Geosynthetics Engineering: In Theory and Practices
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Module - 06
Lecture - 27
Geosynthetics for Reinforced Soil Retaining Walls

Dear students, welcome to NPTEL phase 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 number 27 Geosynthetics for Reinforced Soil Retaining Wall.

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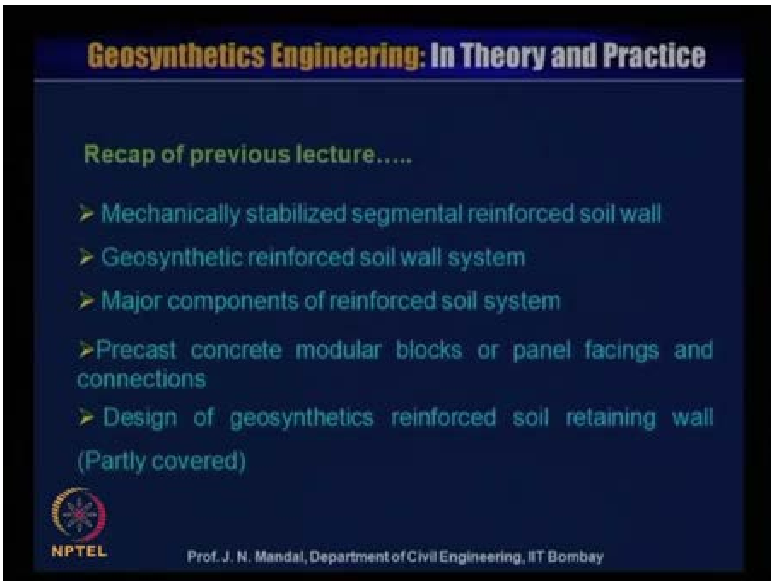

I will now show the recap of the previous lecture, we covered mechanically stabilized segmental reinforced soil wall, geosynthetics reinforced soil wall system, major component of reinforced soil system, precast concrete modular block or panel facing and connection, design of geosynthetics reinforced soil retaining wall partly covered.

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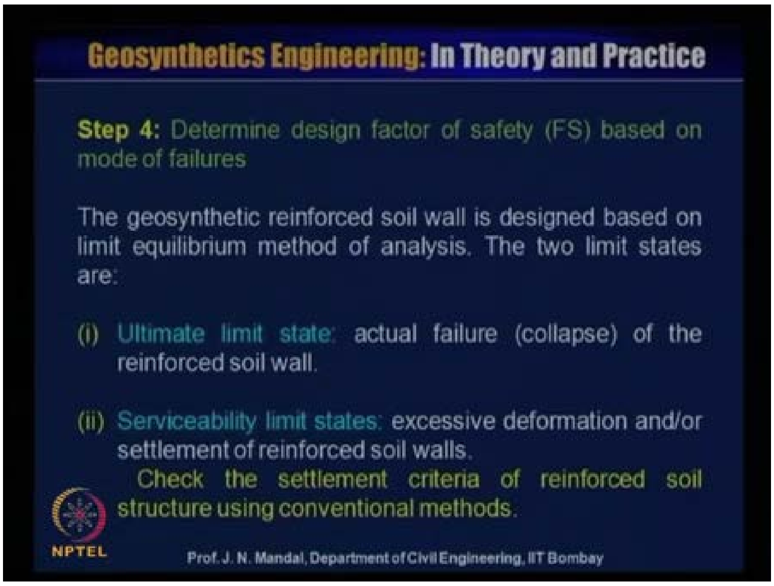

Now, step 4, determine the design factor of safety based on mode of failure, the geosynthetics reinforced soil wall is designed based on limit equilibrium method of analysis. The two limit state are, one ultimate limit state, actual failure or collapse of the reinforced soil wall and two serviceability limit state that means, excessive deformation and or settlement of reinforced soil wall. You have to check the settlement criteria for reinforced soil structure using the conventional method.

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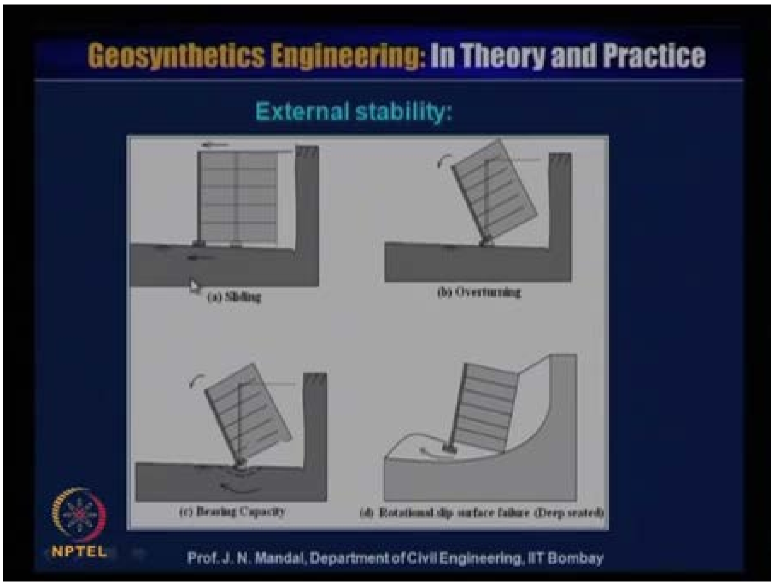

Now, we will discuss about the external stability, in this course we will cover the three parts and part 1, which we will cover the mechanically we civilized reinforced wall, in which we will use this ((Refer Time: 02:53)) geogrid material and this have a different strength. So, we will see, how we can design the geosynthetics reinforced soil wall system using this geogrid material. So, this is the kind of geogrid material, you can have the different strength and different types of the geogrid material.

