Geosynthetics Engineering : In Theory And Practices
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Module - 06
Lecture - 26
Geosynthetics For Reinforced Soil Retaining Walls

Dear student, warm welcome to NPTEL to 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, India. The name of the course Geo synthetics Engineering in Theory and Practice, Lecture Number 26, this Module 6 Lecture 26 Geo synthetics for reinforced soil retaining wall.

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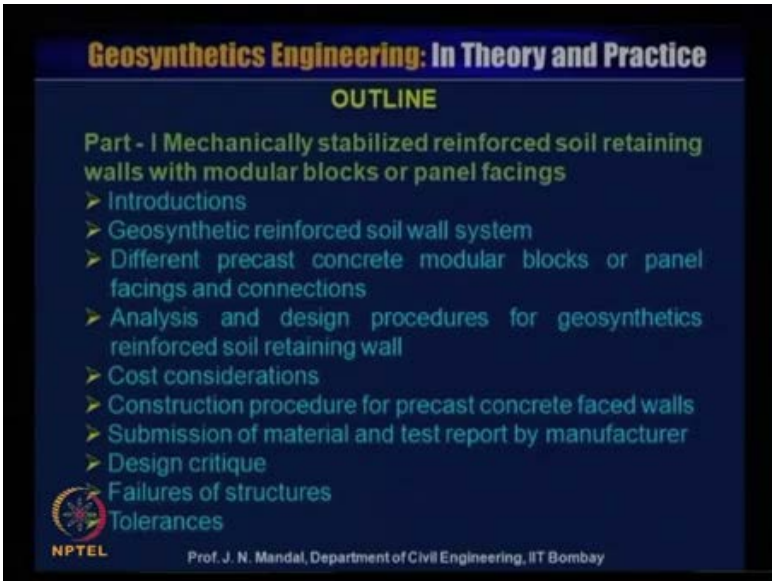

The outline of this course part 1, mechanically stabilized reinforced soil retaining wall with modular blocks or panel facing will cover introduction, geo synthetics reinforced soil wall system; different precast concrete modular block or panel facing and connection, analysis and design procedure for geo synthetics reinforced soil retaining wall, cost consideration, construction procedure for precast concrete faced wall, submission of material and test report by manufacturer, design critique, failure of structure and tolerance.

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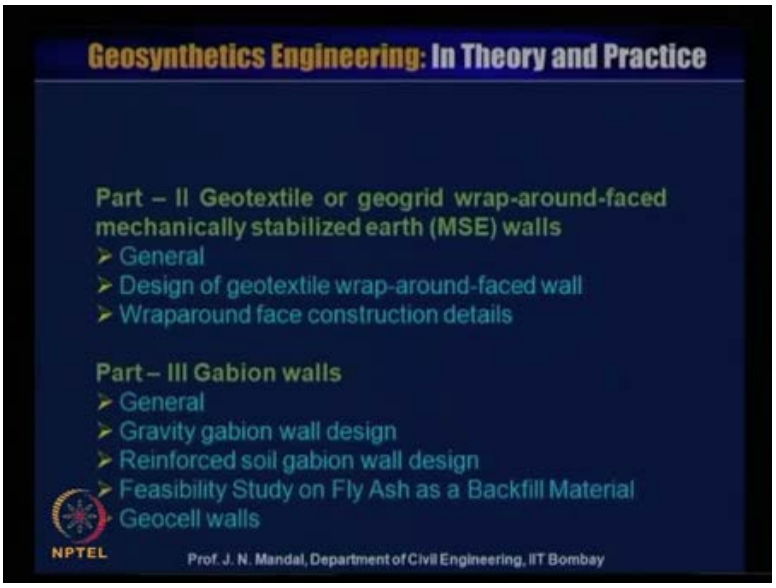

Part 2, we will cover geo textile ort geo grid wrap around faced mechanical stabilized earth or MSE wall, this will cover general design of geo textile wrap around faced wall, wraparound face construction detail. And part 3, gabion wall general then gravity gabion wall design, reinforced soil gabion wall design and feasibility study on fly ash as a backfill material and also the geo cell wall.

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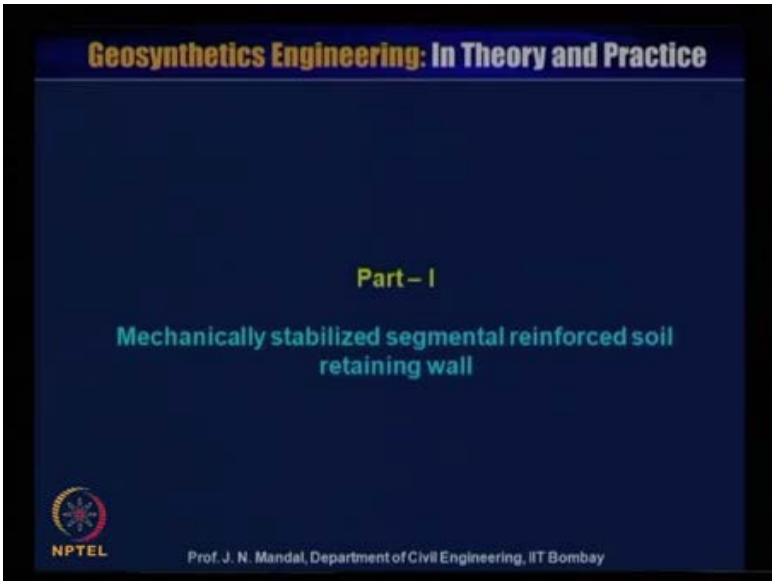

part one mechanically stabilized segment reinforced soil retaining wall.

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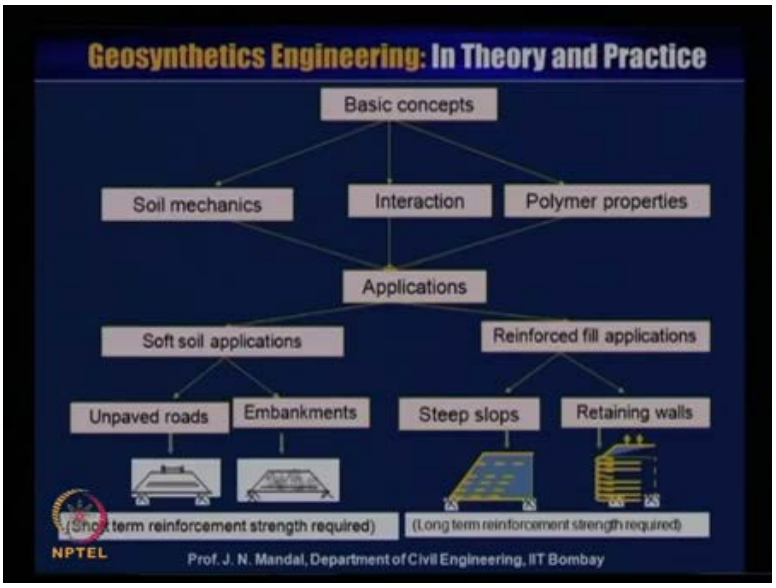

So, you know that basic concept which consists soil mechanics and the polymer material, then application to the reinforced fill application. We have covered for the design and analysis for the unpaved road, which is short term reinforcement strength required whose longevity may be 5 to 15 years. Now, we will discuss the reinforced fill application in case of the retaining wall, reinforced soil retaining wall and this is the long term reinforcement strength required and its service, life time is excess of 75 to 100 years.

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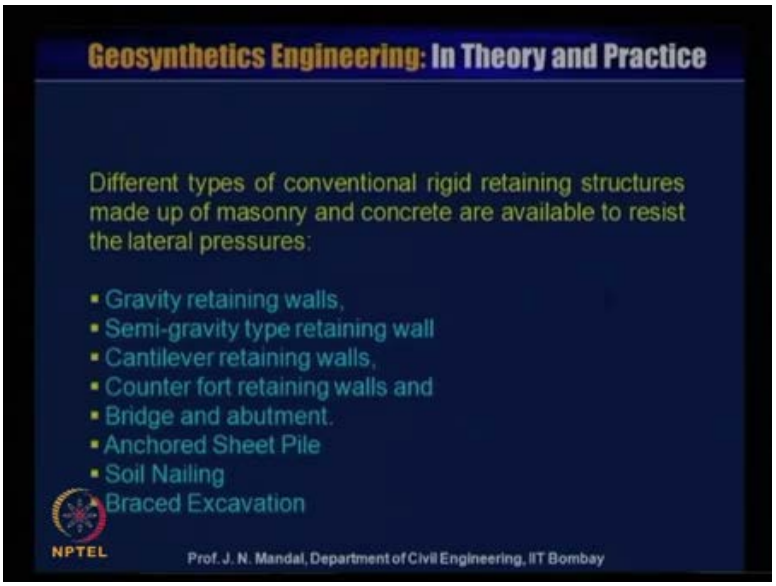

So, different types of conventional rigid retaining structure made up masonry and

concrete are available to resist the lateral pressure, you know gravity retaining wall, semi gravity type retaining wall, cantilever retaining wall, counter fort retaining wall and bridge and abutment, anchored sheet pile soil nailing and braced excavation.

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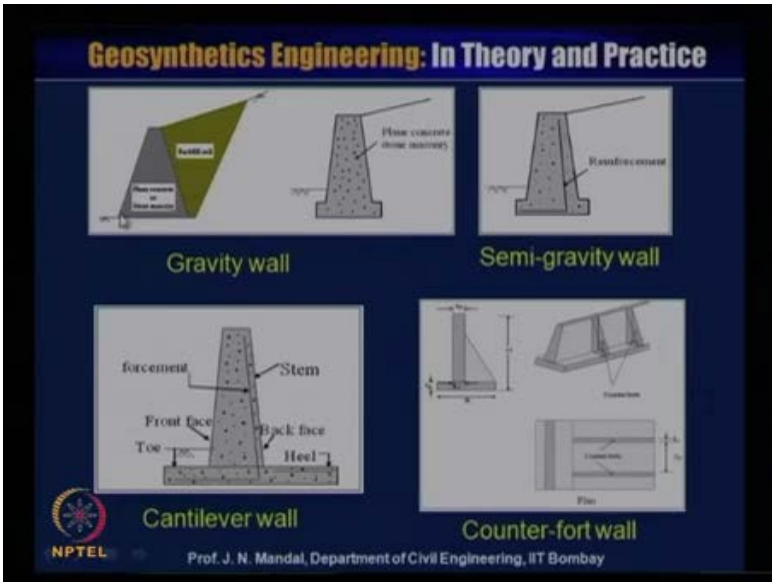

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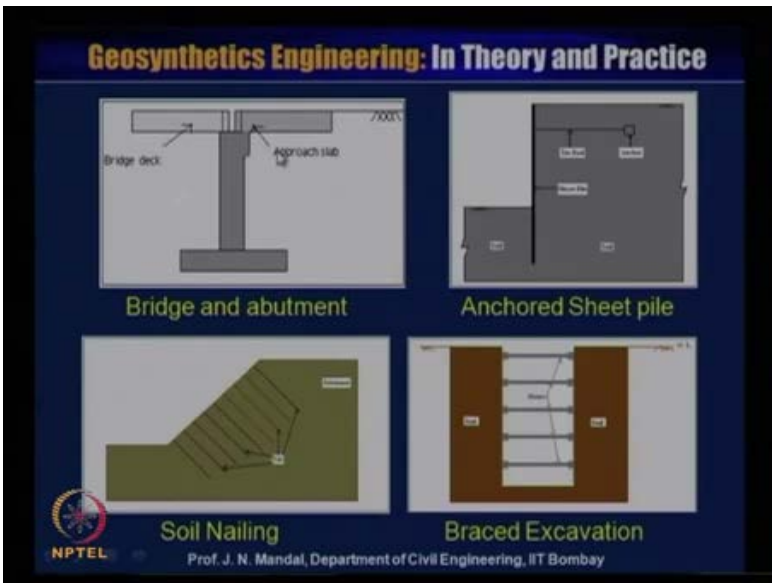

You can see this is the gravity wall and this is a plane concrete and this is a backfill material and this is the plane concrete masonry, these are conventional system. So, the semi gravity wall this the reinforcement material and this is cantilever wall here is the for cement, there is a stem here is a back face here is a heel, this is the front face this is the

toe is there, so this the cantilever wall this is counter fort wall.

So, you know these are the conventional reinforcement soil retaining wall, also bridge and abutment was this bridge disc, these is the approach slab. While we adopt the kind of the concrete structure also the anchored sheet pile for use, we use for the soil nailing in a slope, we can use for the braced excavation for any underground structure, so these are all conventional material or the system.

