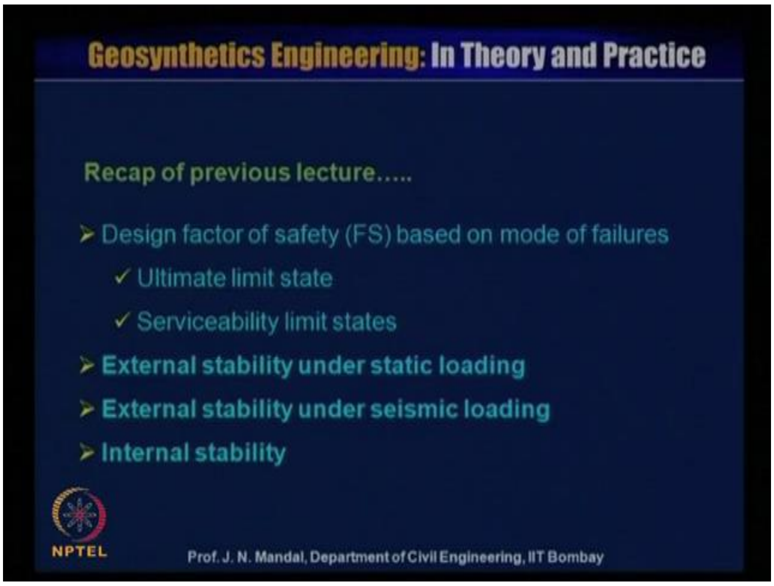
Geosynthetics Engineering: In Theory and Practices
Prof. J. N. Mandal
Department of Civil Engineering
Indian Institute of Technology, Mumbai

Lecture - 28
Geosynthetics for Reinforced Soil Retaining Walls

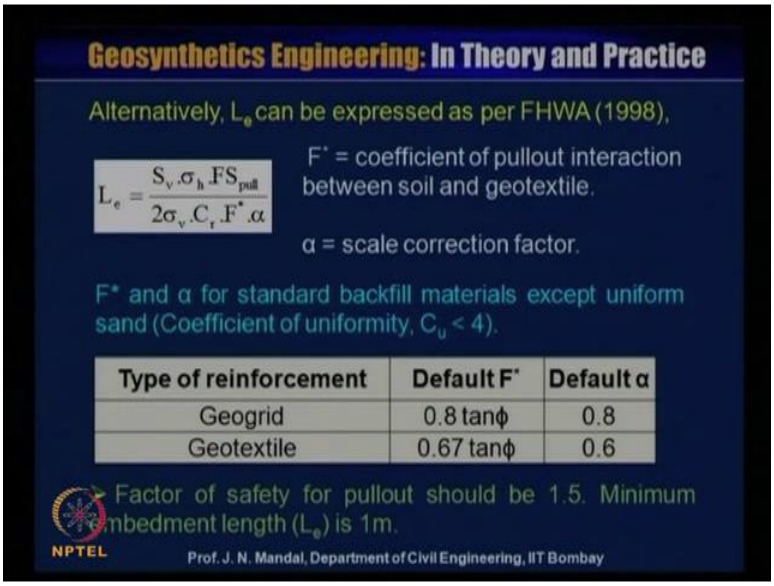
Dear student warm welcome to NPTEL 2 video course on Geosynthetics Engineering in Theory and Practice, my name is professor J.N. Mandal, Department of Civil Engineering, Indian Institute of Technology, Bombay, Mumbai India. The name of the course Geosynthetics Engineering in Theory and Practice, this module 6 lecture 28 Geosynthetics for Reinforced Soil Retaining Wall.

(Refer Slide Time: 00:54)



Now, I will address recap of the previous lecture, which I have covered design factor of safety based on mode of failure ultimate limit state, and serviceability limit state, external stability under static loading, external stability under seismic loading and internal stability.

(Refer Slide Time: 01:43)

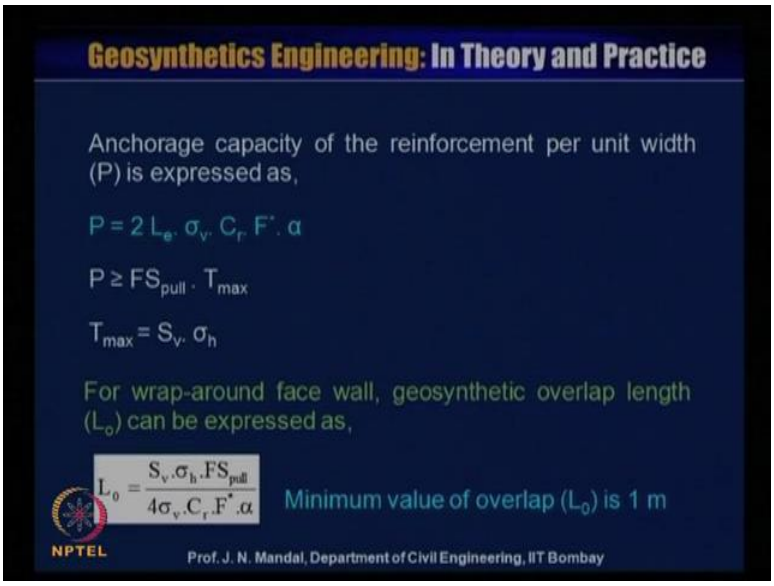


Earlier, we talked about to calculate the embedment length L e by the pull out test, now alternatively L e can be expressed as per FHWA 1998, for L e is equal to S v into sigma h s F S pull divided by twice sigma v C r F star alpha. Where, F star is the coefficient of pullout interaction between the soil and geotextile alpha is scale correction factor F star and alpha for standard backfill material except uniform sand, whose coefficient of uniformity C u less than 4.

So, here typical type of the reinforcement this is the default F star and default alpha if it is a geogrid, so default F star value will be 0.8 into tan phi, if it is a default alpha value is 0.8. And if we add of geotextile then default F star value 0.67 tan phi and default alpha is 0.6, so factor of safety for pullout should be 1.5 and minimum embedment length should be 1 meter, so here if you know that what will be the default factor F star and alpha value.

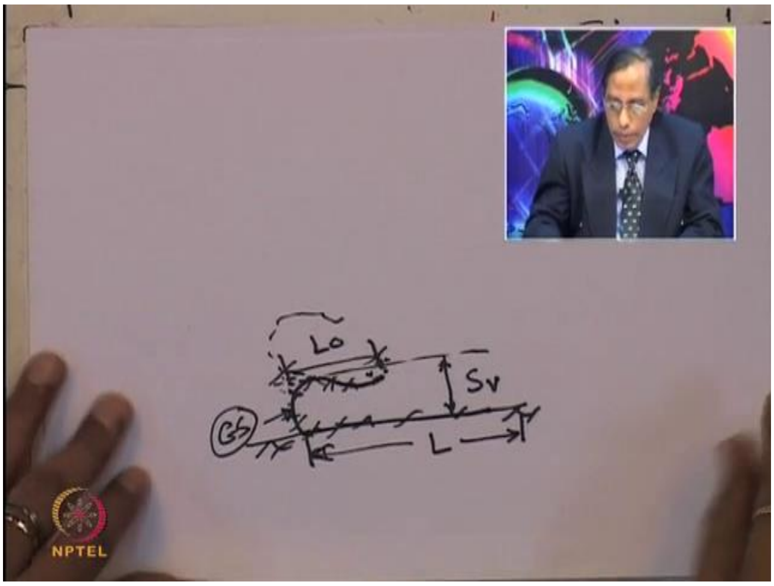
So, here you know the coverage ratio and then sigma h is known S v is known sigma v is known factor of safety against pull out known, so you can calculate alternatively what should be the angle of length from this equation. But, remember that minimum embedment length should be one meter and factor of safety against pullout you can consider 1.5.

(Refer Slide Time: 03:40)



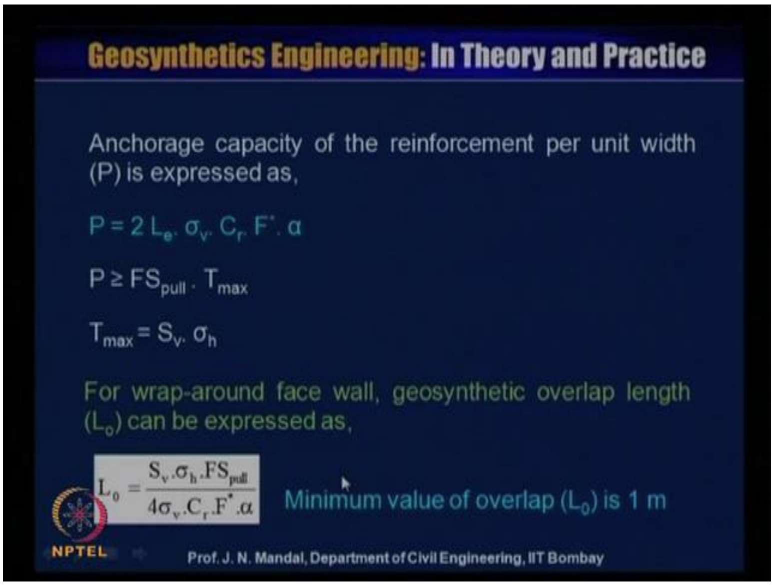
The anchorage capacity of reinforcement per unit width P can be expressed as P is equal to twice L e sigma v C r F star into alpha. So, P greater than equal to factor of safety for pullout into T of maximum, T maximum will be equal to S v into sigma of h, S v is the spacing between the reinforcement, for wrap around face wall geosynthetics overlap length, which we call L 0. It also can be expressed as L 0 is equal to S v into sigma h F s pull divided by 4 of sigma v into C r F star into alpha, so this is the minimum value for the overlap L 0 is equal to 1 meter. I am showing that what do you mean by the overlap of this geosynthetics material, when we will use the woven and non woven geotextile material.