So, it also has a tensile strength in the machine direction as well as tensile strength in the cross machine direction, also you have to be taken care about the elongation of the geogrid in the machine and the cross machine direction. So, we will use mainly this kind of the geogrid material in part 1. We also use this non woven geosynthetics ((Refer Time: 04:03)) material, this is non woven geotextile material and we also design the reinforced soil wall using this kind of nonwoven geotextile material.

And you can see, this is the non woven geotextile, you can wrap it, this you call the nonwoven geotextile material. Also we can use that woven geotextile material ((Refer Time: 04:30)) and it has also in the machine direction and the cross machine direction and you can also construct this reinforced soil wall using this woven geotextile material. So, we will design also using this material, how to design the reinforced soil wall, so this is the part 1, which we will cover with the geogrid and nonwoven geotextile material and woven geotextile material.

And in the part 3, we will cover this gabion as a ((Refer Time: 05:21)) facing element, which we can use the gabion as a facing element, also you can have in the form of the strip, also the gabion has a box as a facing element. So, this we can also cover later on and we will see the design, how you can design the gabion retaining wall using this kind of the gabion material. This is galvanized mild steel, PVC coated, it is hexagonal in shape, so this also we will discuss.

And next, we will use this ((Refer Time: 05:58)) waste bottle, this is the plastic bottle, it is kind of the cellular reinforcement. This give the very good confinement effect, this you can use as a planar form and we will design this also using the cellular reinforcement, which is made of the waste bottle. You can have also in the different diameter and different height of the material and how you can design using this waste plastic bottle, either it is in the mat form, also you can use also in the strip form ((Refer

Time: 06:37)) like this we can use it. It is also the flexible, it has also the different shape and the size, so you can use also has as a reinforcement.

So, in the part 1, we will discuss with the geogrid reinforced soil wall, so when we will design then, it is required the external stability. You know external stability there is a possibility of the geosynthetic reinforced soil wall is sliding, you can see that ((Refer Time: 07:15)), how the geosynthetic material is sliding. So, you have to check up, what will be the factor of safety against the sliding then, you can see this here, that how the wall is overturning, there is a possibility for failure for the overturning.

So, you have to check, what will be the factor of safety against overturning, similarly also it may fail due to the bearing capacity. If the soil is very soft, it is required to improve the bearing capacity of the soil or the foundation soil. So, also you have to check, what will be the factor of safety against bearing capacity and it is also required most of the time. we do not consider for checking the rotational slip surface, failure or deep seated failure or global failure.

We can see that, failure line is passed beyond the reinforced zone, these also is required to check, so you require to check that, what will be the factor of safety against the global stability or rotational slip surface stability or deep seated.

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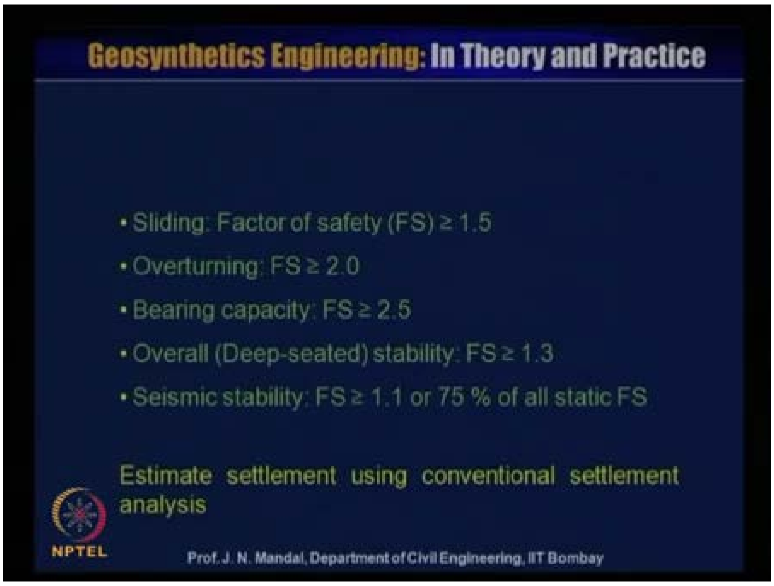

So, for sliding factor, so you require some factor of safety, it should maintain that, what should be the factor of safety against sliding and it should satisfy this criteria for the design of the reinforced soil wall. So, for sliding, factor of safety should be greater than equal to 1.5, for overturning you require factor of safety greater than equal to 2, bearing capacity you require factor of safety greater than equal to 2.5, overall or deep seated stability or global stability you require factor of safety greater than is equal to 1.3, the same time you require the seismic stability.

So, this factor of safety should be greater than equal to 1.1 or 75 percent of all static factor safety. So, if you know what will be the factor of safety in the static due to the sliding, overturning, etcetera then, you have to check up the seismic stability and the factor of safety, atleast it should be 75 percentage of the static factor of safety. It is also essential to estimate the settlement and this settlement you can use the conventional settlement analysis.

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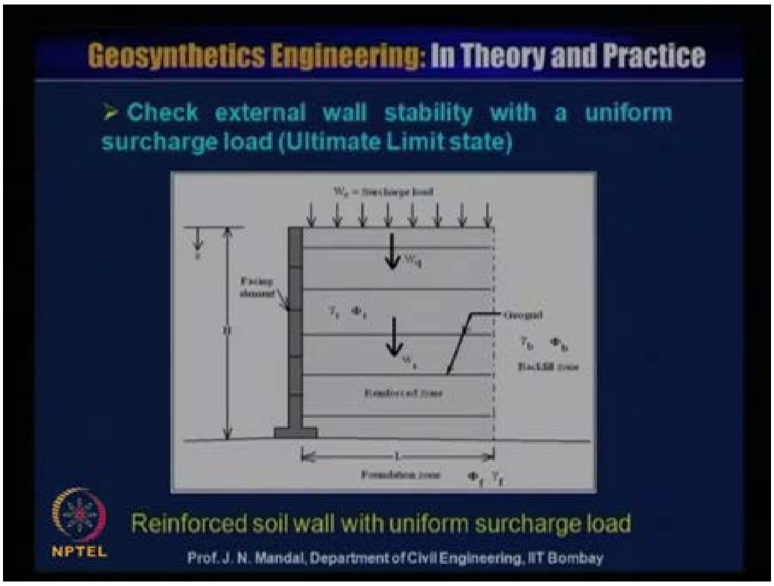