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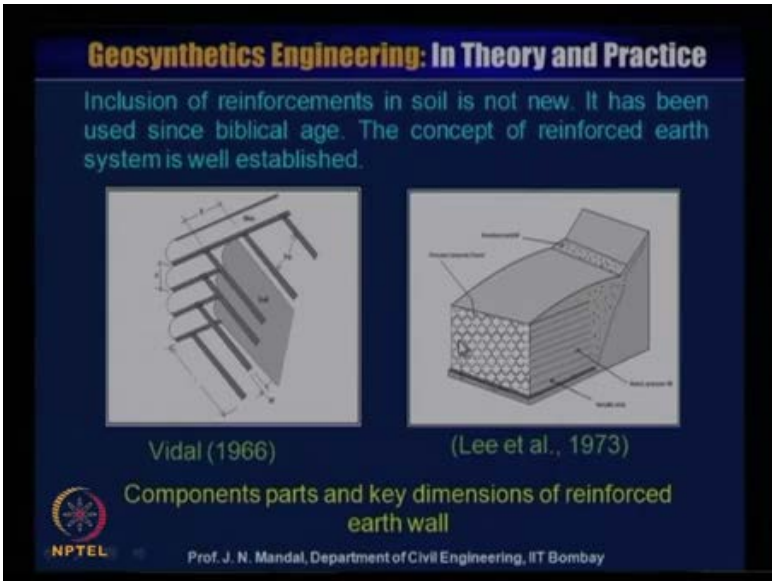

Now, that how the geo synthetics had come into this picture, a tremendous number of the geo grid or the metallic reinforcement wall, have been constructed in the past 40 years. Because, you see that what will be the depends in the cost of the conventional reinforced concrete retaining wall system, with the traditional or the newly reinforced mechanically reinforced soil earth system. If you can compare you can observe, that there is differences in terms of the cost and in terms of the time.

So, you can convince to the agent that this is more economical and you can complete, the structure with a very short time and the differences in the cost can be equally shared by the contractor and the client. So, this is one of the very effective vehicle for the introduction of any kind of the new product or the concept like the geo grid or the geo textile reinforced soil system.

Now, here the inclusion of the reinforcement in soil is not new, it has been used since

biblical age the concept of the reinforced earth system is well established. And this is the some of the component parts of the key dimension of the reinforced earth wall, which is the Vidal vision, Vidal 1966 who had used the metal as a reinforcing material. And here you can see this is the metal very steep, it act as a reinforcement.

And this is as a facing element and it can be placed like this vertically and also the horizontally that means, you have to calculate what will be the vertical spacing between the two reinforcement. And the horizontal spacing between the two reinforcement and this is the strip that width is w and thickness is very less. So, this is the facing element right hand side lee et al 1973 and this is the peak as concrete panel and this is the reinforcement metallic reinforcement. So, this kind of the structure has been completed and it has been used exclusively around the wall.

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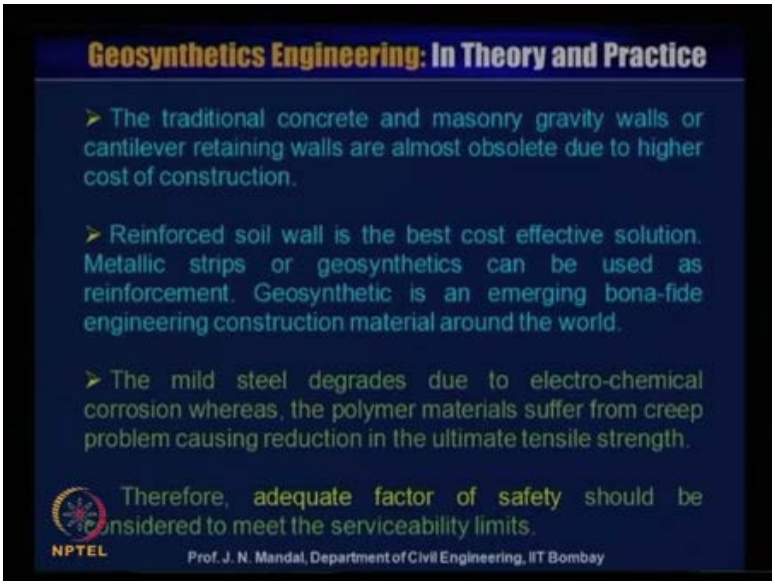

So, traditional concrete and masonry gravity wall or the cantilever retaining wall are almost obsolete, due to the higher cost of construction reinforced soil wall is the best cost effective solution metallic strip or geo synthetics can be used as a reinforcement, geo synthetics is an emerging bona fide emerging construction material, around the world. The mild steel degrade due to the electrochemical corrosion whereas, polymer material suffer from creep problem causing, the reduction in the ultimate tensile strength therefore, adequate factor of safety should be considered to meet the serviceability limit.

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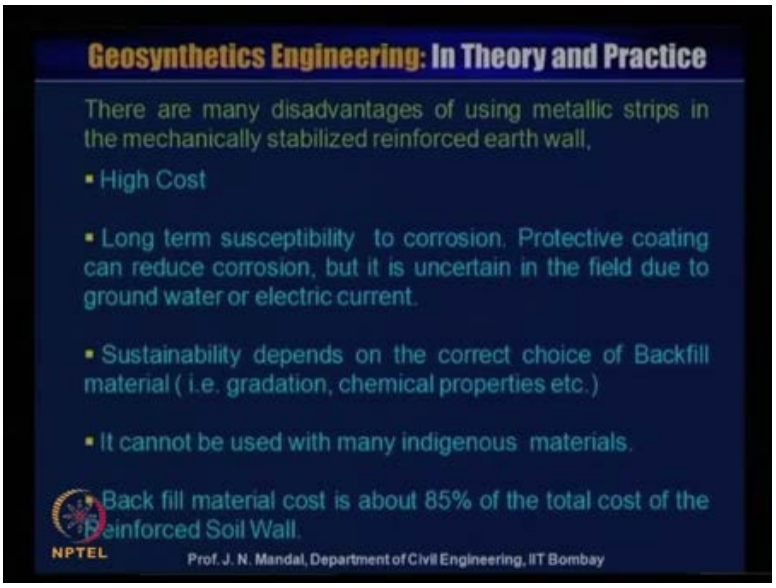

There are many disadvantage of using the metallic strips in mechanically stabilized reinforced earth wall it is high cost, long term susceptibility to corrosion protective coating can reduce the corrosion, but it is uncertain in the field due to the ground water or electric current. Sustainability depend on the correct choice of the backfill material gradation chemical properties.

This is very important that what kind of the material, you choose and which should sustain, which should meet the certain criteria as per the specification, it cannot be use with many indigenous material. And backfill material cost is about 85 percent of the total cost of the reinforced soil wall in generally in India, it may be about 25 to 30 percent of the total cost of the reinforced soil wall.

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Geo synthetics reinforced soil wall system, it has a advantage because polymer do not corrode, it is economical used with many indigenous materials, more deformable than the metal reinforcement long term durability. The geo synthetics is flexible we can move any direction as you like it. And unskilled labor can place, it you do not need any skilled labor for this and you require minimum excavation, it gives good drainage and heavy equipment is not needed.

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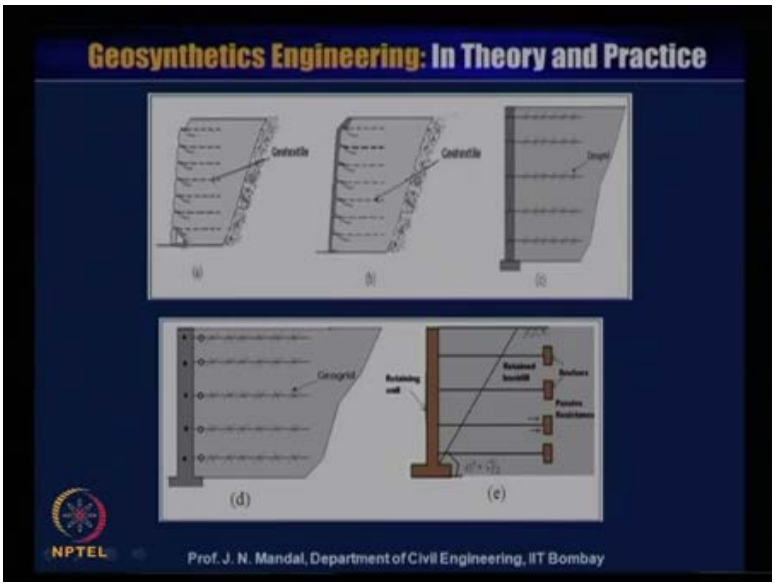

You can see here the different types of the geo synthetics reinforced soil structure here,

the geo synthetics is wrapped like this wraparound face. So, you place the geo synthetics and wrap it and you filled up with the soil and compact it and wrap, it you can construct the geo textile wall, reinforced soil wall ((Refer Time: 12:03)). Because, you cannot keep this geo synthetics in the open sunlight, due to the ((Refer Time: 12:09)) or vandalism, you can spray some shotcrete or asphalt here to prevent, it from the u v light here this is the concrete as a panel.

And this is the geo grid as an reinforcement material has been used, here it is as block you can see its block, which is geo grid is connected with the block and you can construct a reinforced soil wall, here also is the retaining wall and this is the reinforcement and this here is the anchoring. So, there is a passive resistance will act, so you can reduce the thickness of the reinforcement by introducing this anchor, so which can provide with a good passive resistance.

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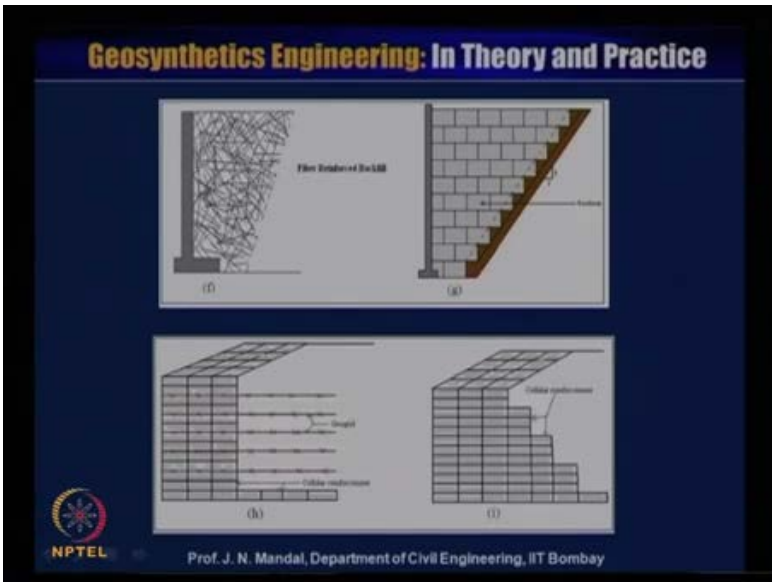

Also geo synthetics material can be made of fiber reinforced backfill or the filled with the fiber reinforced backfill, you can use also fiber reinforced backfill, you can use also this super light material, that is geo foam and you can provide with the drainage also back, you can provide with the cellular reinforcement and the geo grid material. The cellular reinforcement will act as a facing element or you can complete this reinforced soil wall, only using the cellular reinforcement you do not require any geo grid material.

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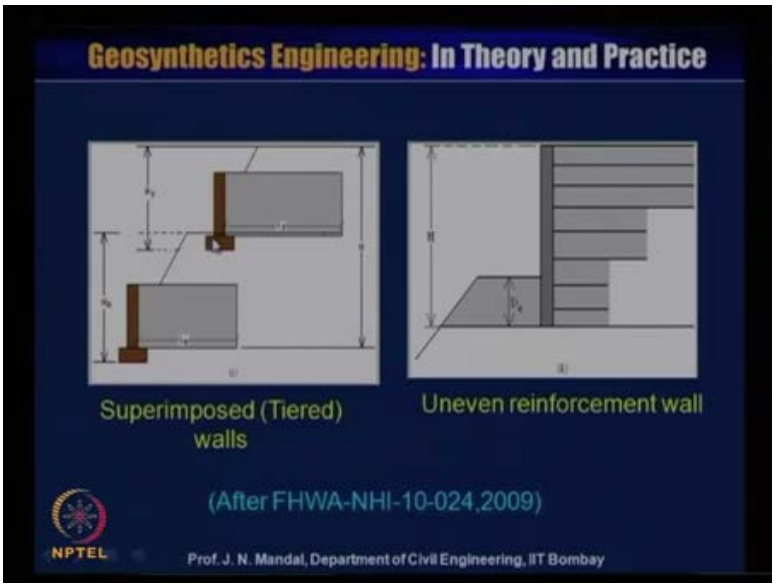

Also superimposed or tiered wall, you can construct one wall and then make a slope and make the another wall, it is superimposed or it is called the tiered slope and this also uneven unreinforced soil wall. You can see that the length of the reinforcement is less, then gradually increasing like this little bit trapezoidal inset and this is the depth of the embankment and this is after f h w a n h I 1 0 0 2 4 2009, so different types of the systems of reinforced soil wall can be constructed.