(Refer Slide Time: 04:50)



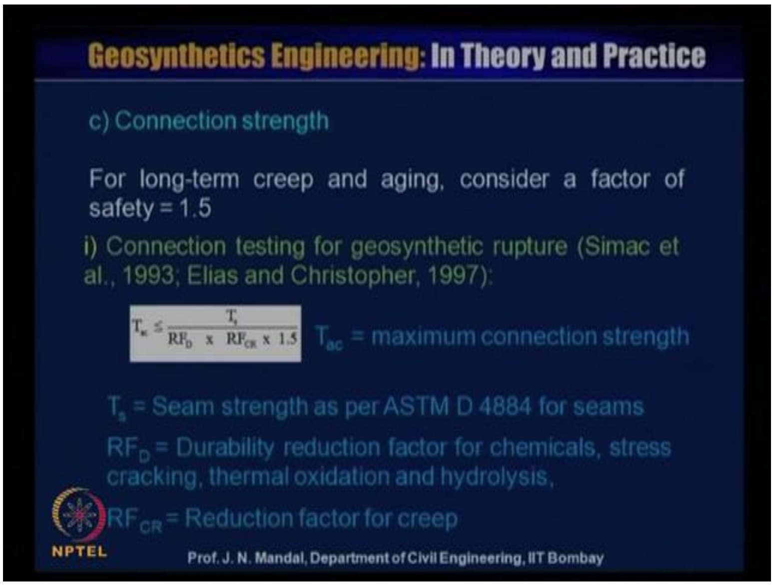
So, we have to overlap like this, distance which you call the overlap that is L of 0, you can construct this wall like this, so this is the geosynthetics material woven and non woven. So, you place this geosynthetic material like this, and then you can wrap it, so this distance is L 0 which we call the overlap distance. And this is the length of the reinforcement that is L, and this is the spacing between the reinforcement that is which we call S of v.

(Refer Slide Time: 05:50)



So, you know what do you mean by overlap length, so this overlap length can be expressed as this, so you if you know the L 0, then you can calculate that also you know the what will be the spacing and length of the reinforcement.

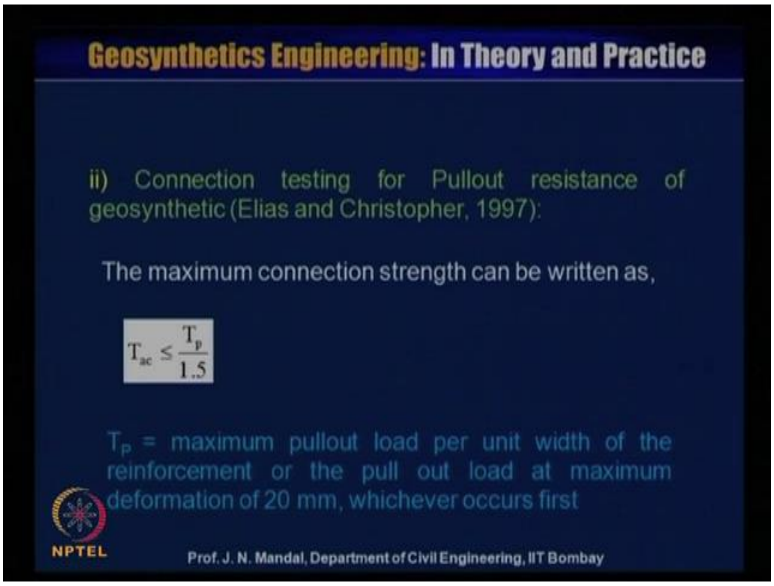
(Refer Slide Time: 05:53)



Now, see connection strength for long term creep and edging consider a factor of safety is equal to 1.51 connection testing for geosynthetic rupture Simac et al 1993; Elias and Christopher 1997, is given this equation that T a c; that means, maximum connecting strength should be less than equal to T of s. That means, seam strength as per ASTM D 4884 for seam testing this divided by this reduction, this is the R F D; that means, durability reduction factor for chemical stress cracking thermal oxidation and hydrolysis.

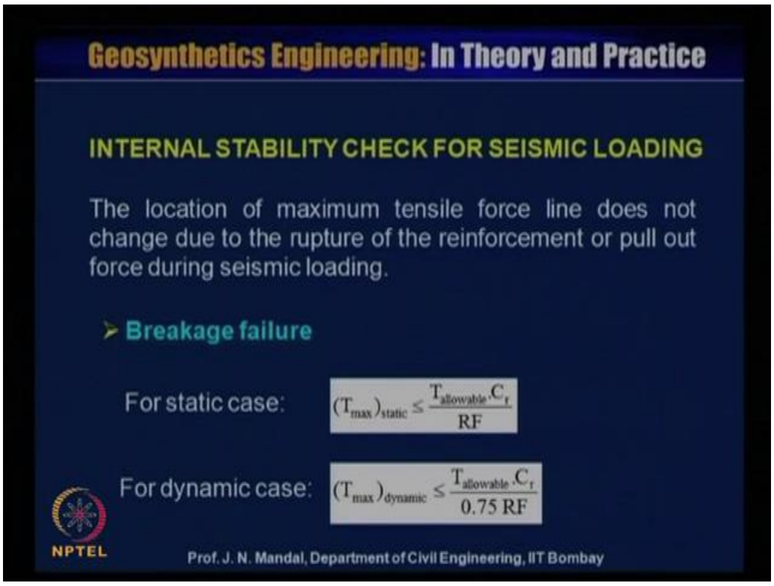
And this is R F C R that is reduction factor for the creep, and this is 1.5 for long term creep factor of safety you consider 1.5. So, it should be that T a c; that means, maximum connecting strength should be less than equal to the T g divided by all this reduction factor, where T s is equal to seam strength, so it should satisfy this criteria for the connecting strength.

(Refer Slide Time: 07:35)



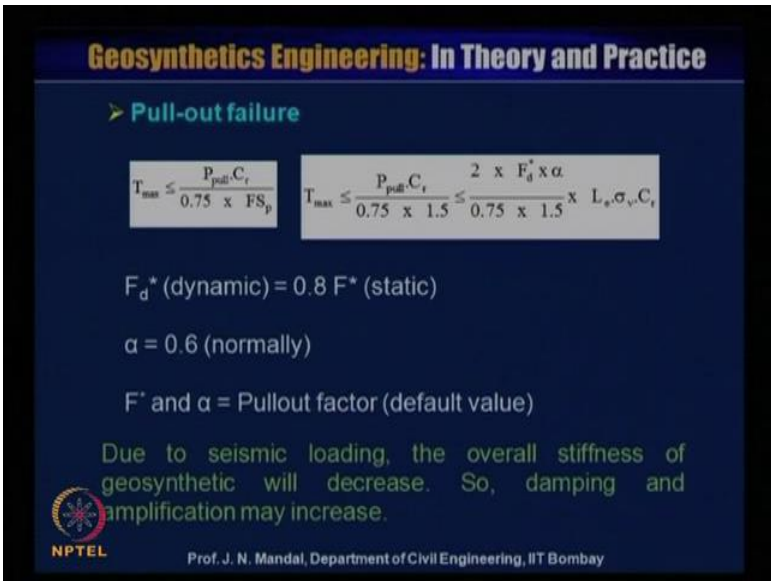
Now, connection testing for pullout resistance of geosynthetics as Elias and Christopher 1997, the maximum connecting strength can be written as T a c less than equal to T p by 1.5. Where, T p is equal to maximum pullout load per unit width of the reinforcement or the pullout load at maximum deformation of 20 millimeter whichever occur first. So, this is also important that what maximum deformation you can take, you can take the deformation up to 20 millimeter or you can say that what will be the maximum pullout reinforcement from the unit width of the reinforcement. So, whichever will occur first, so accordingly you can calculate that what will be the maximum pullout force T p.

(Refer Slide Time: 08:31)



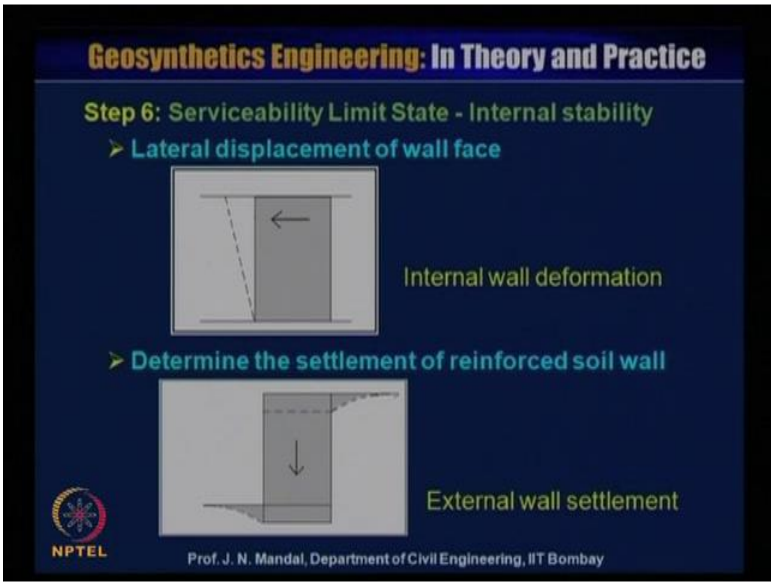
Now, for internal stability check for seismic loading, the location of the maximum tensile force line does not change due to the rupture of the reinforcement or pullout force during the seismic loading. We are assuming that maximum tensile force line is the same as in the case of the static case. So, breakage failure there is a possibility for basic failure due to the static case and due to the also dynamic case, for static case T of maximum static should be less than equal to T allowable into C r divided by reduction factor. For dynamic case T maximum dynamics should be less than equal to T allowable into C r divided by 0.75 into reduction factor.

(Refer Slide Time: 09:28)



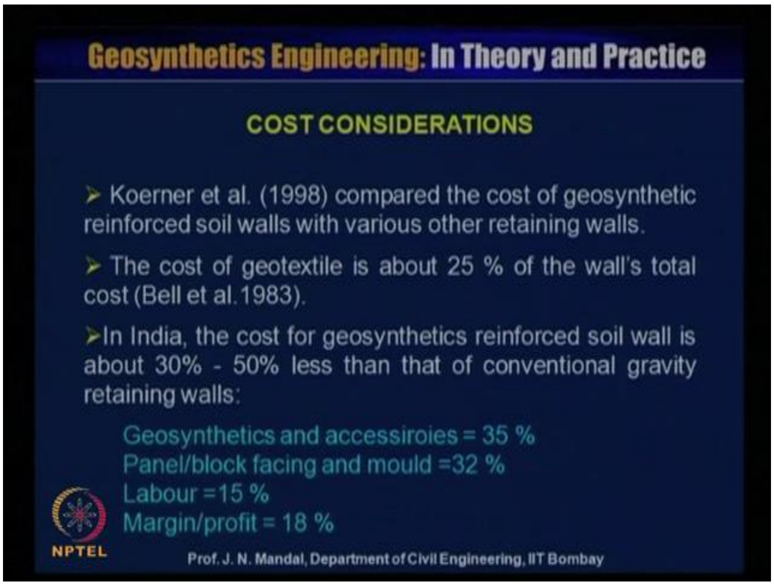
If it is a pullout failure, so T maximum should be less than equal to T p pull into C r divided by 0.75 into F S p and T maximum should be less than equal to P pullout into C r divided by 0.75 into 1.5 or less than equal to 2 into F d star into alpha divided by 0.75 into 1.5 into l of e into sigma v into C r. So, F d star its dynamic should be equal to 0.8 into F star in the static and alpha is generally take 0.6 and F star and alpha is equal to pullout factor, that is the default value. Due to seismic loading the overall stiffness of geosynthetics will decrease, so damping and amplification may increase.

