material and what is happening this.

This is the slide show that compaction curve of the powai soil and soil mix with soil mix with the different percentage of the cement and NANO zinc oxide material. So, you look

at this curve in an, it is it is noted from this optimum moisture content here and dry density here, optimum moisture content is increasing for the treated soil. But, maximum unit weight is decreasing hence the additional of the cement and the NANO zinc oxide material, which will act as a additive would require more water you can see you require for the more water for the treated soil, moreover more water is needed to reach the optimum compaction state. The maximum water content of treated soil with NANO zinc oxide is slightly reduced that means, that optimum moisture content is treated soil increase. Because, more water is necessary to lubricate more water is necessary to lubricate the particle and thereby reach an optimum state, quantity of NANO zinc oxide added to the soil is small the effect of the NANO zinc oxide is less noticeable on the compaction.

So, NANO zinc oxide increase more water is needed in the mean time both the in the mean time both the maximum unit weight and the dry density matrix decrease slightly as more NANO zinc oxide is added to the soil. So, dry density of the mixture is observed to be in the range of 16 point 6 to 17 point 6 kilo Newton per meter cube and most of the mixture satisfy the morth 2000 one criteria for the use of embankment construction. So, we can see that how the NANO zinc oxide material with the cement can be used and where you can energy you can save with respect to the normal conventional soil material.

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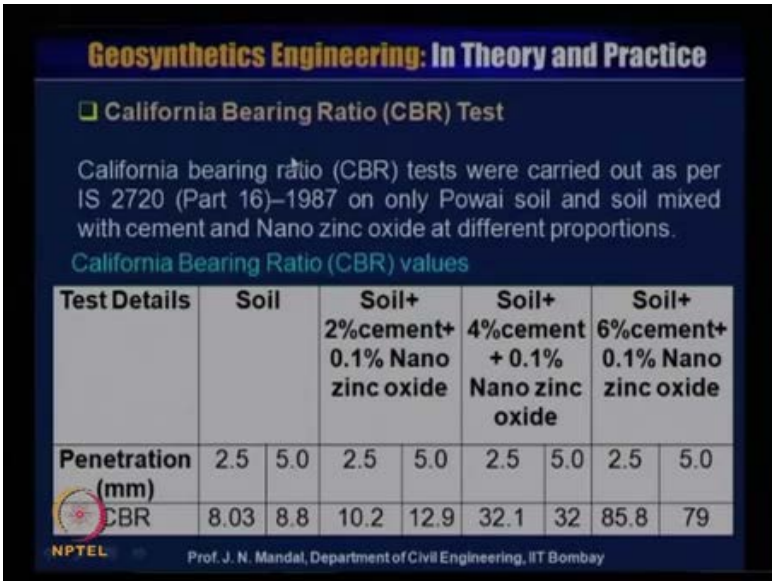

This is California bearing ratio test was also carried out as per ISO 2 7 2 0 part 16 1987 on only powai soil and soil mixed with the cement and NANO zinc oxide at different proportion. So, here tested detail given that this is the test data for the penetration, this is c b r this is soil only and this is soil with 2 percent cement point 1 percent NANO zinc oxide soil plus 4 percent cement plus point 1 percent NANO zinc oxide, soil plus 6 percent cement plus point 1 percent NANO zinc oxide. You can see here that how this c b r value is increasing with the introduction of the cement and the minimum amount of the NANO zinc oxide.

So, here you can see that this is about 30 2 point 1 it is about 85 point eight and 79 percentage of the c b r value, with respect to the soil 8 point 0 3 to 8 point 8. So, what we find that more specification for road and the bridge were in 2001 criteria that c b r value generally 20 to 30 percent for use in the sub base layer for road way pavement. So, whereas, here it has been observed that this c b r value is much on the higher side and then you can use the small amount of the NANO zinc oxide material, which will be very useful for the use and it can also satisfy this criteria or specification.