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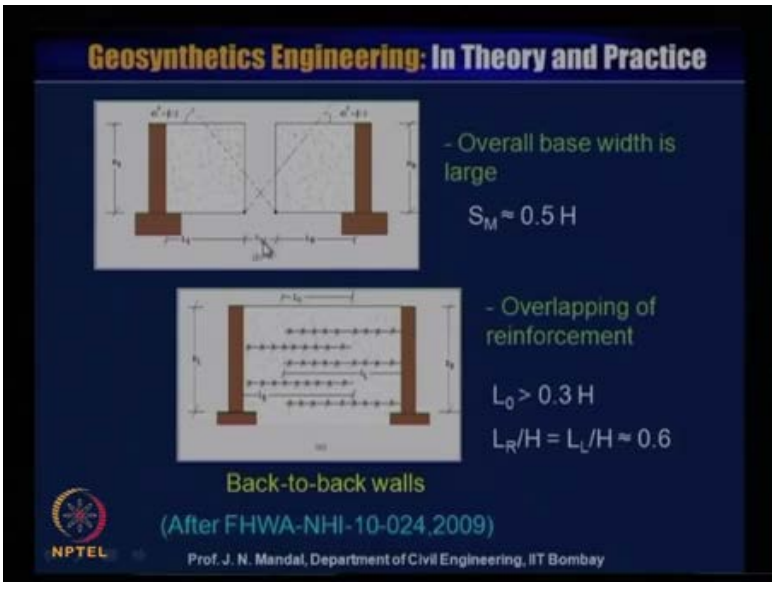

You can see here also the overall base with the large, this is the base of n and this is the l

l on the left hand side of the reinforcement, this is the right hand side of the reinforcement and this angle is 45 degree plus phi by 2 and this is the height of the wall h l on the left side, this h r on the right side and it should not sometimes the overlap. So, overlap base width is large, so you could provide the this s m value and s m value should be point 5 times the height of the wall that means, this s m should be point 5 time the height of the wall, this overlap base width will be required.

Sometimes you can say overlapping of the reinforcement, when there is no space and you require to overlap the geo synthetics material, this is called back to back wall. And whereas, this is the left hand side of the wall h l, this is right hand side h r and this overlap is equal to l 0, this l 0 should be greater than point 3 times the height of the wall and l of r this length, this is on the length l of r, l of r divided by h will be equal to this is l by l h is equal to 0 point 6.

So, overlap length l 0 should be greater than point 3 h and l r by h is equal to l l by h will be equal to point 3. So, this is after f h w a n h 1 point 0 0 2 4 2009. So, you can use that geo synthetics material either as a overlap base width, either a large what you should require, what is the s m value and when, it is the overlapped with the reinforcement and what should be the overlap length should provide.

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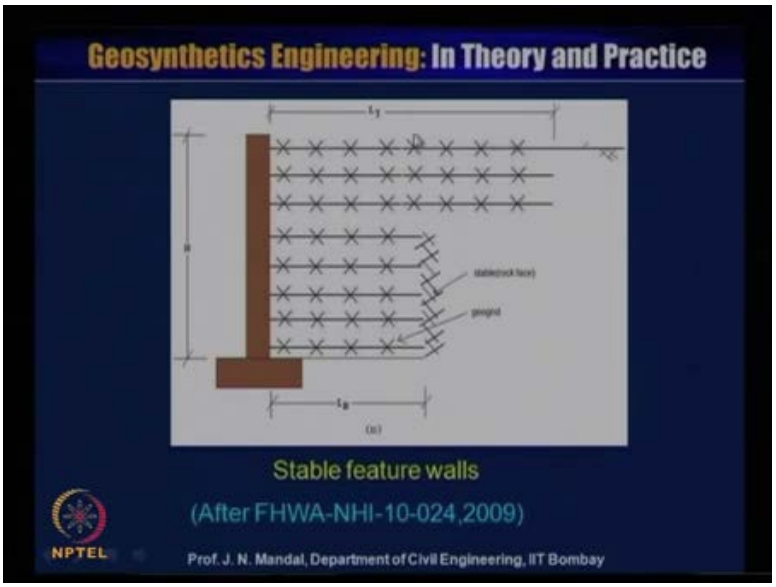

Now, this is stable feature of the wall, you can see here this is the height of the wall and this is the length of the reinforcement and this is a rock here this stable rock face. So, you

cannot go behind this, so this is the length of the reinforcement at the bottom and this is the length of the reinforcement l t at the top, so you can increase the length of the reinforcement at the top and you can reduce, the length of the reinforcement at the bottom. So, this is stable feature wall also can be constructed, this is as per f h w a 2009.

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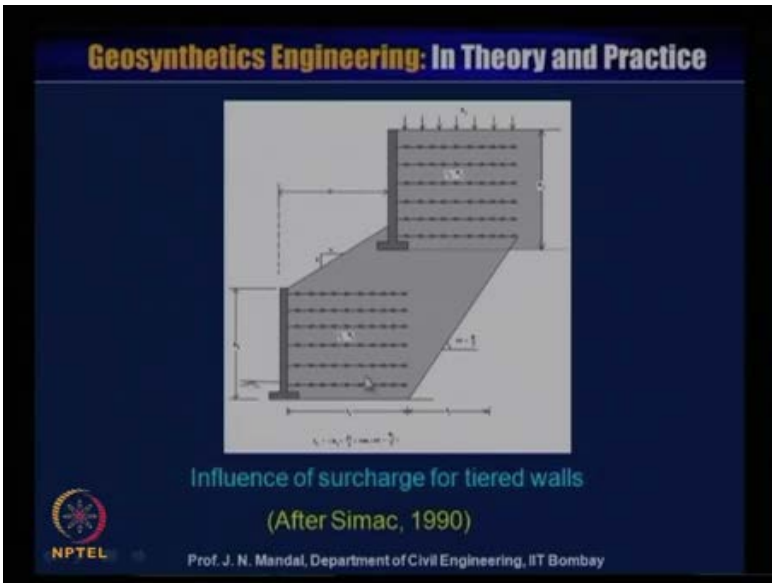

Also influence of surcharge for tiered wall, you can construct the tiered wall number of tiered you can construct after Simac 9 1 9 0 0, this is the wall this is the number of the reinforcement. And this is 45 degree plus phi by 2 then you make a slope here and then you construct a another wall where there is a surcharge load also. So, there should be a certain distance this distance, so where you will be able to require proper design for the surcharge for tiered wall.

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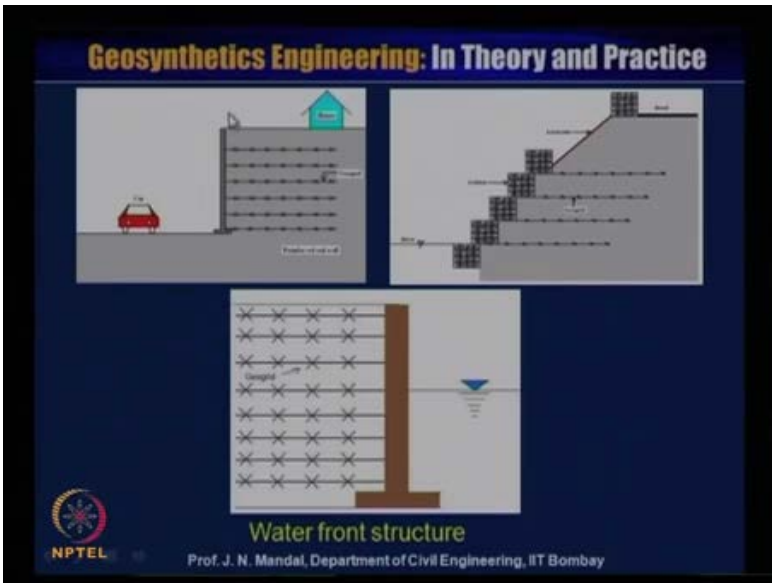

This is the some of the useful use of the reinforced soil retaining wall and when you want to construct a vertical wall, you can provide with the reinforced soil wall and you can construct the building here. So, there will be no problem and the bottom one that there will be a road, the car can pass through this area also when there is a slope you can use this gabion and also the parallel layer of the geo grid reinforced soil retaining wall.

We will design this also later, how you have been design this gabion reinforced soil retaining wall, only with the gabion and as well as gabion plus this geo grid reinforced soil that is your geo grid reinforcement material. In case of the water front structure you can see, this is the water table and then you can construct the reinforced soil wall and this is the layer of the number of the layer of the reinforcement layer.

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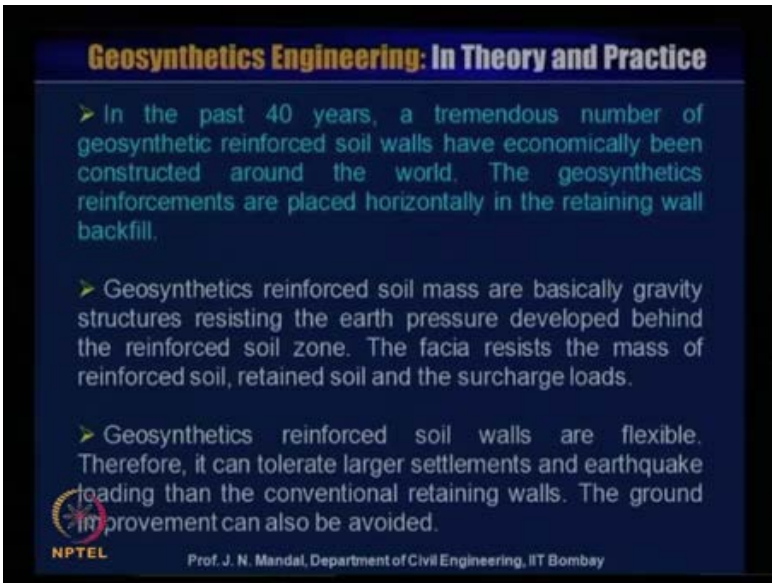

So, in the past 40 years a tremendous number of the geo synthetics, reinforced soil wall have economically been constructed around the wall, the geo synthetics reinforcement are placed horizontally in the retaining wall backfill. Geo synthetics reinforced soil mass are basically gravity structure resisting the earth pressure develop behind the reinforced soil zone. the facia resists the mass of the reinforced soil retained soil and surcharge load.

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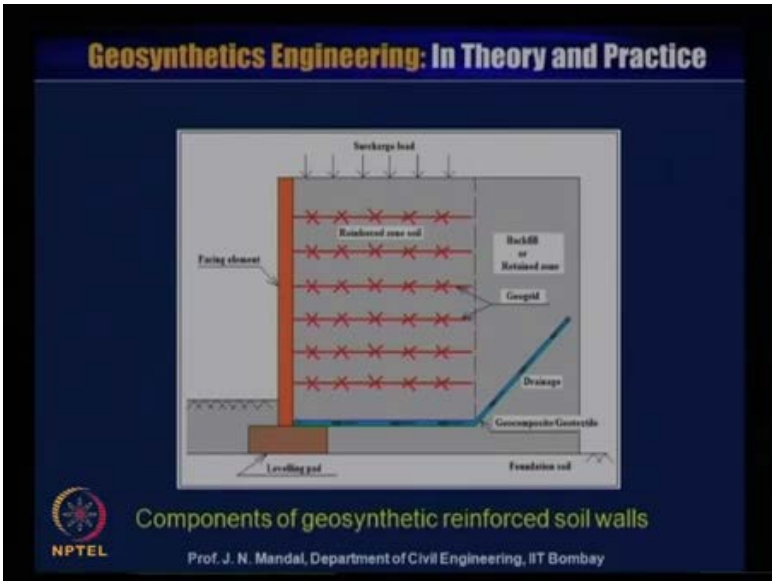

The geo synthetics reinforced soil wall are flexible therefore, it can tolerate the large settlement and earthquake loading then the conventional retaining wall, the ground

improvement can also be avoided.

You can see that different component of the geo reinforced soil wall, here we will show that you can see this is the foundation soil, if the foundation soil is very poor and how we can improve the soil that also, we will discuss. And this is the reinforced zone soil this is the reinforced zone soil and this is the facing element and this is the backfill or the retained zone and this is the reinforcement geo grid as a reinforcement and this is the drainage, you can provide at the back of the reinforced soil wall.

Because, if there is a development of hydrostatic pressure then this should be provide the proper kind of the drainage is preferably with the inclined, the water can pass through drain and it can pass through this and this to toe, this the level impact. And you can provide also sometimes there geo composite or the geo textile material, here we wanted to focus that want are the various component in geo synthetics reinforced soil wall, when we are talking about the geo synthetics reinforced soil retaining wall.

And then we should know what are the main component here there is a surcharge load or if there is any live load, that also you have to take into consideration into the design.