(Refer Slide Time: 10:36)



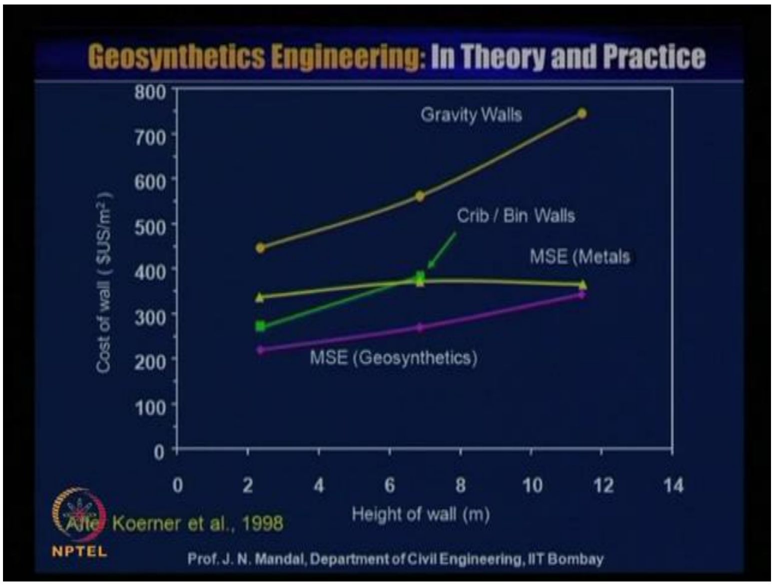
Step 6 serviceability limit state, for internal stability, so there is a possibility for the lateral displacement of the wall face. So, you have to check what will be the internal wall deformation or you have to check as to determine the, what will be the settlement of the reinforced soil wall for external wall settlement, so these are the serviceability limit for the internal stability have to be checked.

(Refer Slide Time: 11:07)



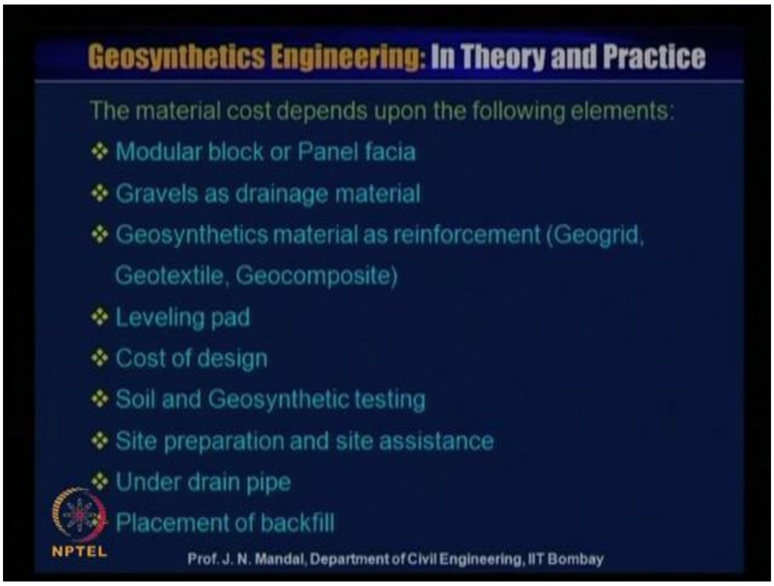
Now, for any project he has to look for the cost benefit analysis, so you have to consider the cost analysis here Koerner et al 1998, compare the cost of geosynthetics reinforced soil wall with various other retaining wall. The cost of geotextile is about 25 percentage wall total cost as per Bell et al 1983. In India the cost of the geosynthetics reinforced soil wall is about 30 to 50 percent less, than that of conventional gravity retaining wall. There are only geosynthetics and accessories about 30 50 percent, panel and block facing and mould about 32 percent, labour 15 percent, and margin and profit about 18 percent.

(Refer Slide Time: 12:01)



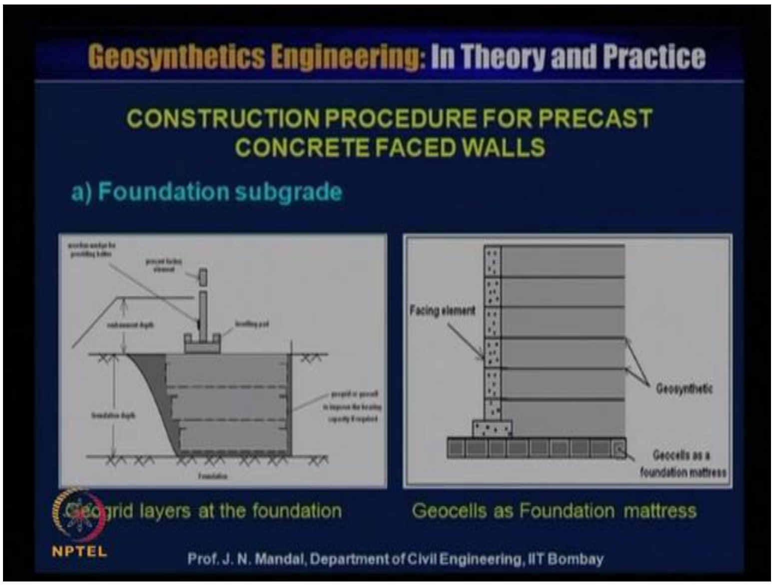
Now, this is figure shows the relationship between the height of the wall and the corresponding the cost of the wall, in U S dollar unit per meter square. This is given by Koerner et al 1998, you can see different types of the wall, this is the gravity wall creep bin wall, mechanically stabilized reinforced earth wall, metal wall. So, if you can compare you can see that with the increasing the height of the wall, cost also are increasing. So, if you compare with all the kinds of the wall, whether it is a gravity wall, whether it is a crib or bin wall, or it is a mechanically stabilized earth wall using the metallic reinforcement you find that mechanically stabilized geosynthetics reinforced soil wall, is much more cheaper compared to any other system or the material.

(Refer Slide Time: 13:08)



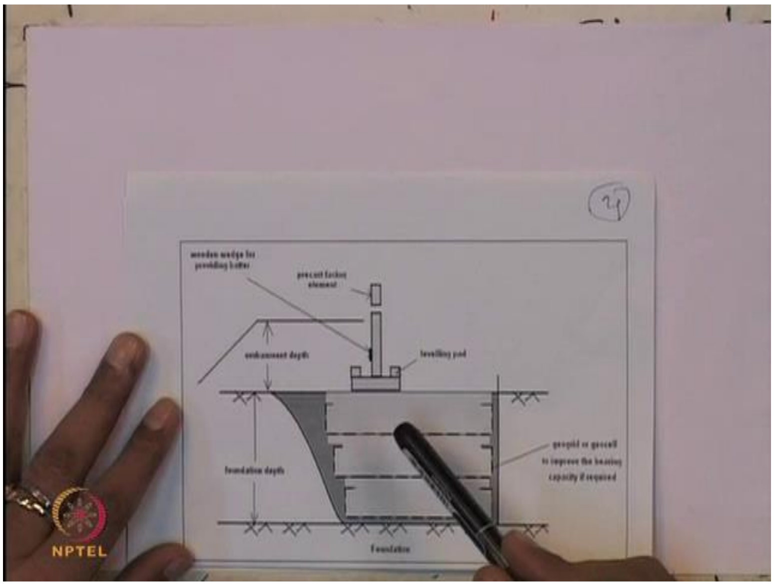
Material cost depend upon the following element, that is modular block gravel of panel facia, gravel as drainage material, geosynthetics material as reinforcement, it may be geogrid, it may be geotextile, it may be geocomposite. Also, leveling pad when you construct these reinforced soil wall you require the leveling pad, cost of the design, soil and geosynthetics testing, site preparation and site assistant, and under drain pipe, placement of the backfill.

(Refer Slide Time: 13:51)



So, these are the require construction procedure for precast concrete faced wall, here geogrid is layered at the foundation soil here and they are showing.

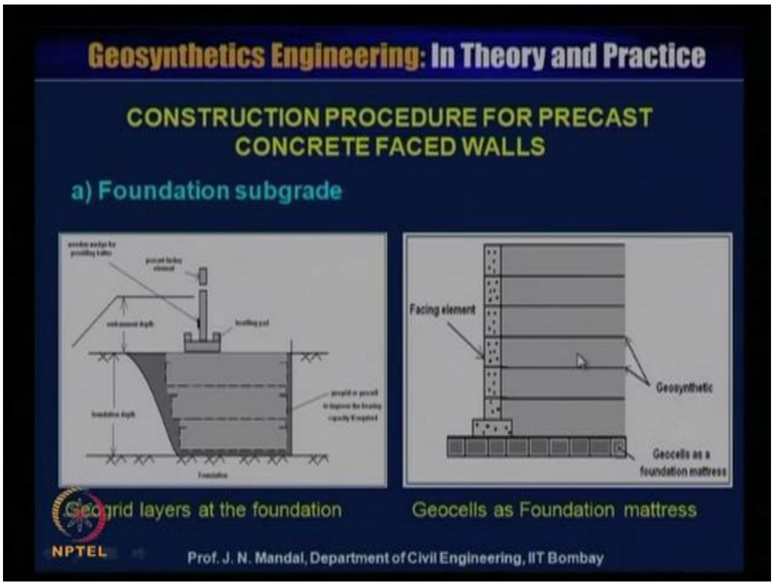
(Refer Slide Time: 14:10)



This is the wall and this is the leveling pad, and this is the foundation depth this is foundation, so if you want to improve this foundation, you have to provide with geogrid or the geocell material to improve the bearing capacity if required. And you have to provide certain embedment depth here, and this panel or the block which could be the wooden wedge for providing the better, and this is the leveling pad in which that precast concrete facing element will rest.