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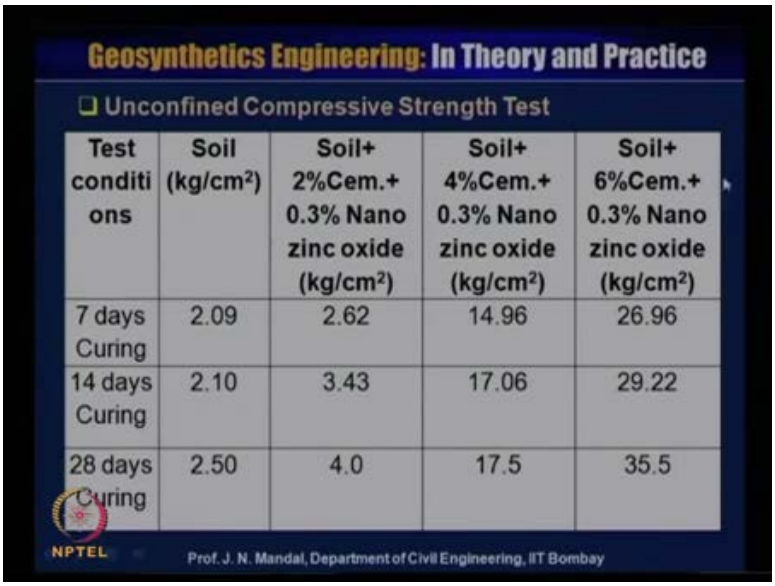

Now, we have conducted also the unconfined compressive strength test and this is the test condition this is for the 7 days 14 days, curing then 28 days curing and soil alone is unconfined compressive, strength value is coming about 2 point 0 9 to 2 point 1 0 and after 28 days 2 point 5 0, whereas when we add the soil plus 2 percent cement point 3

percent NANO zinc oxide. It is 2 point 6 2 k g per centimeter for 7 days curing 3 point 4 3 for 14 days curing and 4 k g per centimeter square for 28 days curing, soil plus 4 percent cement plus point 3 percent NANO zinc oxide, that it is 14 point 9 6 for 7 days, 14 days 17 point 0 6 and 28 days 17 point 5.

Whereas, soil plus 6 percent cement and point 3 percent NANO zinc oxide this is 26 point 9 6 29 point 2 2 and 35 point 5 k g per centimeter square for 28 days curing. So, use of the treated soil increase as the amount of cement also the increases or when we add the point 3 percent of NANO zinc oxide then because for NANO zinc oxide soil to speed up the hydration reaction.

And act as a filter to pores in treated soil, that is why the unconfined compressive strength of this material is improved when cure is for the 14 days, this usage also this increasing you can see from 17, then it is increasing since 29 point 2. And also 21 days, it increasing from 17 point 5 to 35 point five. So, this result would be due to the fact that because of the NANO zinc oxide material require higher water absorption the moisture content of the soil of point 3 percent NANO zinc oxide added is relatively less, where this lead to insufficient water to support, the hydration reaction in the soil for extended curing.

In case of the rural road as per the I r c code specification unconfined compressive strength of the cement stabilized material and 14 days should not be exceed than 17 point 5 kg per centimeter square, where cement required about to 5 to 7 percentage. So, here you can see that when you add only 4 percent cement and point 3 percent which is satisfying this criteria or this specification.

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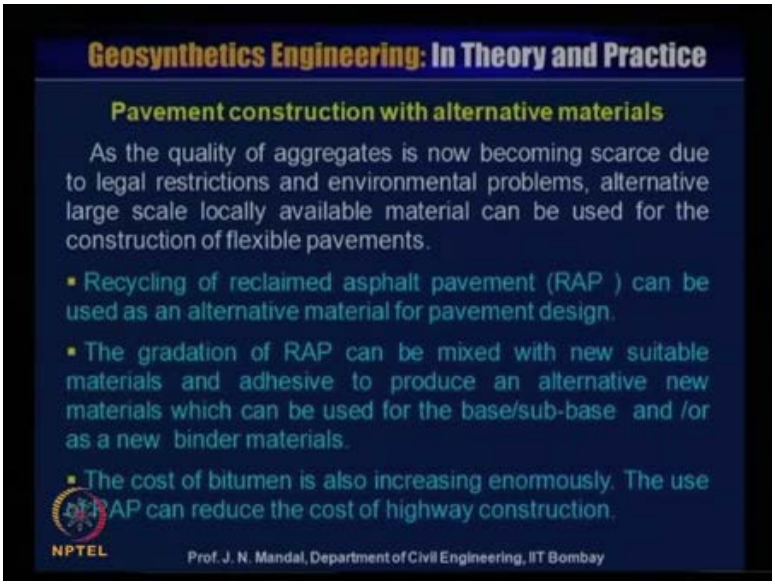

So, pavement construction with alternative material as the quality of the aggregate is, now becoming scarce due to the local restriction and environmental problem. Alternative large scale locally available material can be used for the construction of the flexible pavement, this kind of the system is now going around the world and also in India. We are now trying and also been small way have been introduced the recycling of the reclaimed asphalt pavement can be used as alternative material for the pavement design.