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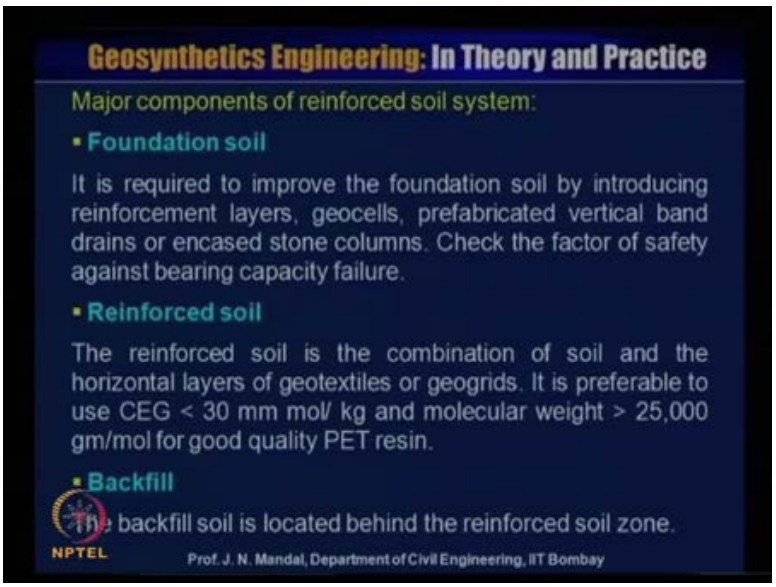

But, you should aware about most of the component and saying you all the major component of reinforced soil wall, first is the foundation soil it is required to improve the foundation soil by introducing the reinforcement layer or you can use geo cell or you can

use prefabricated vertical drain or encased stone column and check the factor of safety against the bearing capacity failure. You can provide two three layer of the geo grid reinforced soil wall or you can provide with the geo cell, geo grid geo cell to improve the ground.

So, different kind of the improvement for the modification of the soil can be adopted depending upon, the site of the project and you should know what will be the characteristics of the soil and based on that, we have to be select we should be the more economical. And what kind of the system can be adopted for the improvement of the bearing capacity and you check up what will be the factor of safety against this bearing capacity.

So, now the reinforced soil, the reinforced soil is the combination of soil and the horizontal layer of geo textile or the geo grid, it is preferable to use c e g less than 30 millimeter mol of the k g and molecular weight should be greater than 25,000 gram per mol for good quality of p e t resin. When we talk about the reinforced soil this is the reinforced soil zone, where you are using the soil and the geo grid material.

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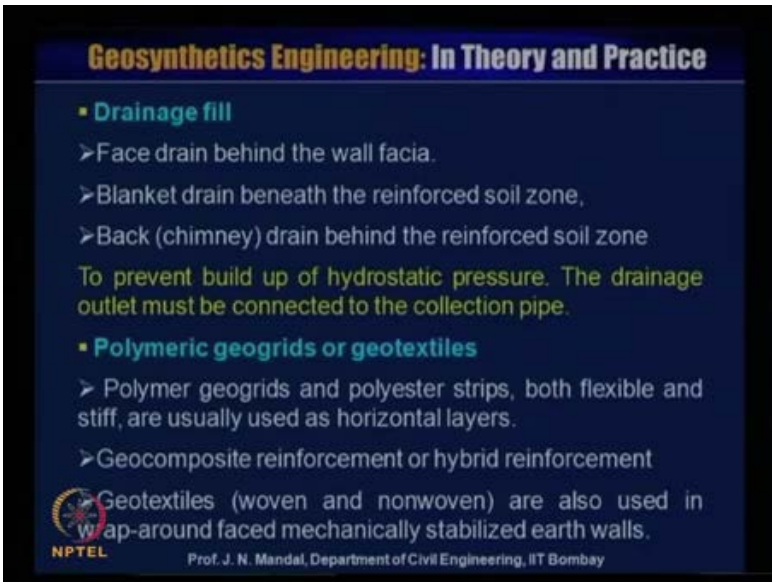

So, you should know that what exactly that kind of the geo grid it is, so that soil this criteria you should satisfy that this what would be the value of c e g, it should be less than 30 meter mol per k g and also at the same time, what will be their molecular weight that greater than 25,000 gram per mol. So, this you can satisfy the criteria that for the

reinforcement that you can accept, this as a geo grid material for the reinforcement. And the backfill soil is located behind the reinforced soil zone this is the backfill soil, this is the reinforced soil zone.

Now, drainage fill this is also very important, I showed you the face drain behind the wall facia, blanket drain beneath the reinforced soil zone and back the chimney drain behind the reinforced soil zone to prevent the buildup of hydrostatic pressure drainage outlet must be connected to the collection pipe. Now, polymeric geo grid or geo textile polymer geo grid and polyester strip both flexible and stiff are usually used as a horizontal layer, also geo composite reinforcement or hybrid reinforcement, there are also lot of hybrid reinforcement or geo composite.

It is a geo grid laminated with the woven and nonwoven geo textile material, which can be also used for the construction of the reinforced soil retaining wall. Because, the geo grid will take care for as a reinforcement function whereas, the geo textile either woven or nonwoven geo textile, geo material will act as a good drainage material. So, geo textile geo synthetics mechanically stabilized reinforced soil wall, can be constructed using the hybrid reinforcement or the geo composite reinforcement.

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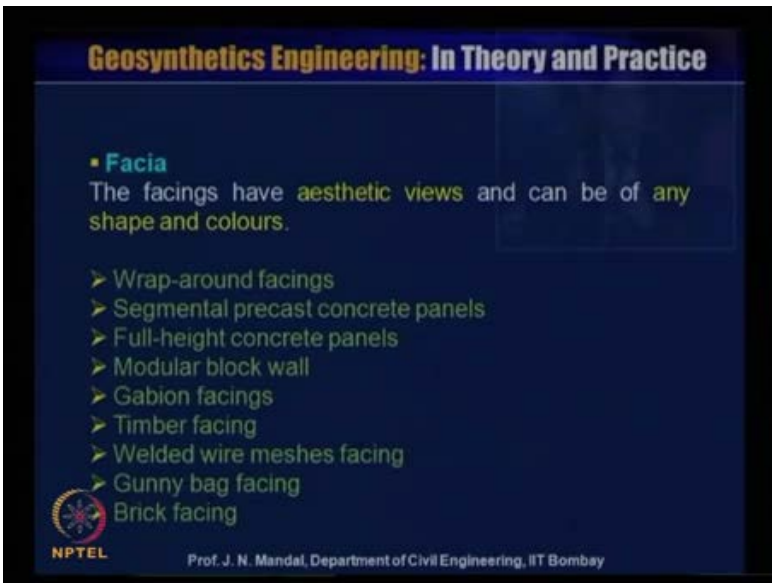

Now, geo textile it may be woven and nonwoven are also used wrap around faced mechanically stabilized earth wall. So, you do not need that any facing element, like the geo grid what you wanted to use this kind of the panel or kind of the block instead, of

that in case of the geo textile, where whether it is a woven and nonwoven geo textile you can simply the wrap the face element, so you can construct this wall.

Now, facia the facing have aesthetic views and can be of any shape and color, so many aesthetically pleasing facing design are also possible. So, there are different types of the facing elements, which I just shown that wrap around facing segmental precast concrete panel, full height concrete panel modular block wall, gabion facing, timber facing, welded wire mesh facing and gunny bag facing and brick facing. So, you can see that why how the different types of the facing element can be constructed. So, this is the wrap around facing.

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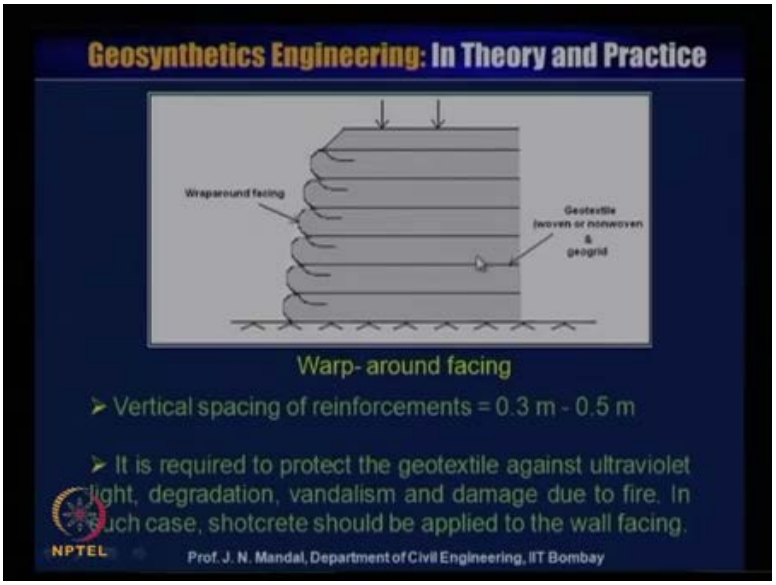

So, vertical facing of the reinforcement generally point 3 to point 5 meter and it is required to protect, the geo textile against the ultraviolet light or degradation vandalism and damage due to the fire. In such case that shotcrete should be applied to the wall facing, here the shotcrete should be applied to the wall facing, this may be the geo textile woven and nonwoven geo textile material, this is wrap around facing.

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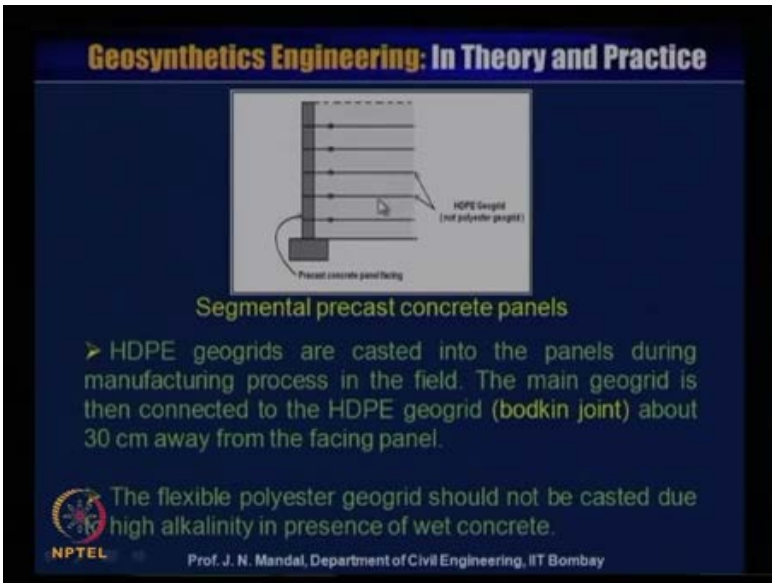

You can see this is a segmental precast concrete block and this is the number of layer of the geo grid material, it may be the high density polyethylene geo grid or non polyester geo grid also. So, here is the segmental precast concrete block this is the block, so high density polyethylene geo grid are casted into the panel during the manufacturing process in the field.

The main geo grid is then connected to the high density polyethylene geo grid, which we can say that bodkin joint, we call bodkin joint which is about 30 centimeter away from the facing element. The flexible polyester geo grid should not be casted due to the high alkalinity in the presence of wet concrete, so one has to be very careful that what kind of the material should be casted with the concrete, we can use the high density polyethylene geo grid material, but not the polyester geo grid material, because for its high alkalinity presence in the wet concrete.

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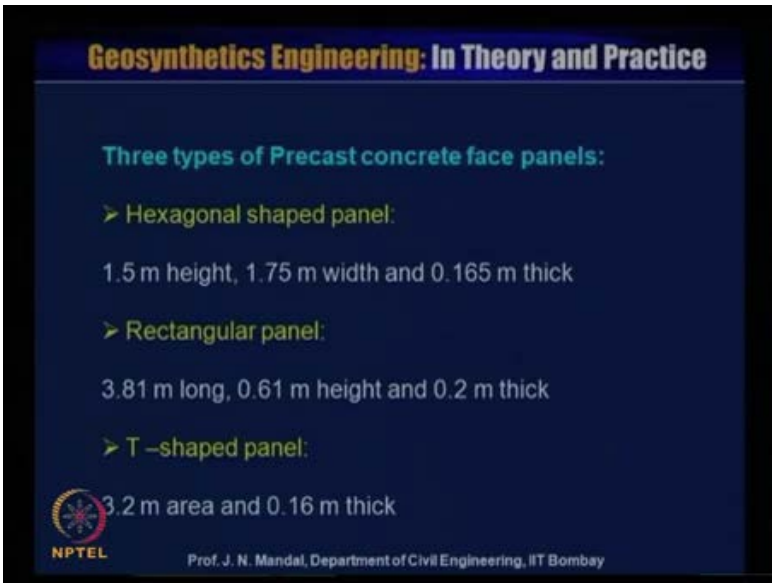

So, three types of the precast concrete face panels this is hexagonal shaped panel, it may be 1.5 meter height, 1.75 meter width and 0.165 meter thick or rectangular panel. It may be 3.81 meter long 0.61 meter height and 0 point 2 meter thick or t shaped panel, it may be 3.2 meter area and 0.16 meter thick.