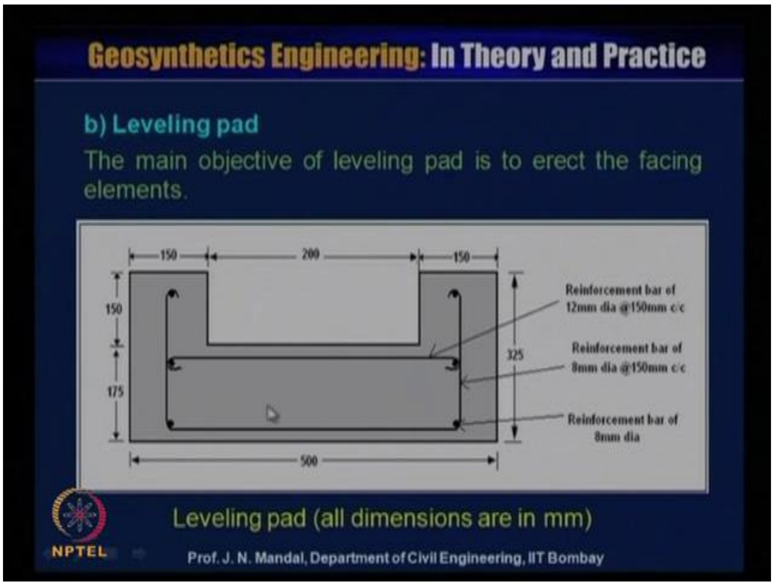
This is flexible like a hinge, and then reinforcement will be on the other side it can be resist by the reinforcement. So, this is the geogrid layer at the foundation of the foundation subgrade can be improved either if the number of the layer of the reinforcement or you can provide with the geocell also at the base for geocell, for the as a foundation matrices and this is as a facing element.

(Refer Slide Time: 15:31)



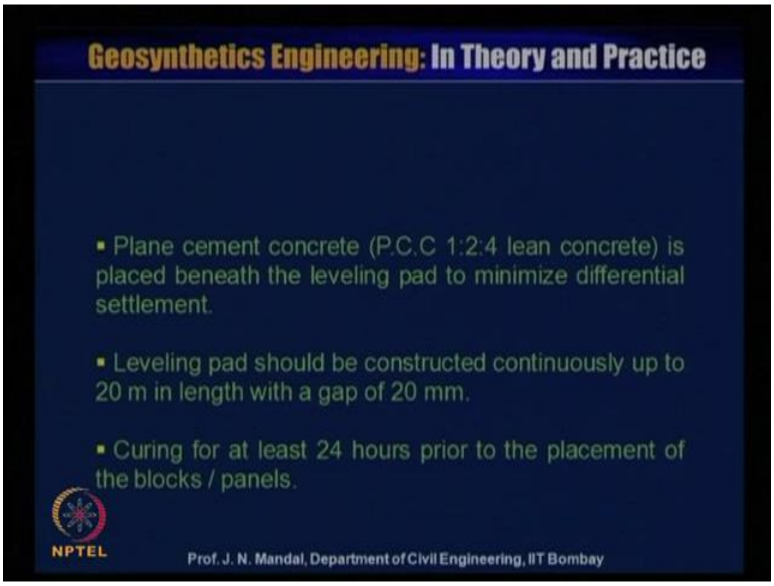
So, here also geocell has a foundation matrices shown, so this you recall foundation subgrade.

(Refer Slide Time: 15:36)



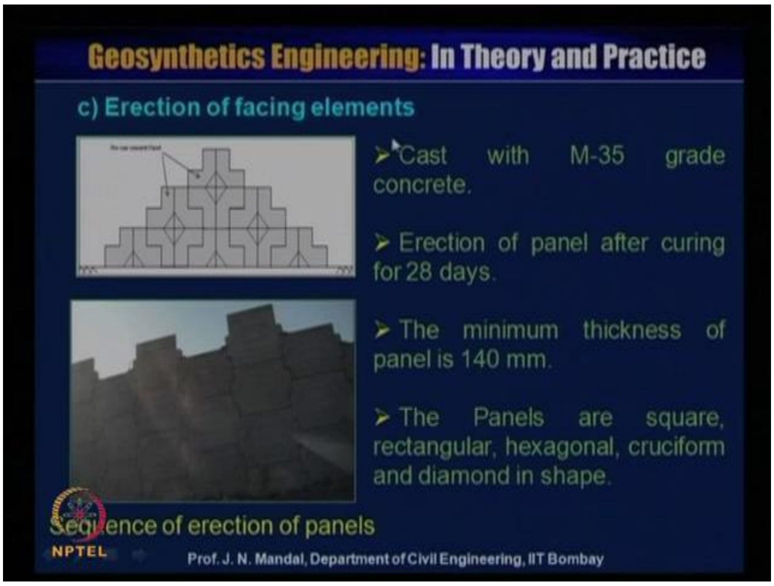
Now, leveling pad the main objective of the leveling pad is to erect the facing element, so this is one that shown the leveling pad with dimension, what is the reinforcement bar or 8 millimeter diameter or the reinforcement bar 8 millimeter, at the rate of 50 millimeter center to center. And here the reinforcement element bar at 12 millimeter diameter at the rate of 50 millimeter center to center and this is 500 millimeter this is 170, 150 and 150 and this is about 200 and this is 150 and that this total is about 325. Then this main objective of the leveling pad is to erect the facing element a r, you have to erect the facing element a r, so foundation soil you have to provide with the this kind of the leveling pad.

(Refer Slide Time: 16:37)



Now, plane the cement concrete or P C C 1 is to 2 is to 4 lean concrete is placed beneath the leveling pad to minimize the differential settlement, leveling pad should be constructed continuously up to the 20 meter in length with the gap of 20 millimeter, and curing for at least 24 hour prior to the placement of the block or the panel.

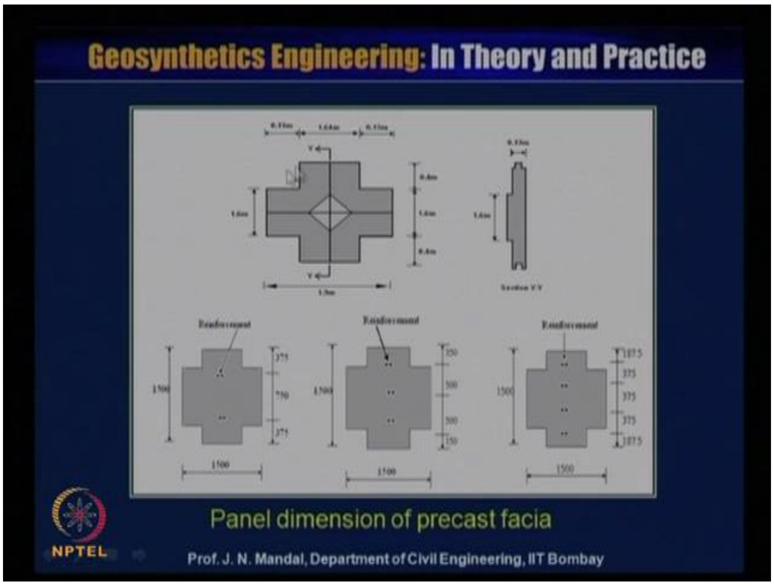
(Refer Slide Time: 17:08)



So, here you can see the erection of the facing element here cast with M 25 grade concrete, erection of the panel, after curing for 28 days. The minimum thickness of the panel is 140 millimeter, the panel are square rectangular hexagonal cruciform and diamond shape. Here, you can see that how the sequence of the erection of the panel, you can see initially you have to place like this half of the mould like this, then you can place the entire the facing element.

This is something cruciform in shape then cruciform like this you can construct, here it has been shown that sequence for the erection of the panel. This is also important and that how you have to erect the facing element and what you have to place the geogrid material which will be connected with the facing element.

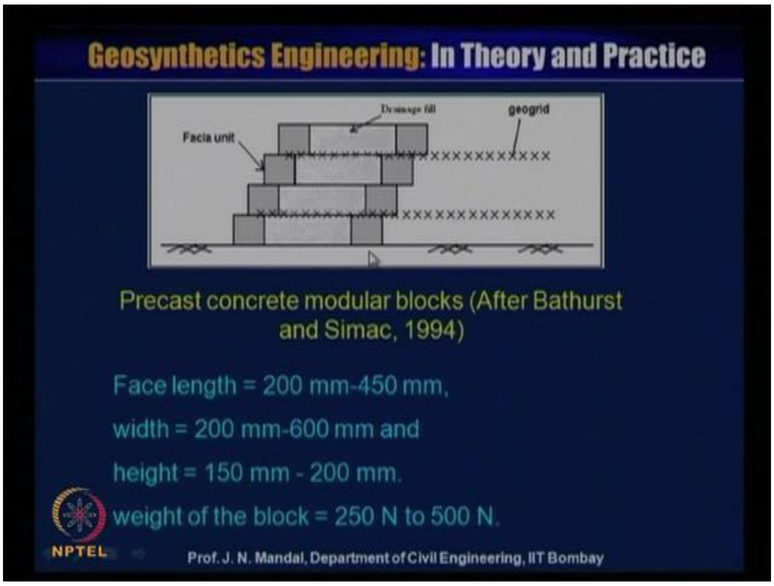
(Refer Slide Time: 18:26)



Here the different panel dimension in the precast facia, you can see that here may be 0.4, then 1.6, then 0.4 meter or it may be 375, then this is 750, and this is 750 millimeter, and this is about 1.5 meter by 1.5 meter. This is cruci shape panel and then you can connect these geogrid material here, this is 3.75, this is 3.375 this is c 75 millimeter and this is 750. So, you can get one layer of the geogrid material here, and another layer of the geogrid material here, and then you place the another panel here, then this is 375, then upper will be also 375, so entire will be about 750, so spacing is almost 750 millimeter. So, 750 millimeter, like this the spacing remain the constant, also different manufacturer have come up with the different types of the prefabricated spacing element.

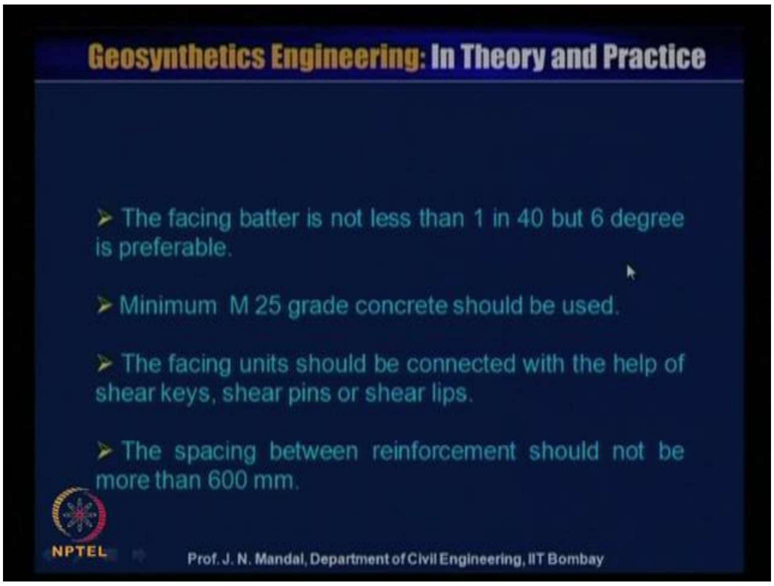
So, according to their manufacturing process and the quality of the geogrid material, and sometimes you can see that there will be the spacing is almost the fix, and sometimes depending upon the block also you can change the spacing also depending upon that what will be the thickness of the block. Whether, you are using the panel or you are using the block, so here precast concrete modulus block after the Bathurst and Simac 1994.