Now, when we talk about the external stability, here you want to check the external wall stability with a uniform surcharge load or ultimate limit state. So, this is the reinforced soil wall with the uniform surcharge load, this is the wall, this we will call the facing element and this is the height of the wall is capital H. So, you can calculate at any depth, what will be the pressure, you can also calculate and this is the number of the layer of the reinforcement, this is the geogrid here as a reinforcement, I showed you what is the geogrid material.

You require what should be the property here in the reinforced soil zone, here gamma r the unit weight of reinforced soil, phi r this angle of friction of the reinforced soil zone and then, you require the back of the wall, this is the backfill zone. So, what will be the unit weight of the backfill soil gamma b and friction angle of the backfill soil phi b. You also require the foundation soil, what will be the properties of the foundation soil and foundation soil this unit weight of foundation gamma of f and the angle of friction of foundation soil is equal to phi into f.

And there also will be the development of the friction between the reinforcement and the soil, which you can express also as a delta of r. Apart from this, there will be surcharge load, here we are considering the only uniform surcharge load, which is designated as W of s with an slope angle also it can be, so it can change the equation. So, here initially we are considering for external or stability with the uniform surcharge load there.

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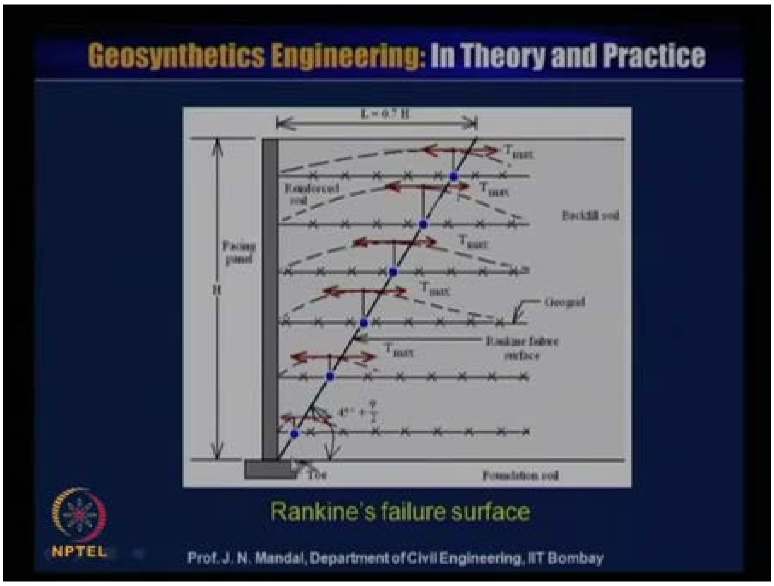

And this is showing the Rankine failure surface, we have discussed already how you can obtain the Rankine failure surface line. And if this is, which is making at an angle of 45 degree plus phi by 2 and this is the toe and this if the height of the wall is H and this distance will be equal to 0.7 times the height of the wall that means, 0.7 H.

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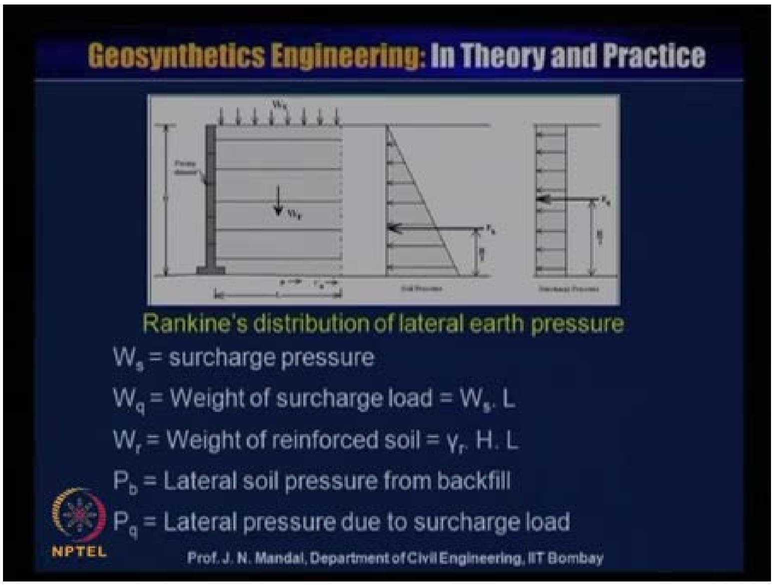

Now, Rankine's distribution of lateral pressure if this the wall, so we have to check, what should be the pressure on the wall, what will be the soil pressure, what will be the surcharge pressure.