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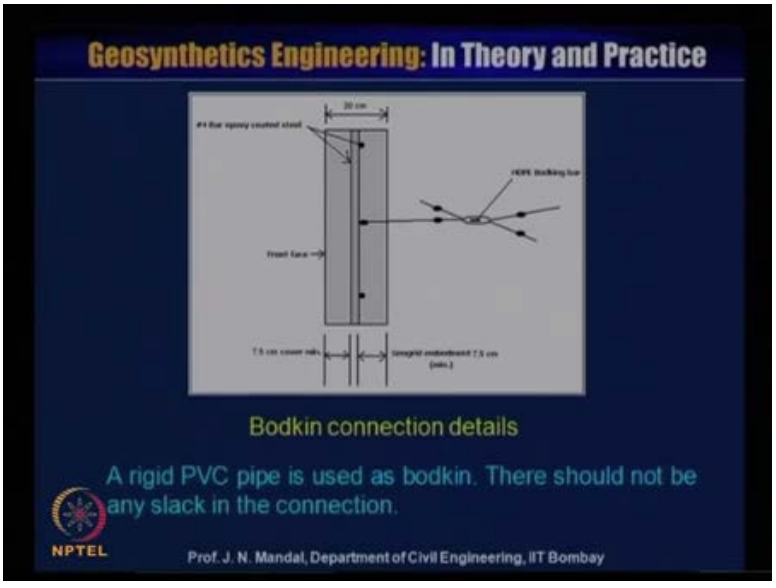

So, you can have the different types of the facing element, now when this geo grid uniaxial, this geo grid you wanted to join. So, this joint also be it called the bodkin connection joint, here is the bodkin connection joint here you can see that that this is the

4 bar concrete f c coated steel and this is 20 centimeter and this is the front face and this is 7.5 centimeter cobalt minimum require.

And this is the geo grid embedment 7.5 centimeter, this is minimum required and this is the geo grid material, high density polyethylene geo grid material, which is higher from the facing element about 30 centimeter and then you can joint here, with the remaining geo grid material and this here it is a bodkin. And this bodkin joint a rigid p v c pipe is used as a bodkin, this is a rigid p v c pipe which is used as a joint and there should not be any slack in the connection, so this way you can join this material.

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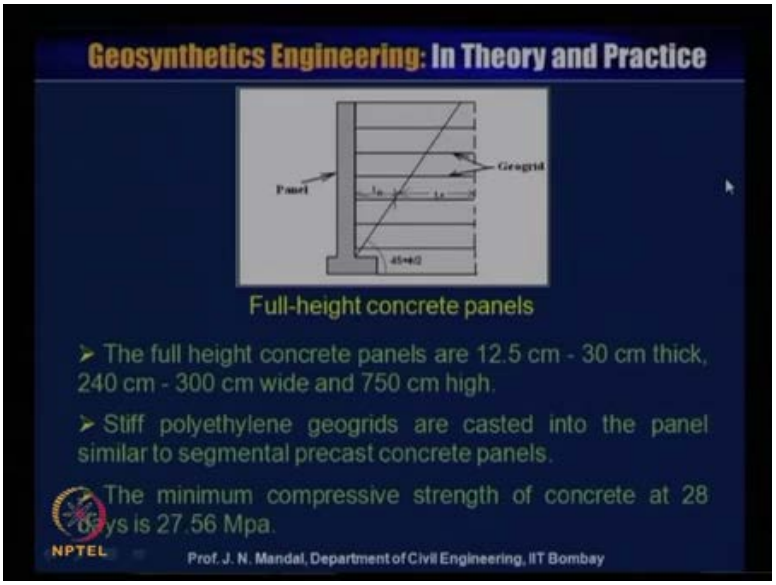

This is full height concrete panel, this is absolutely this full height concrete panel, this is the number of the layer of geo grid reinforcement. Now, full length concrete panel are 12.5 centimeter to 30 centimeter thick and 240 centimeter to 300 centimeter wide and 750 centimeter in height. Stiff polyethylene geo grid are casted into the panel similar to the segmental precast concrete panel and the minimum compressive strength of the concrete at 28 days is 27.56 Mp a, so you should maintain this strength.

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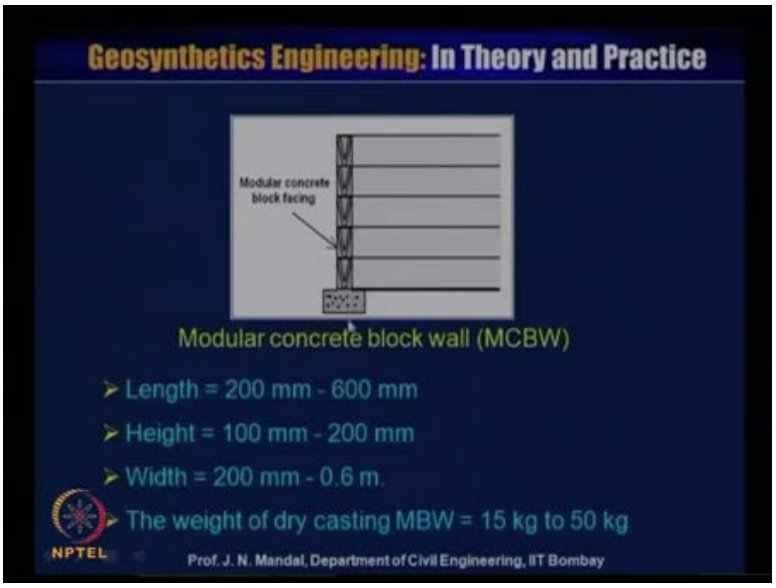

Now, this modular concrete block wall, so this is the modular concrete wall facing and this is the number of the layer of the reinforcement material. And this block has a length about 200 millimeter to 600 millimeter and height is about 100 millimeter to 200 millimeter width is 200 millimeter to 0.6 millimeter and the weight of the dry casting modular block wall is 15 k g to 50 k g.

So, this is a kind of the modular concrete block, so you can place the modular concrete block and then you can place the geo grid material and this will be connected with this block and then you place the another block. And then there are different types of the joining system, I will show you later and then like that you can construct the modular concrete block wall and because this block is weight about 15 k g to 50 k g. So, it is very easy to handle and you can construct, the mechanically stabilized reinforced block wall using this modular concrete blocks.

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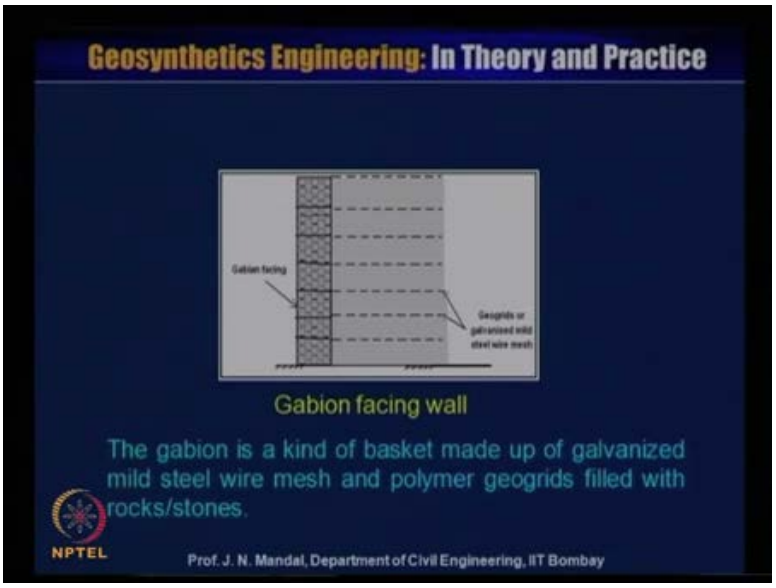

Now, the gabion facing wall, so gabion also can be use as a facing element, so this is a this is a gabion you know the 1 meter cube galvanized mild steel, this will act as a gabion and this gabion you can place 1 by 1 and then you can place these reinforcement which can be connected with the gabion. So, gabion is a kind you know a basket made of the galvanized mild steel, wire mesh and polymer geo grid filled with the rock or the stone, so this also will act as a facing element, so gabion also act as a facing element.

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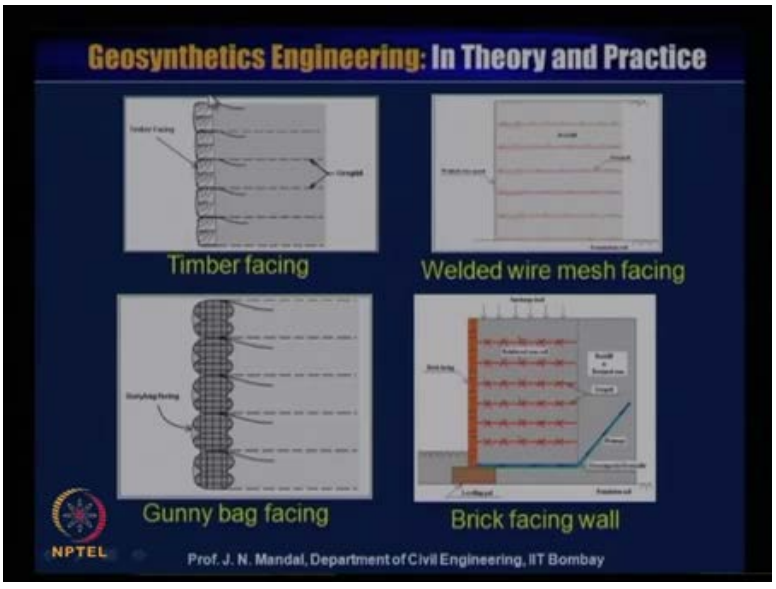

There are many like that timber facing also timber facing also has been use in ((Refer

Time: 33:12)) where there is a locally timber is available, so they provide with the timber and then wrap with the geo textile material like this. So, you can construct the wall as a timber as a facing you can also welded wire mesh facing, sometimes you can place with the geo textile geo grid material like that and you cannot keep it open.

And then you can provide with the welded wire mesh, here you can provide with the welded wire mesh and then later on can grass can grow. So, it looks also greenery the welded wire mesh also has been used in various project also gunny bag facing, this is a kind of the gunny bag. So, and this is the geo textile material and this we will wrap it like this, so this is a gunny bag is act as a facing element. The brick also as a facing wall this is a brick, you can place the brick and then the number of the layer of the geo grid material, so where brick also will act as a facing element.

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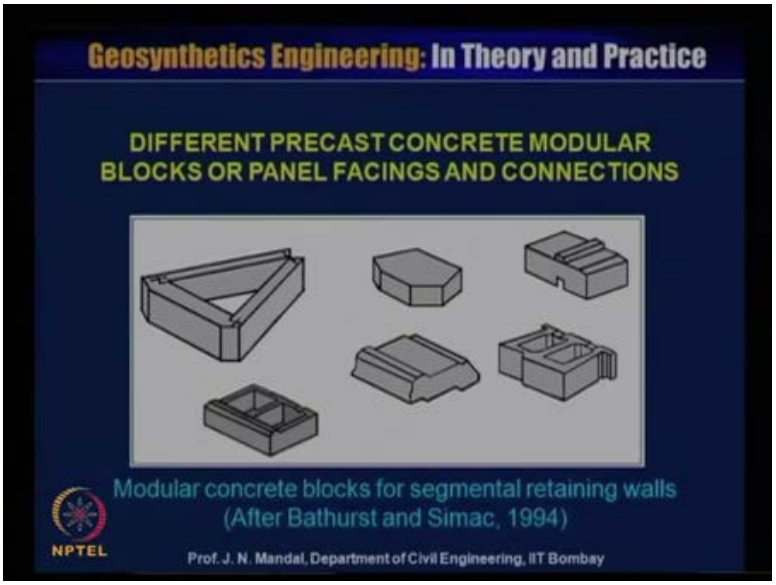

Now, there are different precast concrete modular block or panel facing and connection, you can see this is a some of the modular concrete block for segmental retaining wall after Bathurst and Simac 1994, you can say this is a kind of the block. And you can see that, there is a hole here this is a act as a facing element and this hole is filled up with the aggregate which will act as a drainage.

So, you need the proper kind of the drainage and the facing element apart from the back and the bottom and the top you also require the proper kind of drainage at the facing. So, where this will act as a facing element, you can see that some block here you can place

the geo grid material here and then you can the place another block So, there are different types of the blocks, the way you like you can see here also where you can act as a drainage if it filled up with aggregate.

So, there is a collection how we have to collect one modular block with the another modular block and this kind of the block generally weight about 15 to 50 k g and it is very easy to handle.

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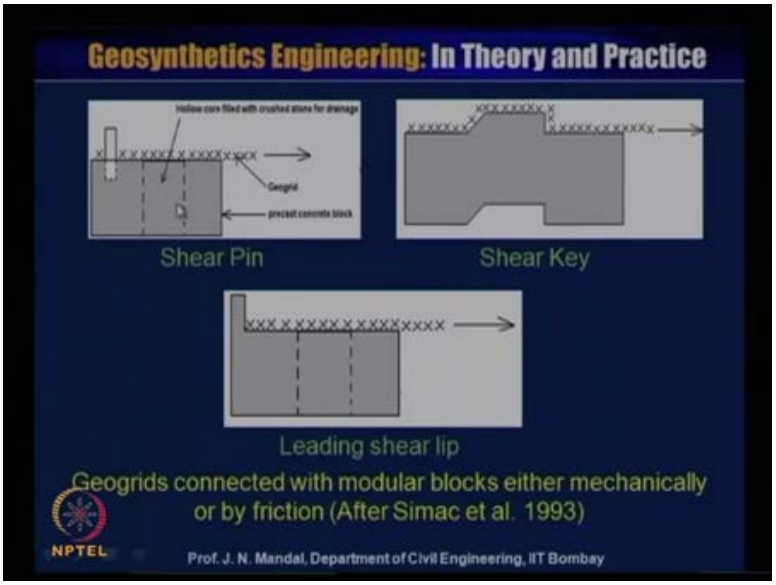

Now, this slide shows some geo grid connected with the modular block, either mechanically or by the friction are after Simac et al 1993, you can see here is the shear here is the shear pin, this is the hollow core and filled with the crushed stone or the drainage, this is the geo grid material. And this is the precast concrete block for its here act as a shear pin, here the shear key you can see like this geo grid material is placed like this and like this.