(Refer Slide Time: 20:20)



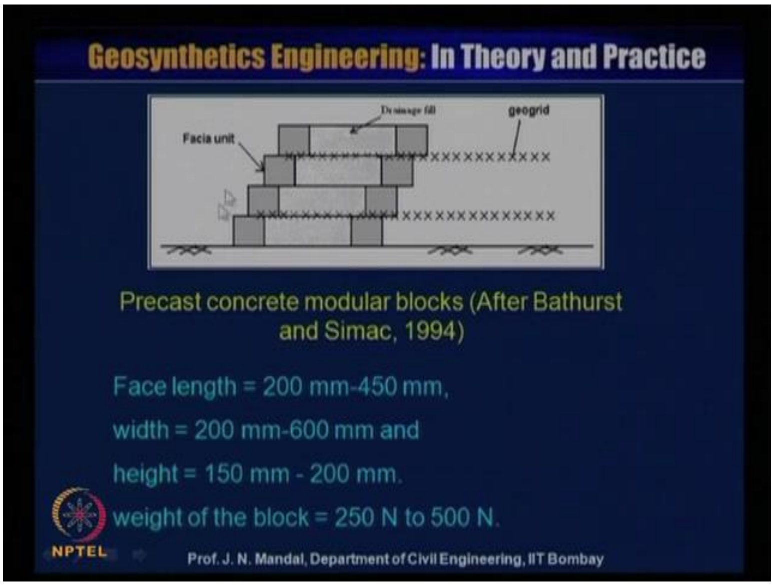
You can see that face length may be 200 millimeter to 450 millimeter, with the 200 millimeter to 600 millimeter, height is 150 millimeter to 200 millimeter and weight of the block generally 250 Newton to 500 meter. Here this is the block and this is act as a facing element, and because there is a gap over we can fill up with the aggregate it will act as a drainage material, and geogrid is connected with this facing element or this block. So, it depend upon if it is a 200, 200 then your spacing is 400, if it is a 300, 300 block then you can have the 600 millimeter spacing. So, depending upon the size of the blocks and the design you will be placed the geogrid material with the facing element accordingly.

(Refer Slide Time: 21:24)



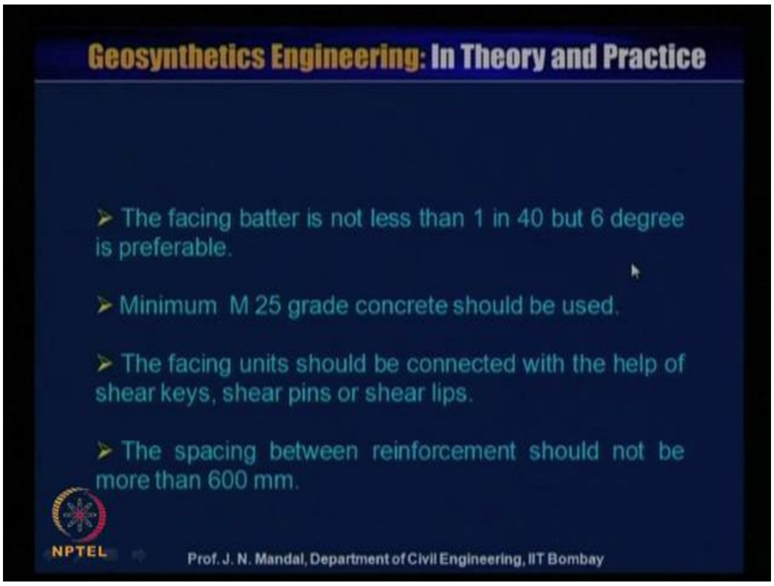
So, facing batter is not less than one in forty, but six degree is preferable.

(Refer Slide Time: 21:35)



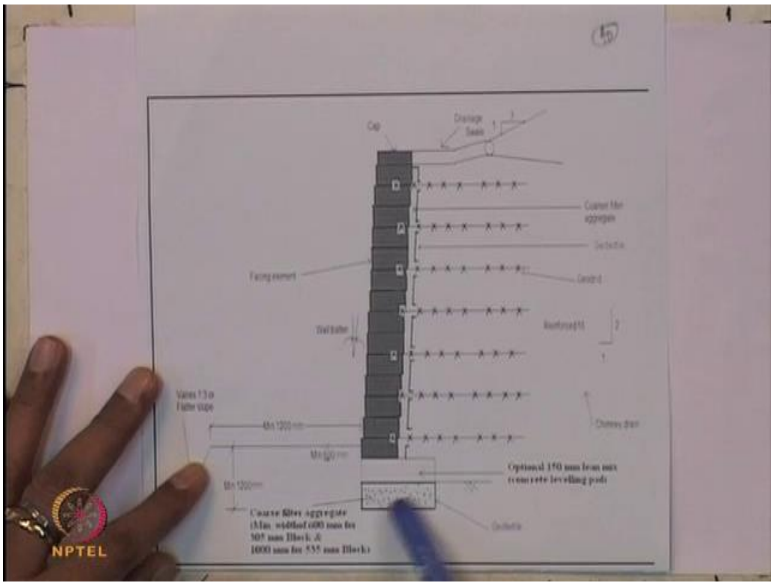
When you will these construct this wall, then you require some batter here some angle.

(Refer Slide Time: 21:43)



That is generally 1 in 40, but 6 degree is preferable and most of the Indian project, you use the 6 degree as a facing batter, so minimum M 25 grade concrete should be used, the facing unit should be connected with the help of shear key, shear pin or shear lips.

(Refer Slide Time: 22:19)

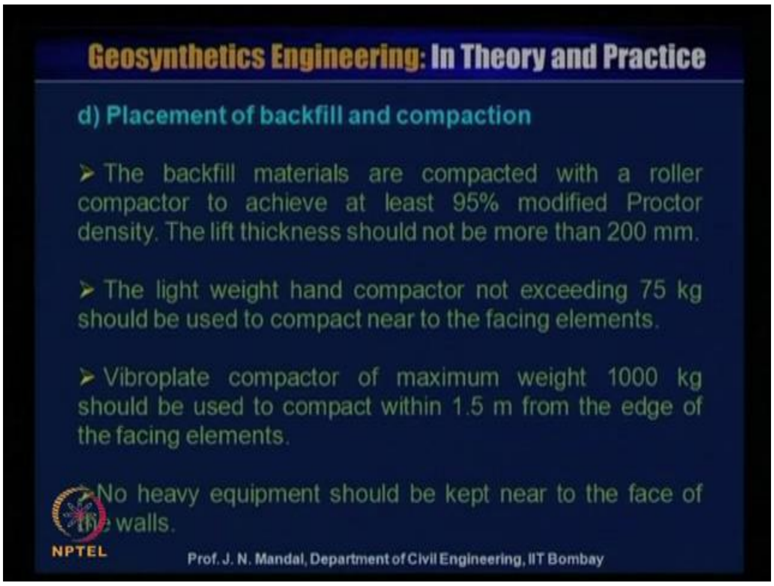


This placing between the reinforcement should not be more than 600 millimeter, so here you can see the some standard design of mechanically stabilized reinforced earth wall after they face W A 2009. Here, is the course filter aggregate this minimum width about the 600 millimeter, for 300 millimeter block and also the 1000 millimeter for 535 millimeter block, and this is a warp with geotextile material. and this is the optional that is 150 millimeter lean mix or concrete leveling pad, and this is the facing element here from this distance will be about 1200 millimeter and here, minimum about 600 millimeter.

You require certain distance from here what the drain is out this is minimum about 1200 millimeter, and then drain 1 into 3 or the flatter slope. You see here this is the facing element and here is the facing element and this is the wall batter, it may be within the 4 and on the top of the facing element and the wall, here is a gap and this is the drainage. So, that you can provide with slope 3 2 1 and this is the number of the layer of the reinforcing material or you can say it is the geogrid material and in between you can provide with the geotextile material here. May be woven or non woven geotextile material and inside this is the course of aggregate.

So, at the same time also you require the drainage system at the back of the reinforced soil wall, so this side you should provide with the kind of the drainage here with a certain angle, you recall from drainage with a slope of 2 vertical to 1 horizontal. You can provide with the any geocomposite or geotextile material, and water can also it can be drained out through this.

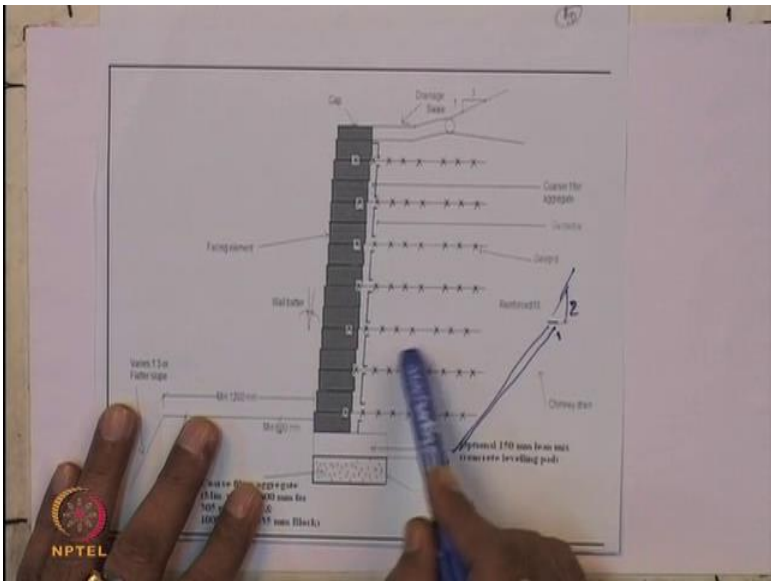
(Refer Slide Time: 24:38)



Placement of the backfill and compaction, this is important because you should properly place the backfill material, sometimes if you do not properly compact the material and proper selection of the material there is a possibility for the failure. So, the backfill material are compacted with a roller compactor to achieve at least 95 percentage modified proctor density, the lift thickness should not be more than 200 millimeter.