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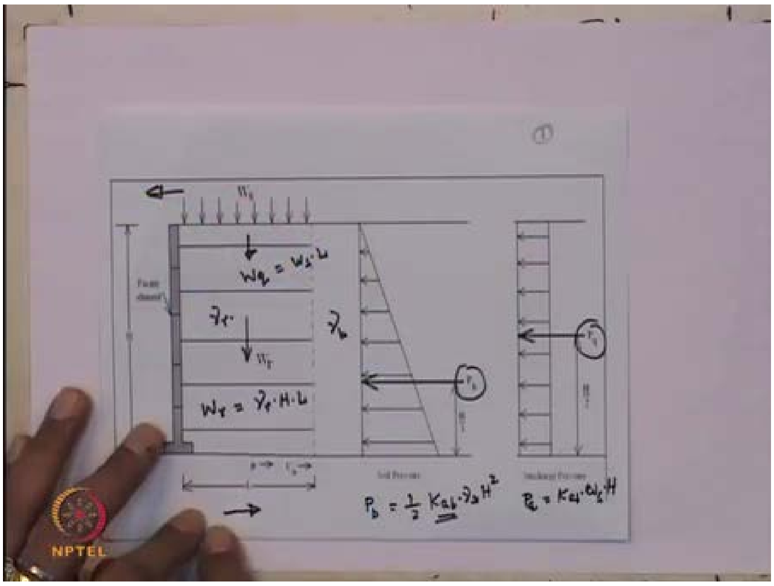

So, here I am showing like this, if this is the wall whose height is equal to H and this is the facing element and this is the length of the geogrid reinforcement is the L and this is the W h is the surcharge pressure. And this you have to check, what will be the weight of the surcharge load, if weight of the surcharge load is equal to W of q, so W of q will be equal to W s into length of the reinforcement is L. That means, weight of surcharge load W q will be equal to W s into L and this W r, this is the weight of the reinforced soil.

So, weight of the reinforced soil means, you know what will be the length, you know what will be the height and you know what is gamma of r here in the reinforced soil zone, if this a gamma of r. So, weight of the reinforced soil that is, W of let us say r, will be equal to gamma of r into H into L. So, the weight of the wall will be gamma r H into L, but in case of the surcharge load, if the weight of the surcharge load is W of q, W of q will be equal to W s into L, this is W s and this is the length of the geogrid material.

And we will see that, there is a soil pressure, so lateral soil pressure from the backfill, this is the backfill zone, so there will be the lateral soil pressure on the backfill zone. And this soil pressure distribution will be the triangular in pattern and this P b is the lateral soil pressure from the backfill and which is acting at a distance of one third of the height of the wall. If height of the wall is H and then, this distance from the base of the wall will be H by 3.

So, this is the soil pressure, which will acting on the backs of the wall, so this is the lateral soil pressure from backfill, which is designated as P b. Apart from this, there is a surcharge pressure, so we check what will be the lateral pressure due to the surcharge load. So, such for due to the surcharge load, you know that there will be uniformly distribution of the surcharge pressure.

And this surcharge lateral pressure due to the surcharge load is designated as P of q and this lateral pressure due to the surcharge load, which is acting at a distance of the wall and this distance is H by 2, so H is the height of the wall. So, you know that, what are the pressure, what it is acting, so these we have to taken into consideration for the design. Apart from this, you see that, if the wall moves then, there will be a development of the friction.

So, this is mu for tan delta, you can say that what will be the coefficient of shearing resistance between the soil and the reinforcement, so that delta is called angle of shearing resistance between soil and the reinforcement. If there is a possibility for any cohesive soil then, C a also you have take into account, so this C a what we call here as a adhesion between soil and the reinforcement. So, if it is the entirely cohesionless soil then, you can take only consideration for the mu on the tan delta, what we call the coefficient of shearing resistance between soil and the reinforcement.

But, if there is a both cohesive and the cohesionless soil then, you have to consider both these factor mu and also the adhesion. When it is interact with the other material, we say that it is a adhesion, so C a adhesion between the soil and reinforcement. So, you have to consider both these factor, one is the friction factor, another is the adhesion factor, so this you have to be considered into the design. Now, if the wall slide, so you have to calculate that, what will be the factor of the safety against the sliding.

So, wall may move in this direction, so you have to calculate, what will be the factor of safety against the sliding. So, factor of safety against the sliding is equal to summation of horizontal shearing resisting force divided by summation of horizontal driving force. So, what are the resisting force and what are the driving force, so total force is that P b and the p q. So, what is P b, P b is equal to half into K a b into gamma b into H square is gamma b here, the backfill soil unit weight of the soil.

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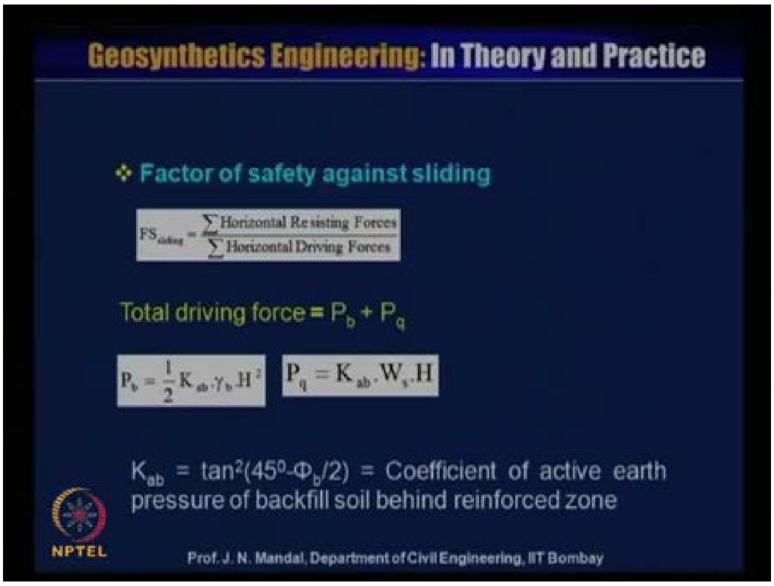

So, P b will be equal to gamma b half K a b gamma b into H square, so you can write that, P b is equal to half into K a b into gamma b into H square. Similarly, P q due to the surcharge, so P q also you can write is equal to K a b into W of s into H. So, where K a b is equal to tan square 45 degree minus phi b by 2 or coefficient of active pressure of backfill soil beyond reinforced zone. So, we know that, what should be the phi b value, so you can calculate what will be K a b value.