So, here it can act as a shear key here it can act as a shear pin here act as a shear key and sometimes also you can go leading shear lip like this shear lip like this, so these geo grid connected with the modular block either the mechanically or the friction.

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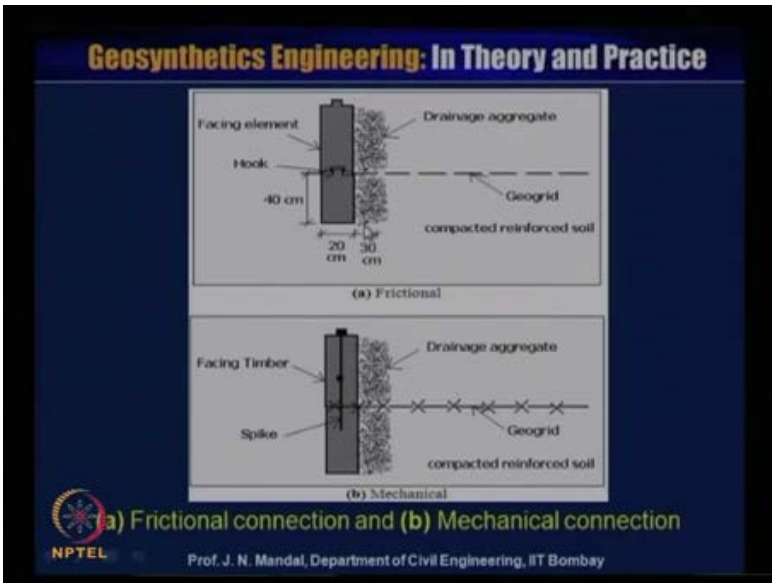

So, here site you can see, that how it is the friction is connected here this is the one modular block, you can see the size about 20 centimeter to 40 centimeter and this is the geo grid material and there is a hook, you can see there is a hook And this geo grid material, pass through this and then you can place, the another block here and with it will act as a facing element.

So, this is the frictional connection and you can provide with the drainage about 30 centimeter here or aggregate or you can provide with the geo textile or the any geo composite drainage material also. And this is the as shown the mechanical connection, this is mechanical connection, this is the facing that is the timber, this is the spike and then this is the geo grid material, this is compact with the reinforced soil and this is drainage aggregate as it is in the frictional case where it can be mechanically connected.

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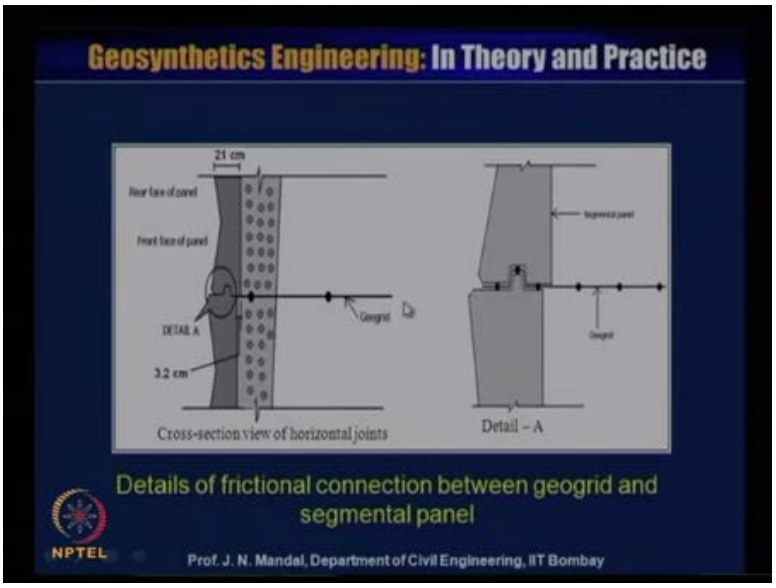

So, more about this you can see here, that cross sectional view of the horizontal joint this is about detail about, And you can see here 3 point 2 centimeter and this is the front face of the panel this is the rear face of the panel and this is 21 centimeter, it is like this you can see detail of the here and this is the geo grid material and this is the segmental panel. So, this is the detail of frictional connection between the geo grid and the segmental panel.

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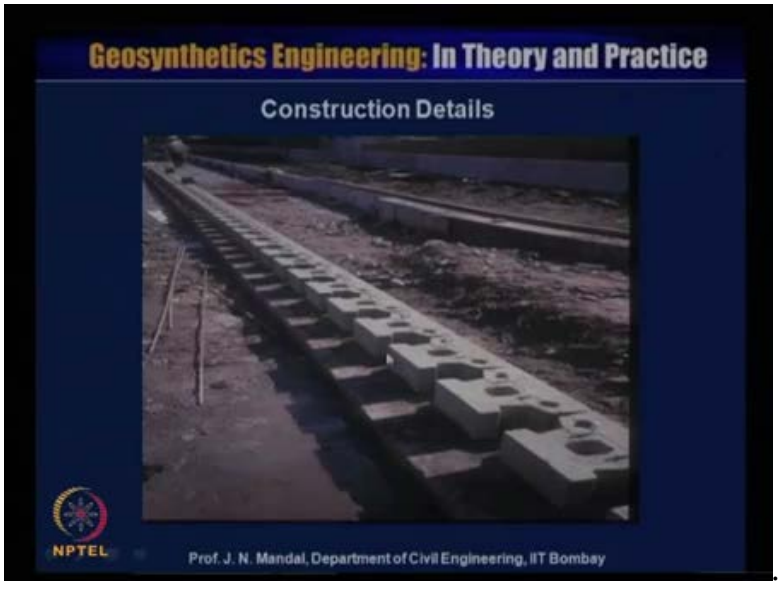

I am showing that some of the construction details, you can see the different types of the

block how it has been placed here.

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And you can see the wall how it is constructing and this is h filled up, with the aggregate it will act as a drainage, this is the block, so it is in the small mall block and the weight is not, so much. So, one can carry and can fix it up and then you filed up with the aggregate for the drainage.

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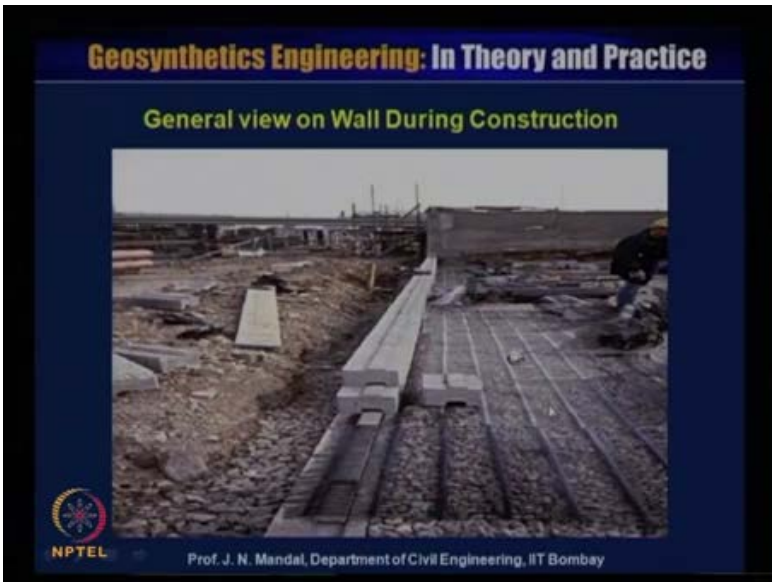

You can see how this geo grid material has been replaced and how, it is connected how the block is placed, this is a general view of wall during the construction.

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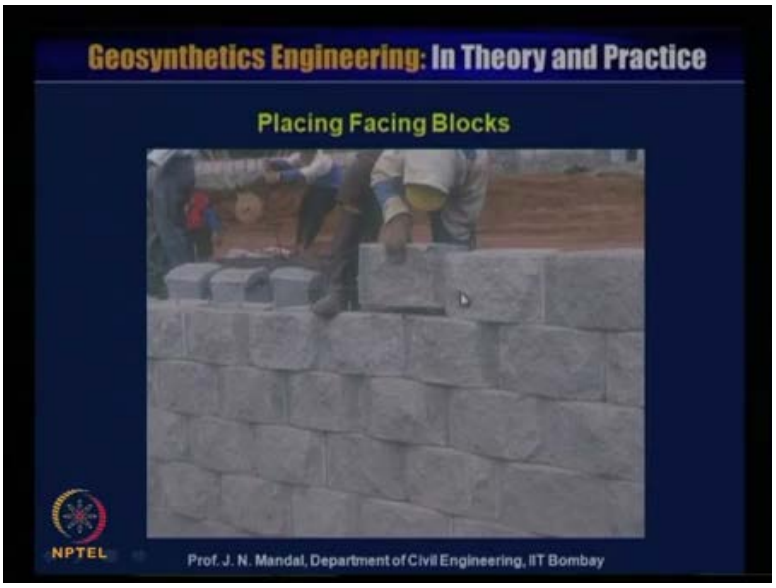

You can see how the placing of the facing blocks, one with the other you have to place the properly, the lift should be proper it should be joint, it should be connected the geo grid material with the block in proper placing.

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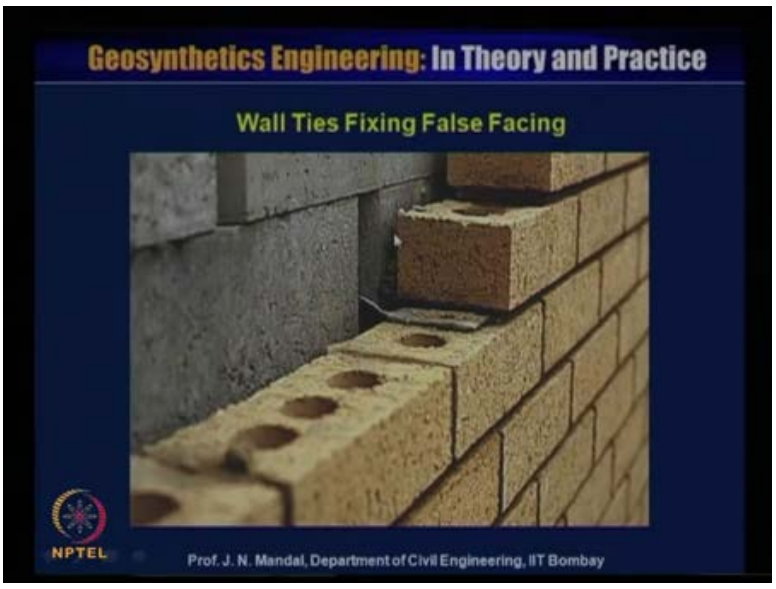

You can see wall ties existing the mobile with the false facing element here.

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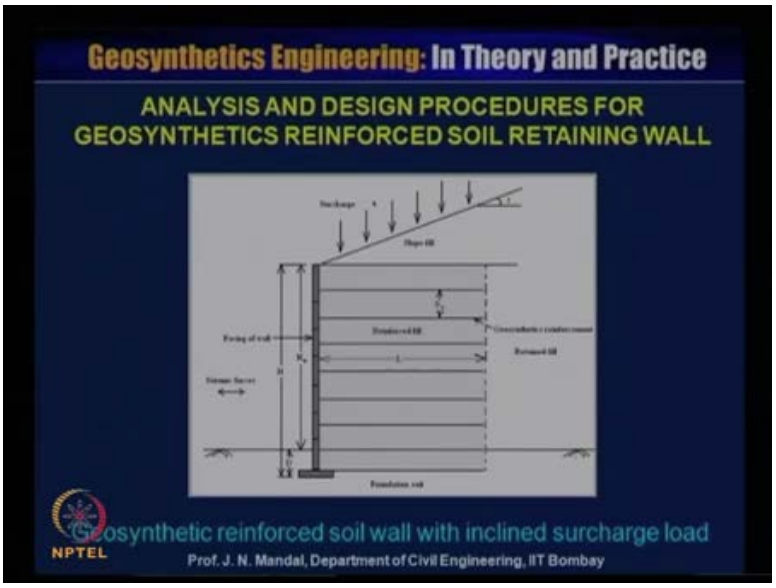

So, now you require further analysis and design reinforced is for geo synthetics reinforced soil retaining wall, these are geo synthetics reinforced soil wall with inclined surcharged load. Sometimes it may be the inclined, sometimes it is not inclined if there is a inclined, then you have to be consider, what will be the surcharge load here you can see key with the surcharge load, which is making at an angle of beta and this is the slope field.