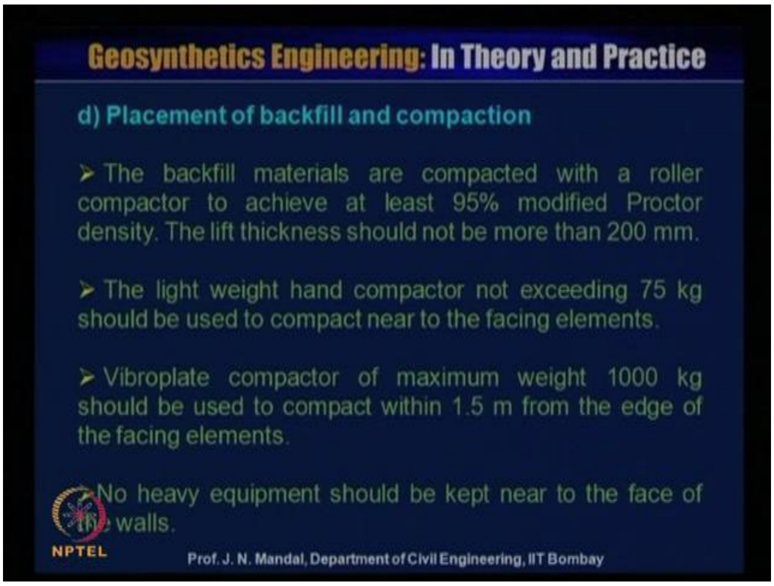
The light weight hand compactor not exceeding 75 k g should be used to compact near to the facing element, so you can see sometimes when you will compact the one layer. Then you fill up with the soil and then you have to compact it and you should maintain certain thickness between the geotextile and the soil. So, it should maintain the 200 millimeter or 250 millimeter, otherwise there is a possibility for the damage of the geogrid material, and when you are compacting like if this is the facing element of the wall and when you are compacting; that means, this light weight compactor.

(Refer Slide Time: 25:55)



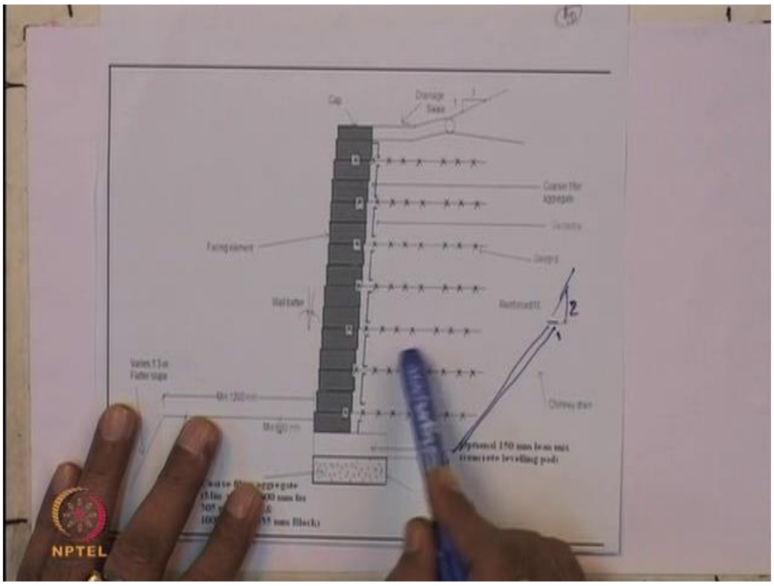
The light weight hand compactor not exceeding 75 k g should be used to compact near to the facing element, and then vibro plated compactor it may be 1.5 meter from the edge of the facing element. So, within 1.5 meter facing element, you have to use the light weight hand compactor and not exceeding 75 k g. And beyond the 1.5, so you can use vibro plate compactor or maximum weight may be 1000’s k g should be used to compact with one point five meter from the edge of the facing element.

(Refer Slide Time: 26:46)



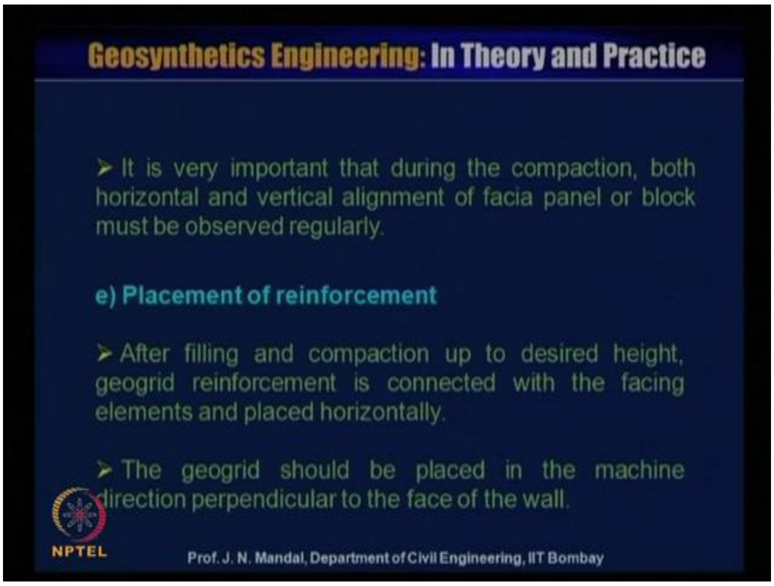
So, no heavy equipment should be kept near to the face of the wall, because if you keep the near to the face of the wall and there is a possibility for bulging of the facing element.

(Refer Slide Time: 26:56)



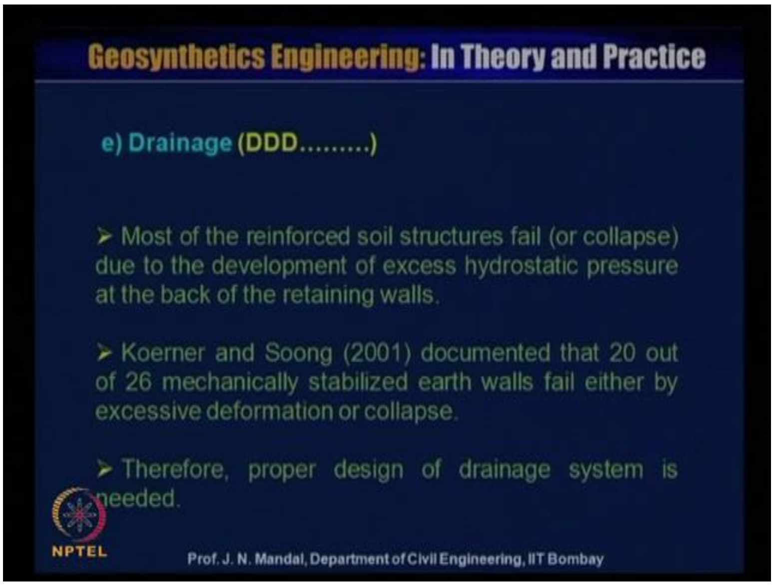
So, it is to be careful when you will compact, this reinforced soil retaining wall near to the facing element, so it is very important that during the compaction both horizontal and the vertical alignment of facia panel or the block must be observed regularly. Now, placement of the reinforcement, after filling and compaction up to the desired height geogrid reinforcement Is connected with the facing element and place horizontally.

(Refer Slide Time: 27:32)



So, for example, if you place here compact it after that you are placing these geogrid material here and which geogrid material should be connected with this facing element and place horizontally. So, geogrid should be placed in the machine reaction perpendicular to the face of the wall; that means, which direction the strength is more. So, you should not sometimes the place the geogrid material in the cross machine direction, whose strength is less. So, you have to be careful that how you are placing the geogrid material, whether it is machine direction or cross machine direction for the construction of the reinforced soil wall. So, you have to place the geogrid material in the machine direction, whose tensile strength is more, next the drainage this drainage is very, very important.

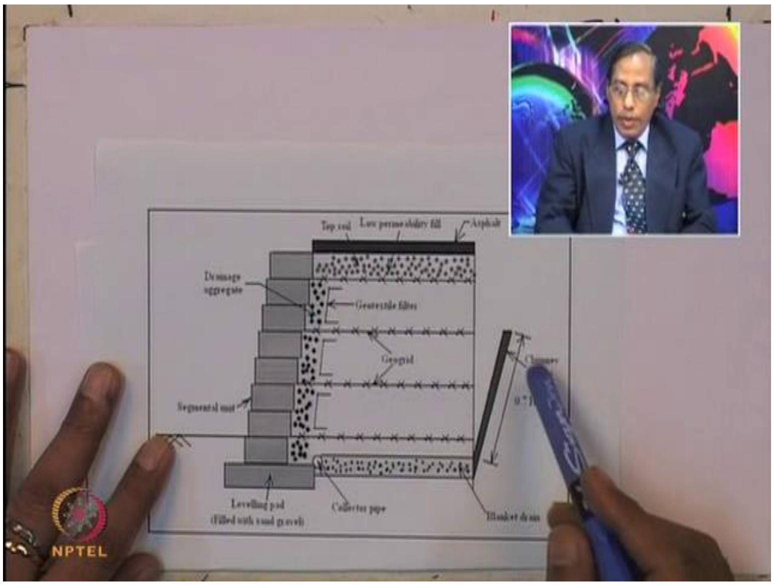
(Refer Slide Time: 28:35)



Most of the reinforced soil structure fail or collapse due to the development of excess hydrostatic pressure at the back of the retaining wall, you can see if this is the wall this is the reinforced soil wall back of the reinforced soil wall there is a possibility for development of excess pore water pressure. And if there is a excess pore water pressure then there is a possibility for the collapse of the geosynthetics reinforced soil wall.

That is why you should provide proper kind of the drainage system drainage is very, very important, so you can provide with the chimney drain, and the back of the retaining wall in conventional you use to 300 400 to 500 millimeter thickness of the good quality of aggregate. Alternative, to that you can provide with a geotextile material either woven or non woven or you can provide with the geocomposite material. So, this is very important Koerner and Soong 2001 documented that 20 out of 26 mechanically stabilized earth wall fail, either by excessive deformation or collapse.