Because, this area lot of research work is still need needed IIT Bombay also carrying out some research work in this related area. The gradation of the rap can be mixed with the new suitable material and adhesive to produce an alternative new material. Which can be used for the base or sub base and or as a new binder material the cost of bitumen is also increasing enormously, the use of the rap can reduce the cost for highway construction.

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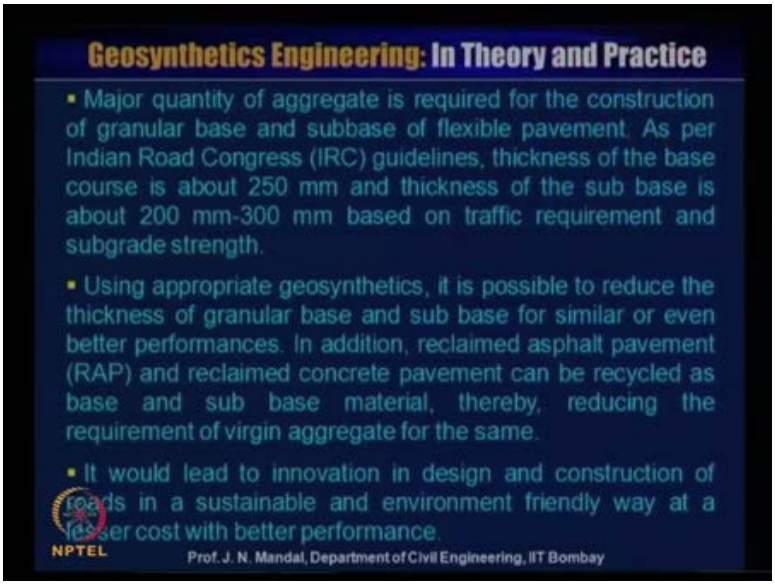

More quantity of aggregate is required for the construction of granular base sub base flexible pavement as per the Indian road congress guideline, the thickness of the base course is about 250 millimeter. And thickness of the sub base is about 200 millimeter to 300 millimeter based on traffic requirement and sub grade strength, using the appropriate geo synthetics, it is possible to reduce the thickness of the granular base and sub base for similar or even better performance.

In addition reclamation asphalt pavement and reclaimed concrete pavement can be recycled as base and sub base material, thereby reducing the require of the virgin aggregate for the same. It would lead to innovation in design and construction for the road in sustainable and environmental friendly way at a lesser cost with the better performance.

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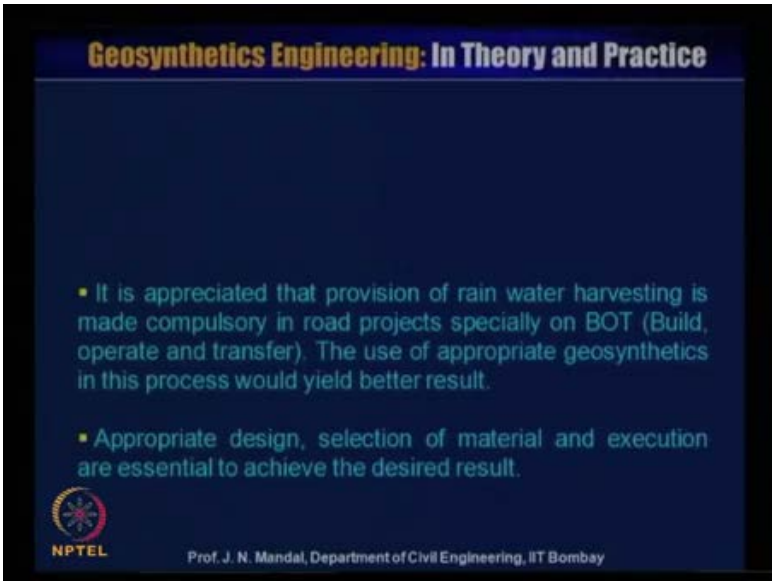

It is appreciated that provision of the rain water harvesting is made compulsory in road projects specially on BOT build operate and transfer, the use of appropriate geo synthetics in this process would yield better result appropriate design selection of the material execution are essential to achieve the desired result. So, you can use rap material whatever the recycle material, whatever the waste material and also we are carrying out with some of the waste material with NANO material.

Where the asphalt is very expensive where the alternative system can be minimized, the thickness of the asphalt and cost can be use and you can make a green road. So, with this I end it up this today is lecture please let us hear from you any question thanks for listening.