And as I say this is the reinforced field, you always remember this is the reinforced field and this the length of the reinforcement is l and this is the foundation soil and this is the geo synthetics reinforced retained field and this is the facing of the wall and this is the depth of the embedment. We will design this mechanically stabilized reinforced soil wall and there, is a possibility for any the seismic forces that also we will take into account. So, here this slide showing that, what is the geo synthetics reinforced soil wall with inclined surcharged load.

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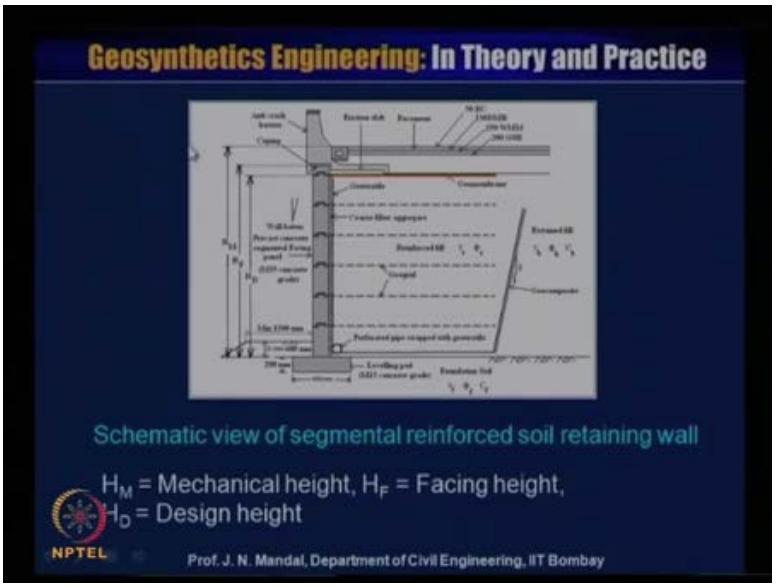

This is some schematic view of segmented reinforced soil retaining wall and where this is h m, here you can see this is the anti that cross barrier here is the cross barrier and here this we call the copping and where because this kind of the barrier is needed, when this is the road. So, in road we can as usual you know that how to design the road, where you require for the b c bituminous coated or the d m b dense bituminous macadam or w m m or the g s b.

So, you can design this you can provide sometimes here also with the addition of the geo grid reinforcement, which can reduce the thickness of the thickness of the pavement. And you require a proper kind of the cross barrier, because sometimes when there is a accident the car can attach this barrier, so it can be prevented. So, this also you required proper kind of the design though sometimes, thus it is related with the structural analysis, but we will deal mainly on the design of the geo grid reinforcement soil retaining wall.

Where h m here is the mechanical height and h f this is the facing height and h d is the design height, so whenever you can see the reinforcement is passing through, this is the reinforcement height. So, height of the design for this up to this that is why, we say it is the design height and also when, we will use either the block or the then it require certain kind of the wall barrier, you cannot construct the absolutely the vertically you can make some kind of the wall barrier.

And precast concrete segmental facing panel and whose criteria will be the m 35, that

concrete grade is required also at the base you require, the level padding first of all you have to construct a level padding and to which length will be about 600 millimeter and this also will be the 200 millimeter and you have to provide, with a minimum embedment depth, which will be about the 1200 millimeter.

And then you provide this what will be the call, that drainage system this is the retained fill and this is the geo composite material which will act as a drainage and you provide with, the with the perforated pipe and wrapped with the geo textile material. So, when we will design this kind of the segmental reinforced soil retaining wall you require that many properties of this material, you require property for the foundation soil, which can be designed of the gamma h phi f and c f, you should know what should be the unit of the foundation soil, what will be the friction angle of the soil of the foundation soil, you should know what will be the cohesion of the foundation soil.

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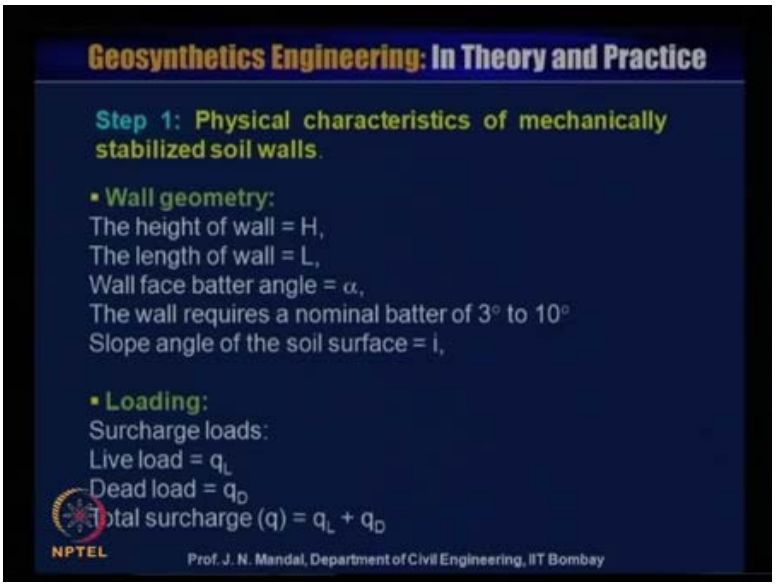

Similarly, you should know that, what will be the properties of the retained soil that means, if there's a gamma b what will be the unit weight of the retained soil or what will be the friction angle of the retained soil, what should be the cohesion value of the retained soil. Similarly you should know what should be the characteristics of the soil in the reinforced fill material, where you required what will be the unit weight of the soil in the reinforced soil zone, what should be the friction angle of the soil and at the same time you required that proper kind of the drainage system and what kind of the drainage

system you should you should consider in your design.

Now, step 1 you require physical characteristics of the mechanically stabilized soil walls, so you require first that will be the wall geometry, you should know what will be the height of the wall is designated as h, what will be the length of the wall that is with the length l, what will be the wall face batter angle, that alpha. And generally the wall require a normal batter of 3 to 10 degree centigrade most of the cases you can use also the 5 to 6 degree.

And slope angle of the soil surface, that I that required if there is any slope, if there is no slope then that is 0 and you should also consider that what should be the loading that means, it is a surcharge load if there is a live load is equal to q l, if there is a dead load is equal to q d. So, total surcharged load you have to take into consideration, which will be the summation of the live load and the dead load.

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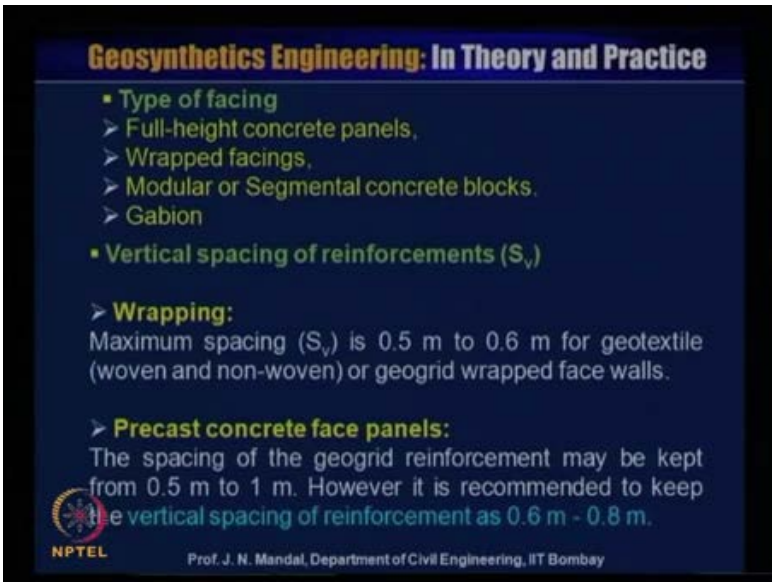

Now, what is the type of facing it may be full height concrete panel, then wrapped facing or modular or segmental concrete block or gabion facing. And you should know the what will be the vertical spacing of the reinforcement s v, if there is a wrapping system, so maximum spacing s v is 0 point 5 meter to 0 point 6 meter for geo textile, it may be the woven geo textile or it may be nonwoven geo textile.

And sometimes also you can use geo grid as a wrapped face wall, the precast concrete

face panel, the spacing of the geo grid reinforcement may be kept from 0 point 5 to 1 meter. However, it is recommended to keep the vertical spacing of the reinforcement as point 6 meter to point 8 meter of course, it depend upon that what will be the thickness of the modular block or what will be the height of the modular block or what will be the height of the panel.

So, accordingly we have to be provide with the vertical spacing, whether it is a point 6 whether it is a point 7, whether it is a point 7 5, whether it is a point 8 and sometimes it may be the one meter. But, it is recommended that facing of the reinforcement would be lie between point 6 to point 8 meter, which will be very reasonable.

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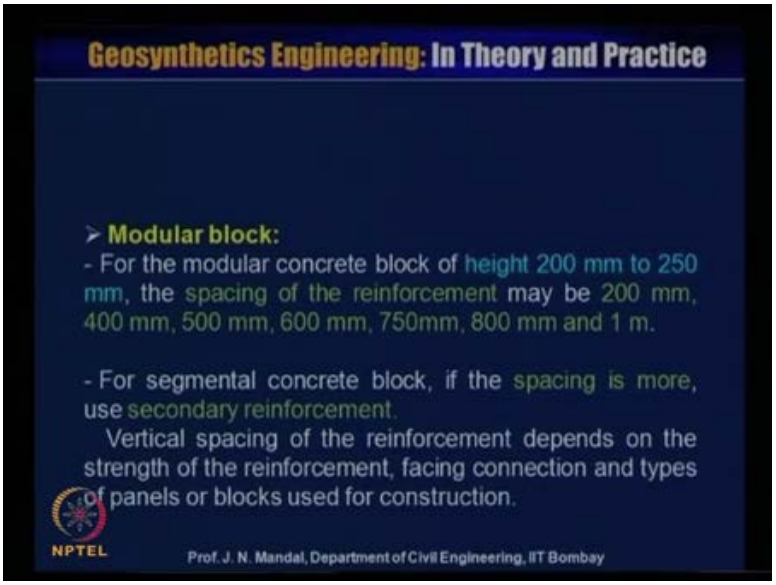

Now, modular block for the modular concrete block of height 200 millimeter to 250 millimeter, the spacing of the reinforcement may be 200 millimeter, 400 millimeter, 500 millimeter, 600 millimeter, 750 millimeter, 800 millimeter and even then 1 millimeter 1 meter. Now, for segmental concrete block, if the spacing is more then you use the secondary reinforcement.

And vertical spacing of the reinforcement depends on the strength of the reinforcement, what will be the facing connection and the type of the panel or block used for the construction. Because, most of the cases failure can come about in the numerous way, there will be geo grid, there will be the tension failure, there will be geo grid, there will be the connection failure, there will be the geo grid, there will be the slipping or

sometimes, that block modular block wall the failed.

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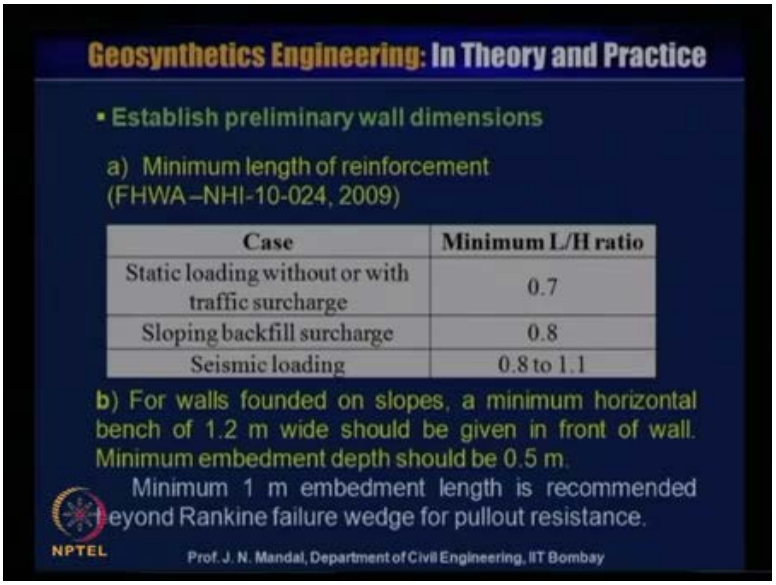

So, you have to establish the preliminary wall dimension a minimum length of the reinforcement, as for f h w a 2009, that case say if it is a static loading without or with traffic surcharge, the minimum length by height ratio is point 7, this is as a thumb rule for any design in the beginning, if you can start you can use to length to height ratio will be equal to point 7, then you can continue with design and check or if it is a sloping backfill surcharge, then minimum length to height ratio will be point 8.