(Refer Slide Time: 29:56)

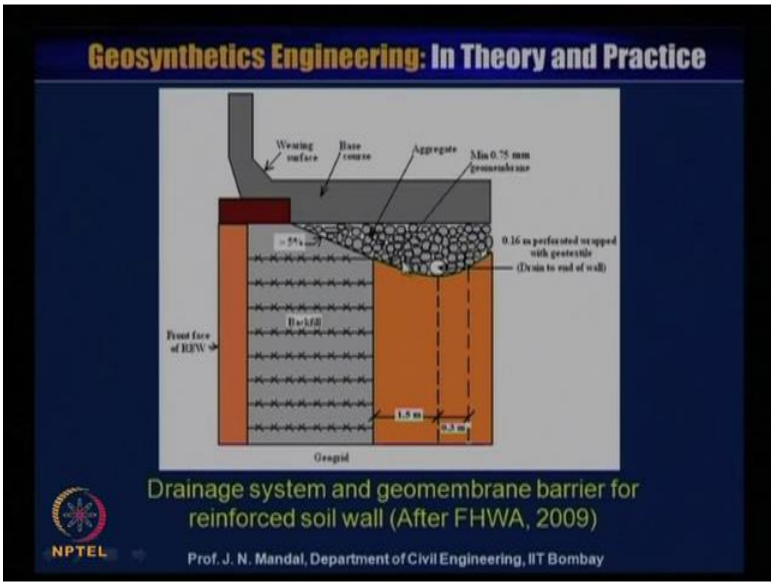


Therefore, proper design of drainage system is needed, so this is a drainage using the blanket with the chimney drain after Colen et al 2006, here is the blanket drain here is the chimney drain, and this drainage you have to provide about 0.78. This is the leveling pad filled with the sand and gravel and this is the segmented retaining wall, and you can see that you have to place the chimney drain at the back of the reinforced soil wall at the base of the wall as a blanket drain and this is the collection pipe.

So, all the water can pass through this collection pipe, and also you can see that back of the facing element where you can provide with the drainage aggregate or the geotextile material, this is the segmental retaining wall, and this is the geotextile material it should not be mixed with the backfill material in the reinforced soil zone. That is why it is provide with the geotextile as a filter, and with this aggregate drainage aggregate that water can pass through, this collection pipe also at the top you can provide with a low permeability fill material, and on the top of that you see the asphalt.

So, water may due to the rain, water may percolate through the asphalt, and it also can pass as a act as a drainage and pass through the collected pipe. So, it require the back of the retaining wall by providing the chimney drain, also at the bottom of the reinforced soil wall which will act as a blanket drain. And also, that back of the facing element, this is as a drainage aggregate and also at the top while you can provide with the low permeability fill material. So, this is important that how you can use the different kinds of the drain to control the drainage system, otherwise most of the cases you find there is a possibility for the failure of the reinforced wall.

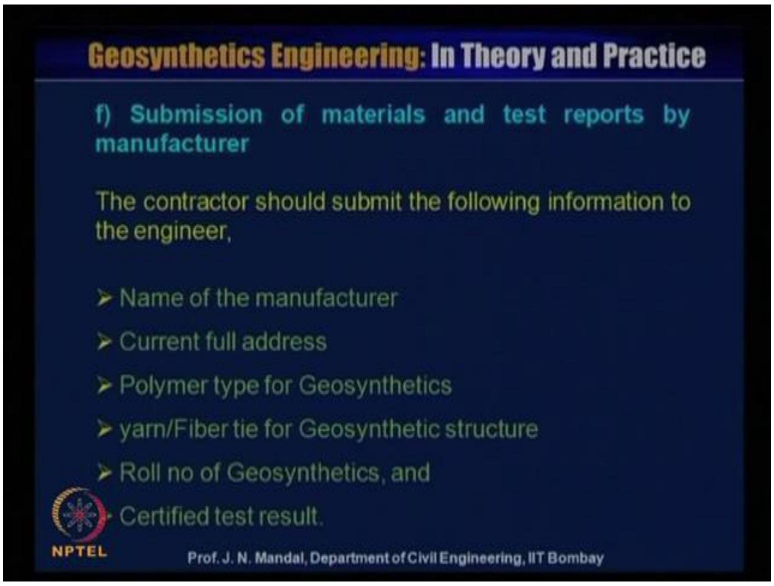
(Refer Slide Time: 32:12)



So, this is also another drainage system, and here you can see that particularly these here, and nowadays also drainage system you can provide with the geomembrane barrier, for the reinforced soil wall after FHW 2009. So, when there is a there is a wearing surface and this is the base course and this is the aggregate, and here is minimum 0.75 millimeter of the geomembrane, you can provide here also you can perforated with the wrap geotextile material. Then if you provide with the impermeable material then water cannot percolate through this to the reinforced soil wall.

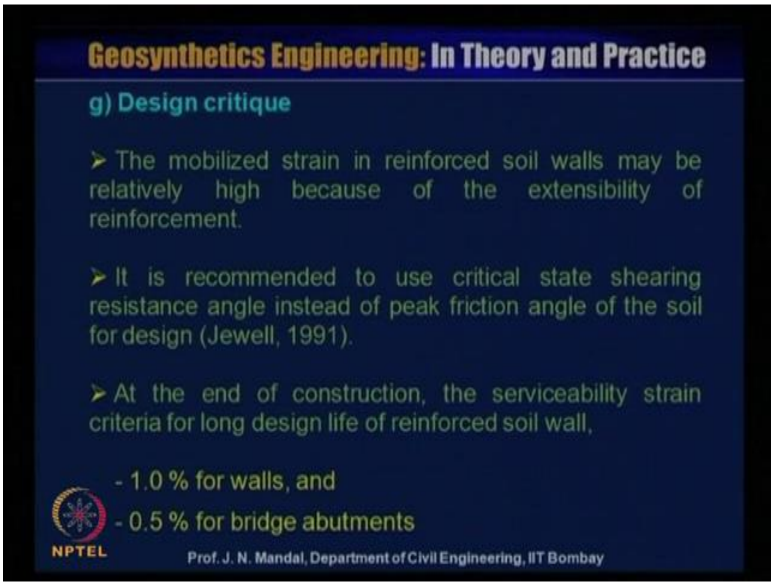
So, the what here that geomembrane will act as a barrier, and then this should be drained out of this wall, so it is also sometimes required on the top of this wall, you can provide with the minimum thickness of 0.75 millimeter thickness of the geomembrane to control the drainage, so water cannot percolate in that case.

(Refer Slide Time: 33:34)



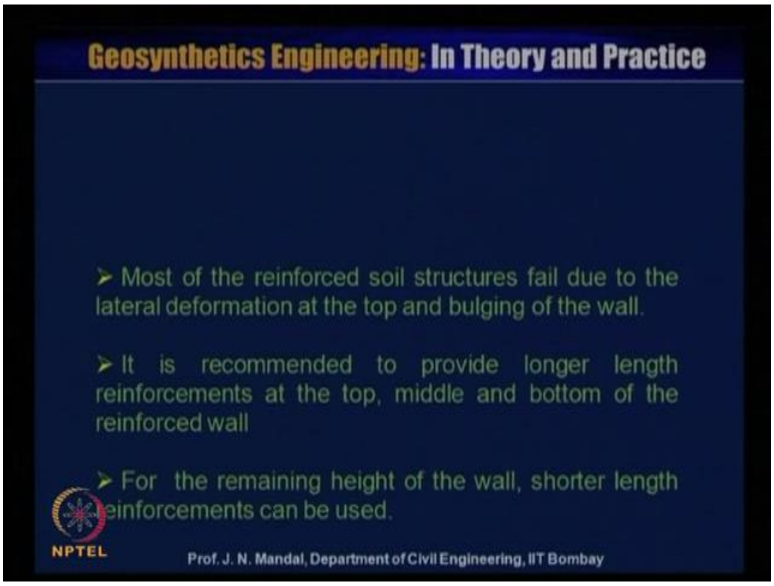
So, summation of material and test report by manufacture, so the conductor should submit the following information to the engineer, the name of the manufacturer current full address polymer type for geosynthetics, yarn or fiber tie for geosynthetics structure roll number of geosynthetics. This is also important, because you should be know that what roll number has been send to the site or to the laboratory for testing and certify the test result.

(Refer Slide Time: 34:15)



Now, design critique the mobilized strength in reinforced soil wall, may be relatively high because of the extensibility of the reinforcement, it is recommended to use critical state shearing resistance angle instead of peak friction angle of the soil, for design the Jewell 1991. At the end of the construction, the serviceability strain criteria for long design life of reinforced soil wall 1.0 percent for the wall and 0.5 percent for bridge abutment most of the reinforced soil structure fail due to the lateral deformation at the top and bulging of the wall.

(Refer Slide Time: 34:56)

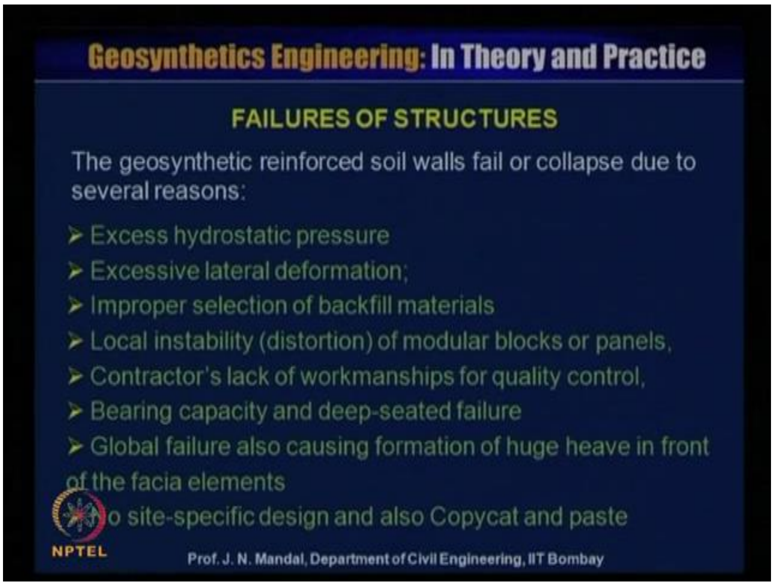


It is recommended to provide longer length reinforcement at the top middle and bottom of the reinforcement, and for the remaining height of the wall shorter length reinforcement can be used. We will show you some example because most of the cases it has been observed the reinforced soil structure fail by the bulging almost at the middle and sometimes due to the seismic affect there is a possibility for the fail at the top.

So, you require proper kind of the reinforcement material, or longer length of the reinforcement material at the top to prevent the kind of the seismic aspect. And also most of the cases as the wall fail as a bulging, so you can provide the longer length of the reinforcement, in the middle and also at the bottom because there is a improvement for the bearing capacity.

So, you can provide the longer length of the reinforcement at the bottom and in between you can reduce the length of the reinforcement or shorter length of the reinforcement can be used. We will give you some of the example, that how you can most economical and stable structure design can be made, where we can use the coverage ratio value whether coverage ratio value is 1 or coverage ratio value 0.6. And how you can save the geogrid reinforcement? How you can make more stable and economical design? So, this we will show you later with some example.