If you know the K a b value. so you can calculate that, what should be the height is known to you, gamma b is also known to you, so you can calculate P b. Similarly, you know what will be the surcharge load, you know the height of the wall, you know the K a b, so you can calculate the P of q, so all the parameter can be calculated.

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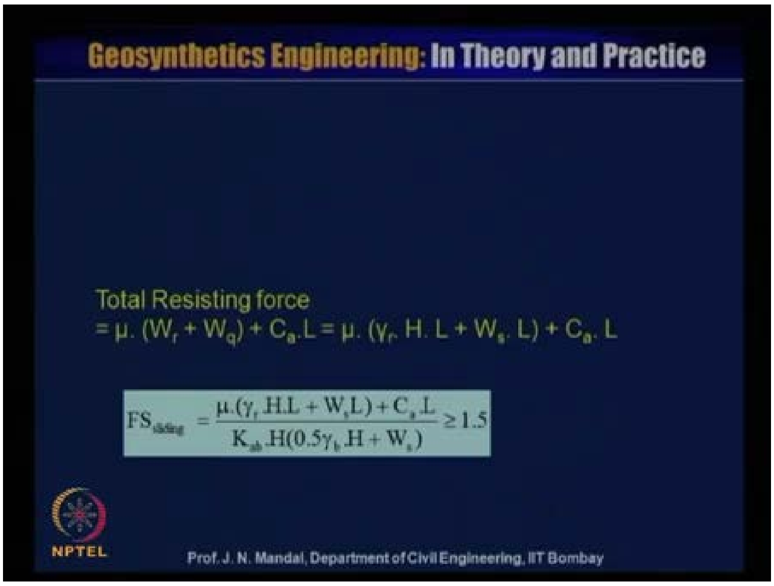

Now, this is the force and there will be also the resisting force, this is resisting force, so resisting force will be mu into weight due to the reinforced soil wall and weight due to the surcharge. That means, mu into W r plus W q plus, due to the adhesion this C a, this C a into L, so these are the total resisting force. So, resisting force can be written mu into W r mean, gamma r H L plus surcharge load W q is equal to W s into L plus C a into L.

So, you can see here, this total resisting force, so you can write mu into W r plus W q plus C a into L is equal to mu W r means, gamma r H into L plus W q is W s into L plus C a into L. Now, if you substitute this equation, that factor of safety against sliding, horizontal resisting force by horizontal driving force. So, driving force you know, this plus this and the resisting force you know this, so if you substitute, you can have this equation, factor of safety of against sliding.

That is, mu into gamma r H L plus W s into L plus C a into L divided by K a b into H 0.5 gamma b into H plus W s. And this factor of safety against sliding should be greater than equal to 1.5 and if there is no adhesion, so then C a will be 0, so only you take into consider this one. So now, you will able to calculate that, what will be the factor of safety against this sliding.

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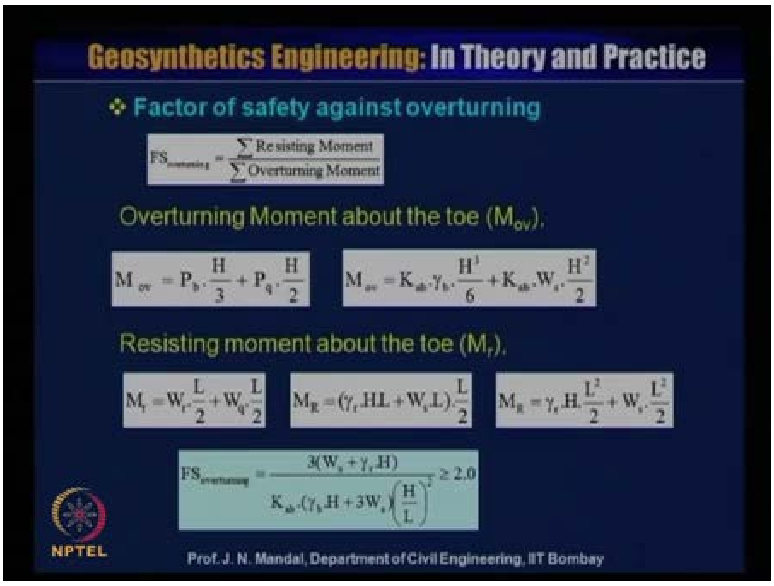

Now, we will discuss factor of safety against overturning, so factor of safety against overturning means, is equal to summation of the resisting moment divided by summation of overturning moment. Now, what is overturning moment about the toe, so you have to take the moment at the toe.

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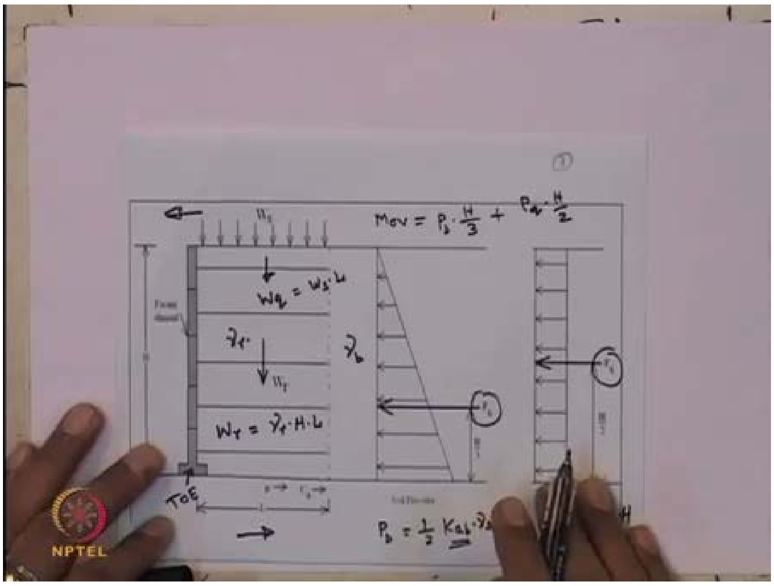

For example, this you know ((Refer Time: 23:42)), this is the toe and you wanted to take the overturning moment not sliding, there is a overturning moment. So, overturning moment above the toe, which you can designated at M of o of v, so this M of o v will be equal to, you take a moment at the toe that mean, P b into H by 3, this distance is H, P b is the force due to the soil. So, P b into H by 3 and due to surcharge this is P q and this distance is equal to H by 2 that is, P q into H by 2.