If it is a seismic loading then minimum length to height ratio is point 8 to 1 point 1. Now, b for wall founded on slope a minimum horizontal bench of 1 point 2 meter wide, should be given in front of the wall. Minimum embedment depth should be point 5 meter minimum 1 meter embedment length is recommended beyond, the ranking failure wedge for pullout resistance.

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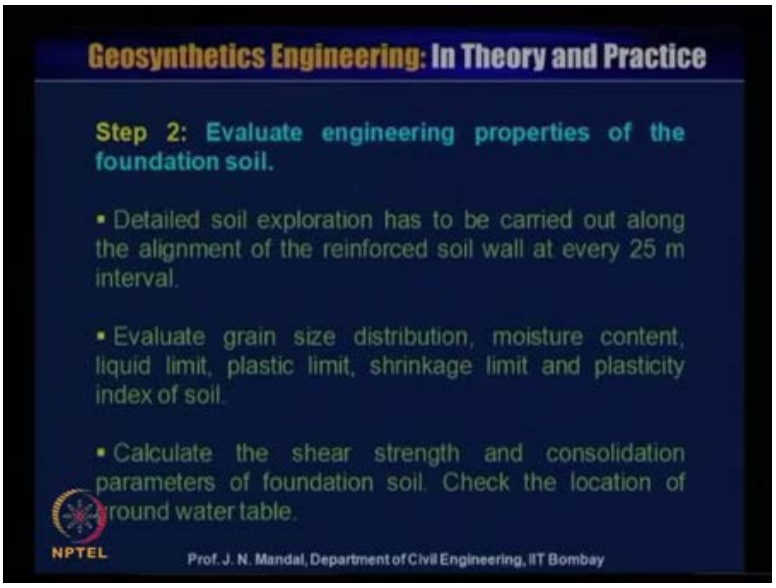

Step 2, evaluate the engineering properties of the foundation soil, detailed soil exploration has to be carried out along the alignment of the reinforced soil wall at every 25 interval. It is necessary to carry out the test, sometimes you can obtain some result without any soil exploration it will be danger. So, it is very important that one should carry out the test along the element of the reinforced soil wall and every 25 meter interval.

And you have to evaluate what will be the grain size distribution curve, what will be the moisture content, what is liquid limit plastic limit, shrinkage limit and plasticity index of the soil. And you calculate the shear strength and the consolidation parameter of foundation soil and check, the location of the ground water table, so these are very common that what has to go for the soil testing.

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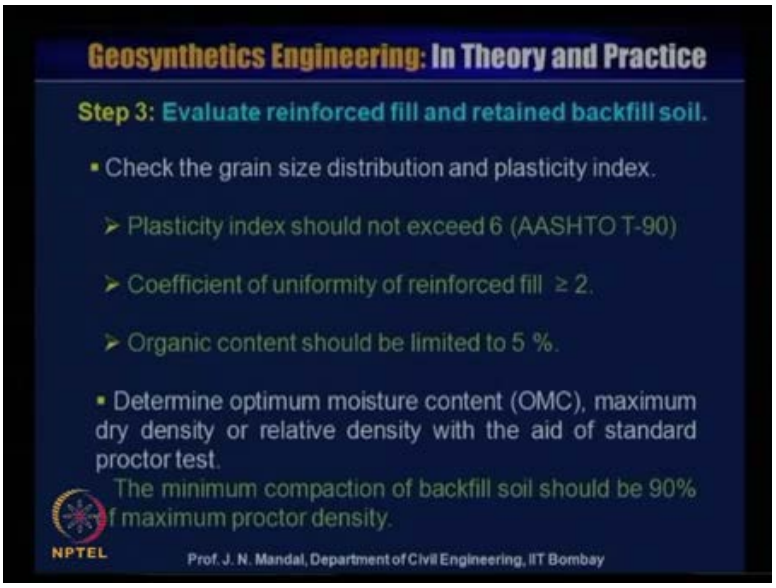

Step 3, evaluate the reinforced fill and retained backfill soil, check the grain size distribution and the plasticity index, plasticity index should not exceed 6 as per AASHTO T 90. Coefficient of uniformity of the reinforced fill should be greater than equal to 2, organic content should be limited to 5 percent and determine the optimum moisture content o m c, maximum dry density or relative density with the aid of standard proctor test.

And minimum compaction of the backfill soil should be 90 percent of maximum proctor density, so you should maintain the density if you do not maintain that density, if you do not properly compact the soil then, there is a possibility for the failure of the reinforced soil structure.

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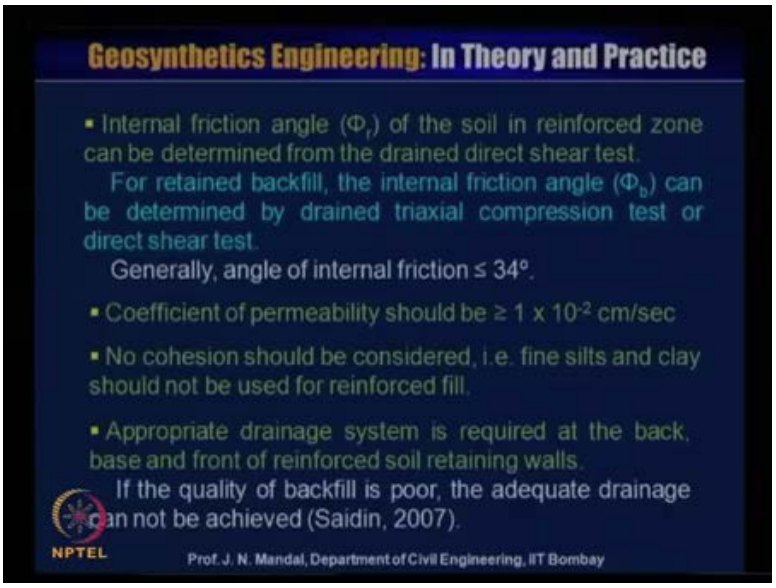

Then internal friction phi r of the soil is the reinforced zone can be determined from the drained direct shear test, for retained backfill the internal friction angle phi b can be determined by drained triaxial compression test or direct shear test. Generally the angle of internal friction should be less than equal to 34 degree, coefficient of permeability should be greater than equal to 1 into 10 to the power minus 2 centimeter per second, no cohesion should be considered, it that is fine silts and clay should not be used for reinforced fill.

Appropriate drainage system is required at the back base and front of reinforced soil retaining wall, if the quality of the backfill is poor the adequate drainage cannot be achieved Saidin 2007 as mentioned.

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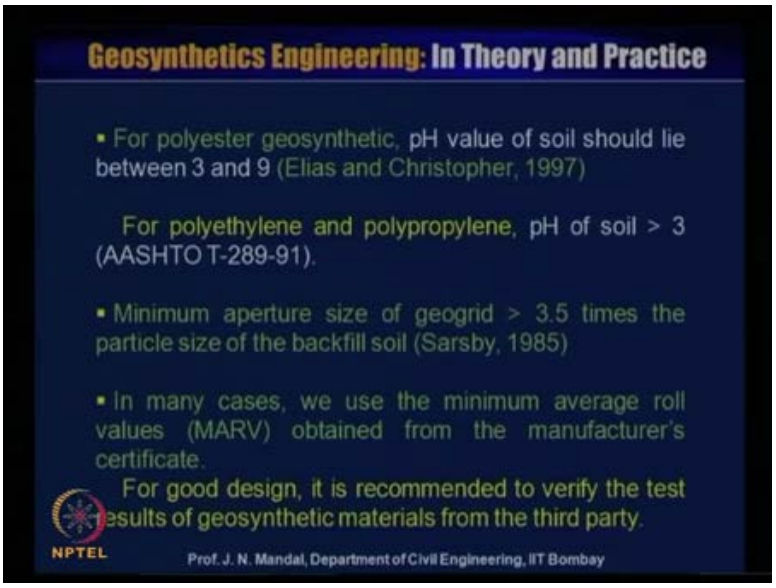

For polyester geo synthetics p h value of soil should lie between 3 and 9, that is Elias and Christopher 1997, for polyethylene or polypropylene p h of soil greater than 3 AASHTO T 2 8 9 9 1. Minimum aperture size of the geo grid should be greater than 3 point 5 times, the particle size of the backfill soil as given by Sarsby 1985, in many cases we use the minimum average roll value m a r v obtained from the manufacturer's certificate.

For good design good construction, it is recommended to verify the test result of geo synthetics material from the third party.

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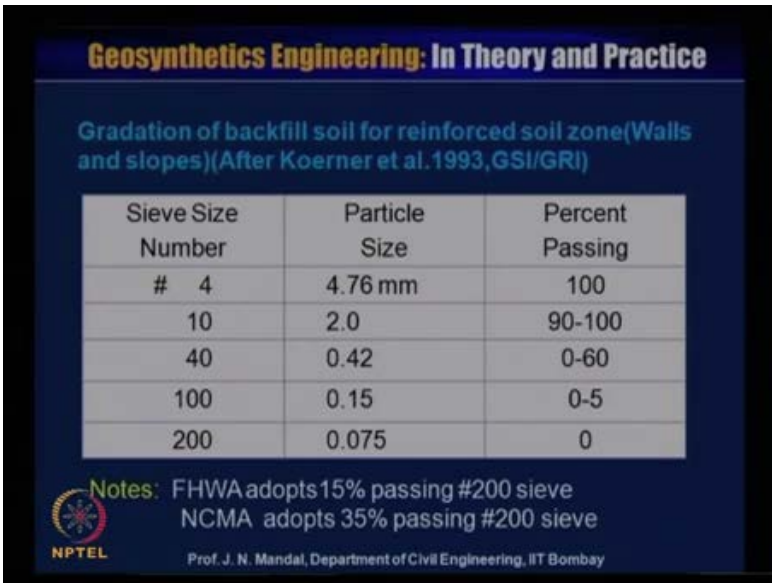

Gradation of the backfill soil of reinforced soil zone wall slope after Koerner et al 1993 g s I and g r I, this is very important. Because, most of the time if we do not or select the proper kind of the gradation of the soil material, then there is a possibility for the failure. So, as for this sieve number 14 15 40 hundred and 2 hundred, the particle size lies between these and percentage of passing will be this.

But, you can see in case of FHWA this adopts this 15 percent passing in 2 thousand 2 hundred sieve whereas, NCMA adopts 35 percentage of passing or 2 hundred sieve. So, sometimes most of the cases that f h w also is follow up, but this Koerner recommend, this for 0. So, when you will use this kind of the backfill soil material, so you have to select proper kind of the gradation of the material.

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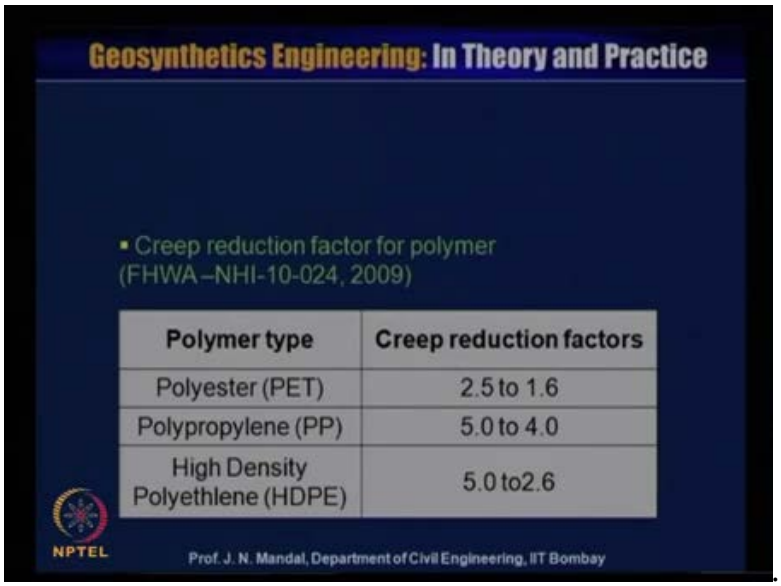

The another factor is the creep reduction factor for polymer this is also very important F HWANH 1 10 0 2 4, 2 thousand 9 it depend upon the what will be the polymer type, it is a polyester p e t or polypropylene p p or high density polyethylene h d p e. You can see that how the creep reduction factor vary 2 point 5 to 1 point 6 for polyester for polypropylene 5 point 0 to 4 point 0 and for high density polyethylene 5 point 0 to 2 point 6.

So, here is the 1 point 2 to remember, that what will be the creep factor and what kind of material, you should use whether it is a polyester polyethylene or high density polyethylene, if the creep reduction factor is more. And then your allowable bearing capacity allowable tensile strength of the geo grid material also equally reduced on the other hand, if you use the polyester material whose creep reduction factor is less.

So, in that case the tensile is allowable tensile strength of the geo grid material will be on the hard side, so that was one of the region that sometimes that polyester material is the better, than the polypropylene and high density polyethylene material. But, whatever it may be you have to be very careful for the key factor and what kind of the material you wanted to use it, so with this I have ended up this lecture today.

Thank you very much.