(Refer Slide Time: 37:18)



Now, failure of the structure the geosynthetics reinforced soil wall fail or collapse due to several reason excess hydrostatic pressure, excessive lateral deformation improper selection of the backfill material. So, you have to be careful for the selection of the backfill material, you should follow up the specification and gradation of the material most of the time, whatever you find the locally available material you should not use it.

You have to check, whether that material is suitable or not, whether that material have satisfy the proper gradation or not, I have shown you earlier the different kind of the system, what will be the number of process passing through that material. Whether, it is a 15 percent 0 percent, you check and follow up, if because most of the structure also fail, because for not proper selection of the backfill material, this is also very important.

And local instability distortion of the modular block or the panel, most of the time that it is also very important to check the modular block or the panel, whether it satisfy the local stability or not, because every block or the panel has its own weight. And you have to check for the shear moment and check that whether this is modular block or the panel is satisfying, the local stability criteria or not.

Then contractor’s lack of workmanship for quality control, this quality control is very, very important it require proper kind of the testing, proper kind of the compaction, you require proper kind of the moisture content what moisture content is to be added? How do you compact whether it will achieve the required compaction or not.

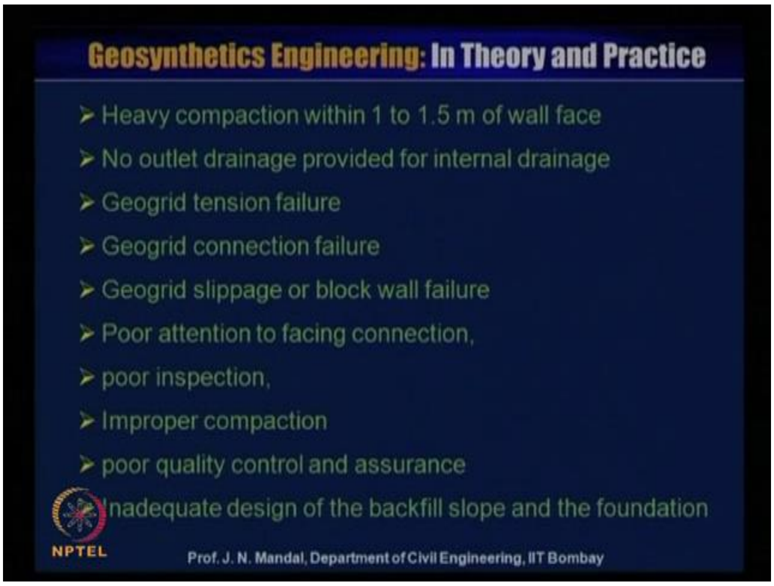
So, this is also very important, that workmanship or quality control, if you do not do proper kind of the work and proper kind of the quality control of the material, then there is a possibility for the failure of the structure, and also you have to check the bearing capacity and deep seated failure. So, you check the bearing capacity you require that proper kind of the soil exploration in detail, and check what will be the bearing capacity of the soil in that locality, if it satisfy the whatever you require then it is, if it is not then you need to improve the soil.

So, there I have I mention different type of the system to improve the soil and you check the bearing capacity, and most of the time also that you do not go for the deep seated kind of the failure or the global stability also failure. So, this one has to be taken care and check, that what will be the factor of safety against the global stability or deep seated failure stability, because for the global failure causing the formation of huge heave in front of the facia element.

This kind of the problem also happen in India, you can see how kind of the heave has been formed in the front of the facing element huge heave, because we do not consider this global stability. So, you should check that global stability problem, no site specific design sometimes it is only is copy cut and the paste it, and also non professional people also are providing with the design, they do not have the knowledge about the civil engineering.

They do not have the knowledge about geosynthetic engineering, sometimes they put it from here and there and paste it and sell the design with 30 percent less, you do not know what kind of the danger what kind of the problem, may occur what kind of the failure may occur for this, so one has to be take care for this, heavy compaction within 1 to 1.5 meter of the wall face.

(Refer Slide Time: 42:09)



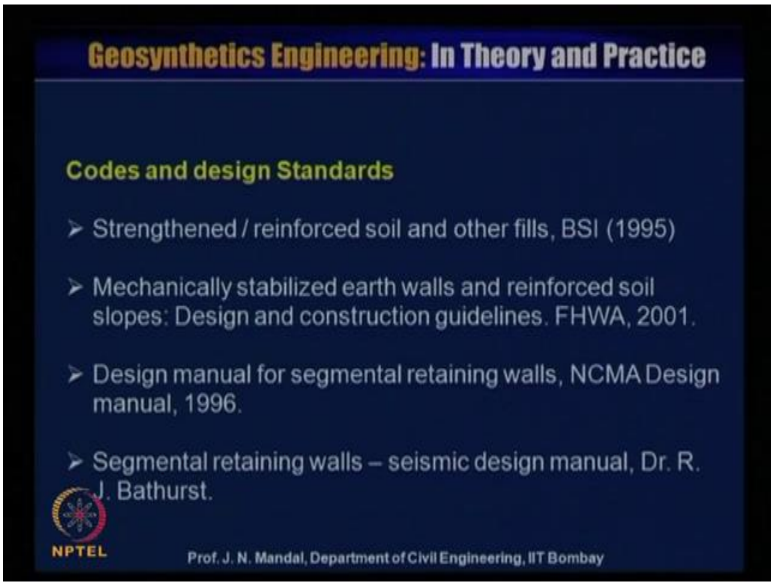
So, you have to be careful for the compaction near to the facing element, I say that you should use the hand roller, whose weight is about 75 k g, if you go for the heavy compaction. Then there is possibility for the bulging you do not know the reason why the bulging also have been formed sometimes, so if we require proper kind of the compaction, you should not go for heavy compaction, within that zone.

No outlet drainage provided for the internal drainage, you find sometimes there has been construction for the reinforced wall, but no outlet you do not know the what the water can pass through, and the placement also of the pipe you can see that you can check up the water level. So, you check that from where it should pass the water through the pipe, so you can provide proper kind of the slope in order that water can be outlet from that zone, so sometimes you find there is no outlet.

And then there is a possibility for the failure and this reinforced soil structure fail due to tension failure, then geogrid may be I say collection failure there is a geogrid slippage or block wall failure block wall itself will fail. And sometimes also the placement of the block properly sometimes the block has been placed upside down, and it happen and this structure collapsed when you look nearer to the wall you find the block has been placed upside down, so that has reason that there is a possibility for the failure.

Then poor attention to facing connection, so when you connect this geogrid material with the facing element, you have to see what kind of the connection you are providing whether, you are placing properly or not and poor inspection. So, sometimes nobody bother about no engineers, no qualified engineers are there to inspect what is happening, and sometimes improper compaction. You require 90 95 percent compaction the contractor finish with 80 85 percent compaction. So, there is a possibility for the failure, and poor quality control and the assurance, you need proper quality control from the manufacturer side from the contractor side and inadequate design of the backfill slope and the foundation.

(Refer Slide Time: 45:14)



You require the proper design, you should follow the some of the code and design standard, which we have also follow in this course that is strengthen and reinforce soil and other fill British standard institute 1995, mechanically stabilized earth wall and reinforced soil slope design and construction guideline FHWA 2001. Design manual for segmental retaining wall that is NCMA design manual 1996, segmental retaining wall seismic designing manual by doctor R. J. Bathurst.

So, you can follow the some of the code and design standard there are many, many different design standard individual country have their own design standard, so most of the cases that we follow up this standard. Particularly, the BSI and the FHW, and then if you follow up properly and then you will be successful, for the design of reinforced soil wall. So, what we cover here that for the reinforced soil wall, how to design and how you can place the geogrid material? What kind of the failure may occur?

There may be failure for the sliding, there is a failure, for the overturning, there is a failure for the bearing capacity, there may be failure for the deep seated or due to the global stability. You require proper kind of the quality control, you require for the quality control from the manufacturer side, quality control from the contractor side, also you require proper kind of the design and proper kind of the selection of the geogrid material. Also we have learnt that what should be the embankment length or the angle length of the design.

So, if it is a anchorage length design how you can calculate that anchorage length design how you can calculate the what will be the total length of the geogrid, also you can you know that how to calculate the spacing between the geogrid reinforcement. That means, spacing is the S of v and also you have to check that what will be the connecting strength, when it is the seismic condition, when it is a static condition and sometimes that structure collapse, because due to the improper connection between the geogrid and the facing element.

So, one has to be careful for the connecting strength, also it is required for the proper selection of the backfill material, so it require proper kind of the gradation of the material, if we wrongly select the backfill material, which will not satisfy the criteria. So, first of all you have to check that what kind of backfill material you want to use for the construction side, so you cannot use the any material as you like it, because most of the cases this structure collapse, because for improper selection of the backfill material.

Apart, from the this backfill material you require proper kind of the drainage system, so you require the drainage system of the back of the retaining wall, at the base of the retaining wall, and also at the back of the facing element, and also at the top of the reinforced soil wall. Now, also you can use the kind of the very minimum thickness of the geomembrane material, in which water cannot percolate from the top to the bottom of the geogrid reinforced soil wall.

So, these are the some of the important issue, which we have to keep in mind and also we will focus next that how you can design? Means you can design more economical design, how the length of the reinforcement can be reduced? How we can place the reinforcement at the different zone or the different layer?

As, I mention that you can provide with the longer length at the top, and also at the middle, and also at the bottom, because you can provide with the longer length, at the middle, because the most of the cases it has been observed there is a possibility for the failure of the structure due to the bulging. To control the bulging, so you can provide with the longer length of the reinforcement at the middle of the reinforced soil retaining wall, and also due to the seismic aspect and their uses sharing resistance can develop on the top of the reinforced soil wall, and that was the reason that you can provide with the longer length on the top of the reinforcement.

And due to the foundation soil problem if soil is not in good condition, so you can also provide with the longer length at the bottom of the reinforcement. And in between you can reduce the length of the reinforcement, so you can make a more economical and the stable design. You can also provide with the system like a cover ratio, that is C of r value, so this also will reflect that cost of the reinforced soil structure, you can provide with the 60 percent of the geogrid reinforcement, instead of 100 percent of the geogrid reinforcement.

It may be 60 percent it may require may be little bit high strength of the geogrid material with respect to 100 percent of the geogrid material. But, if you can think in terms of the overall cost and the quantity of the geogrid material, it may be the suitable or economical for the 60 percent of the geogrid material. So, we require proper design proper selection of the material and also installation technique, so next we will discuss about the some example that how we can make use of the design with the different coverage ratio, with this I ended up the lecture today. If you have any question?

Thank you for listening.