So, overturning moment M ov will be equal to that means, this will be equal to P b into H by 3. So, you can write that P b into H by 3 plus due to the surcharge, you take the moment at the point toe that means, this is P q into H by 2. So, again you know this value of what is P b and what is P q, you can see here that ((Refer Time: 25:02)), P b you have calculated earlier, K a b into gamma b into H cube by 6, because we know that, what is P b here and also you know what is P q here.

So, if you substitute this value then, you can obtain that P b into H by 3 will be this part and then, P q will be the K a b into W s into H square by 2, we have calculated what is P q. So, you know that, what will be the overturning moment about the toe and also you require resisting moment about the toe. So, resisting moment let us say here that, weight of the wall and this is due to the weight of the surcharge. So, here if the weight you take a moment here, this is the resisting, so this is passing through the middle of this wall.

So, if this is W r and this will be L by 2, so resisting moment if you take the moment at the toe, so W r into L by 2 plus due to the surcharge this is W q, W q into L by 2. Now, we know that what is W r, you know gamma r H into L, you know what is W q, W s into L. So, if you substitute this value here, you can see that ((Refer Time: 26:35)) M r is equal to gamma r H into L plus W s into L into L by 2. So, if you calculate, you can have M r is equal to gamma r H into L square by 2 plus W s L square by 2.

Now, you find out what will be the factor of safety against overturning, you know the equation of factor of safety overturning is summation of resisting moment by overturning moment that means, M r divided by M o v. So, you substitute all these value and you can obtain the factor of safety against overturning that is, 3 into W s plus gamma of r into H, this divided by K a b into gamma b into H plus 3 W s into H by L whole square. And this factor of safety value against overturning should be greater than equal to 2, so it should satisfy this criteria against this overturning.

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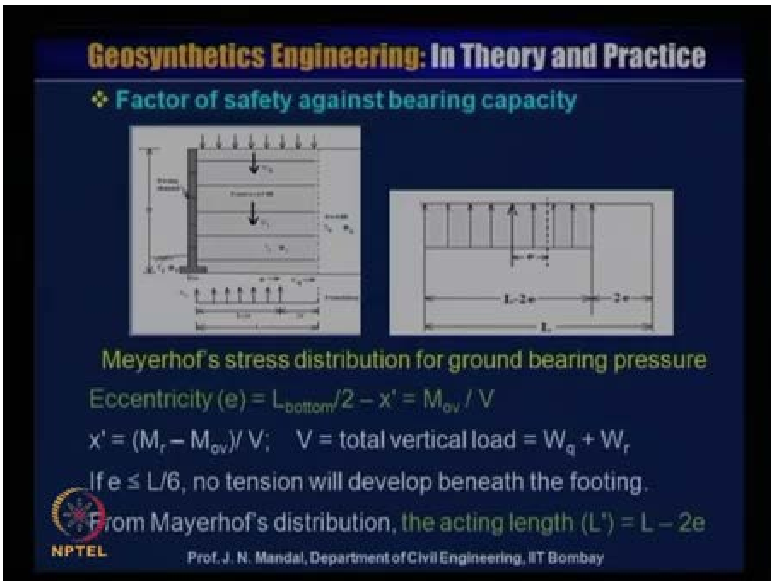

Now, factor of safety against that bearing capacity, if the foundation soil is poor and how you can calculate the bearing capacity of the soil.

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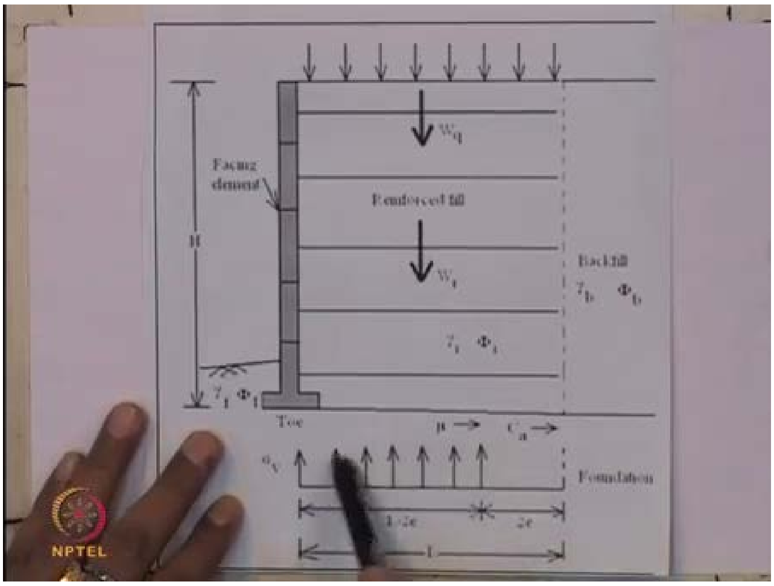

So, what we use, this part the foundation soil, so we take that layer of stage distribution for ground bearing pressure. And we have to calculate that, what should be the eccentricity that means e, e is important here. Now, eccentricity e can be written as, what will be the length of the bottom, this divided by 2 minus of x bar and I am showing here that, L bottom divided by 2 minus X bar is equal to ((Refer Time: 28:36)) M ov by V and this X bar is equal to M r minus M ov divided by V, V is the total vertical load.

So, you know the what will be the total vertical load, so that total vertical load will be equal to W q plus W of r. So, whatever the vertical load V will be equal to W q plus W of r and you have to calculate, what should be the eccentricity and this eccentricity value is should be less than equal to L by 6 and no tension will develop beneath the footing. So, from the Meyerhof's distribution, the acting length, if you consider L dash, L dash will be equal to L minus 2 e. So, you have to consider always that acting length that means, L minus 2 e zone only and this Mayerhof's pressure distribution for ground bearing capacity is recommended.

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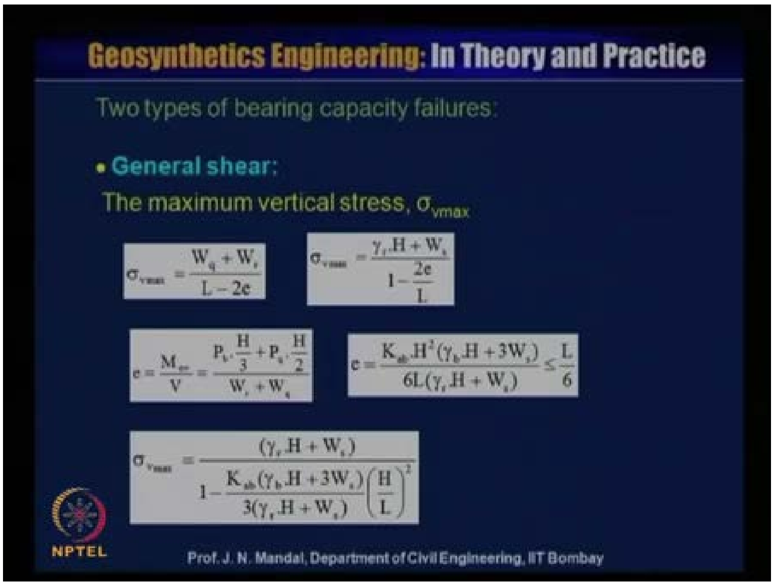

Now, there is a possibility for two types of the bearing capacity failure, one is the general shear or the maximum vertical stress. So, sigma v maximum is equal to sigma v maximum divided by W q plus W r divided by L minus 2 e. So, it acts in, that acting zone only L minus 2 e, so sigma v maximum is equal to, you know that what is W of q, you know W s, you substitute and then, you can have gamma r into H plus W s divided by 1 minus 2 e by L and eccentricity M ov by V.

So, you know this P b into H by 3, this is P q into H by 2 divided V means, W r plus W q and from here, you can calculate that, what will be the e value. E value will be the K a b into H square into gamma b into H plus 3 into W s divided by 6 L into gamma of r into H plus W s and it should be less than equal to L by 6, it should be and then, you can calculate what will be the sigma of v maximum. So, you substitute this e value in this equation here and then, you can calculate this sigma v maximum, which is sigma v maximum is equal to gamma r into H plus W s divided by 1 minus K a b gamma b into H plus 3 W s divided by 3 into gamma r into H plus W s into H by l whole square, so you know what will be the sigma v maximum.

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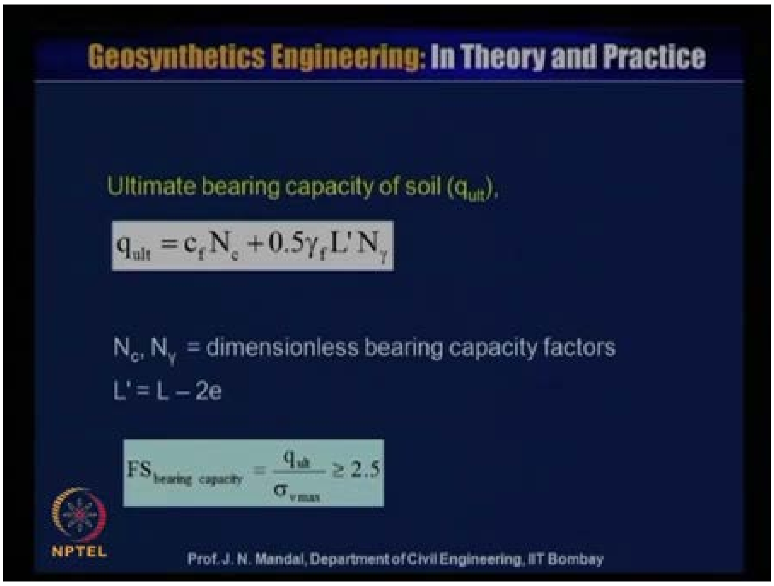

Now, you have to calculate that, ultimate bearing capacity of the soil or q of ultimate and this is known to you. So, ultimate bearing capacity q ultimate is equal to c f into N c plus 0.5 gamma f into L dash into N gamma, for L dash is equal to L minus 2 e, e is eccentricity. So, you know eccentricity, you know what will be the length of the reinforcement, so you can calculate what will be the L dash and here, N c and N gamma are the dimensionless bearing capacity factor.

So, then you check, what will be the factor of safety against bearing capacity, is equal to q ultimate divided by sigma v maximum and it should be greater than equal to 2.5, if it satisfied then, it is ok.

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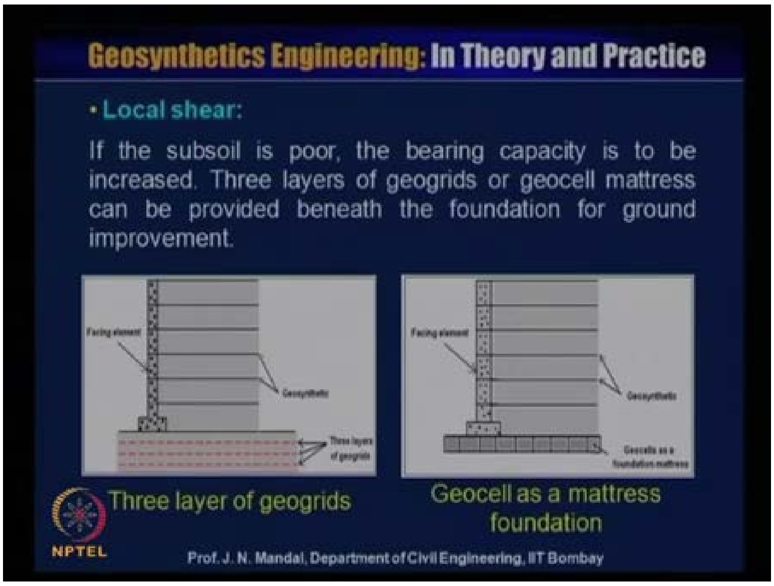

Now, for the local shear, if the sub soil is poor, so bearing capacity is to be increased, so what that you can provide with the three layer of the geogrid or the geocell mattresses, can be provided beneath the foundation for ground improvement. So, there will be the different types of the ground improvement, you can go ahead with the prefabricated vertical drain, you can go ahead with the n case stone column, which we will show you later, how to design the n case stone column.

And also you can go for the number of the layer of the reinforcement to improve the bearing capacity of the foundation soil or you can go for the geocell, which will give the confinement effect, very good confinement effect. So, geocell or mattresses of the foundation, there are different system for the ground modification or the improvement, so we can adopt and you check the local shear.

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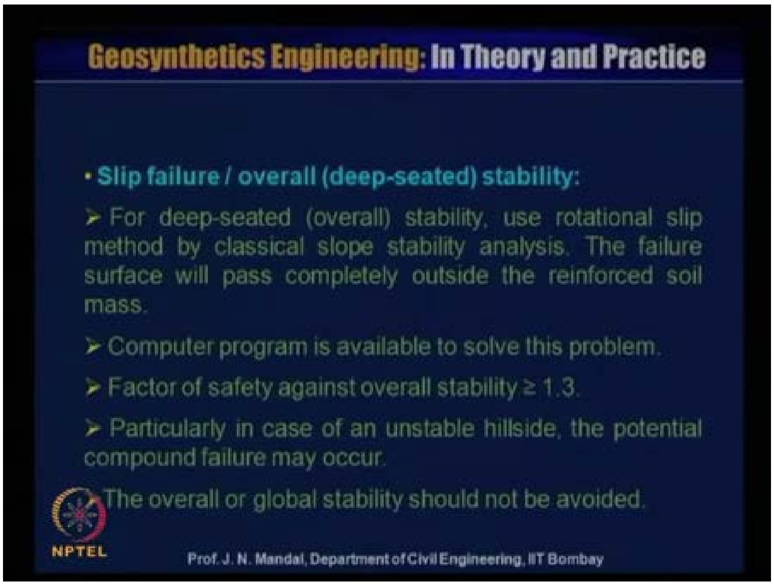

Now, next is the slip failure or overall of deep seated stability or global stability, for deep seated or overall stability, use the rotational slip method by classical slope stability analysis. Failure surface will pass completely outside the reinforced soil mass, computer program is available to solve the problem. So, you check that, what will be the factor of safety against overall stability and that factor of safety against overall stability should be greater than equal to 1.3. Particularly in case of an unstable hillside, the potential compound failure may occur, the overall or global stability should not be avoided.

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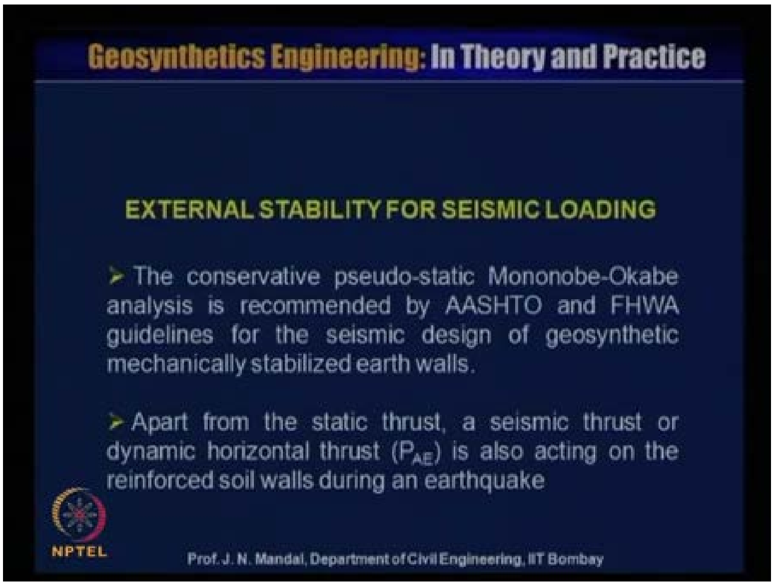

Now, external stability for seismic loading, the conservative pseudo static Mononobe Okabe analysis is recommended by AASHTO and FHWA guideline for the seismic design of geosynthetic mechanically stabilized earth wall. Apart from the static thrust, a seismic thrust or the dynamic horizontal thrust, which is designated as PAE, is also acting on the reinforced soil wall during an earthquake. So, most of the time, we do not consider the seismic effect on the reinforced soil wall.

But, it is very important to consider the seismic effect on the wall, because today lot of earthquake related problem on the infrastructure, so you should consider the seismic effect.

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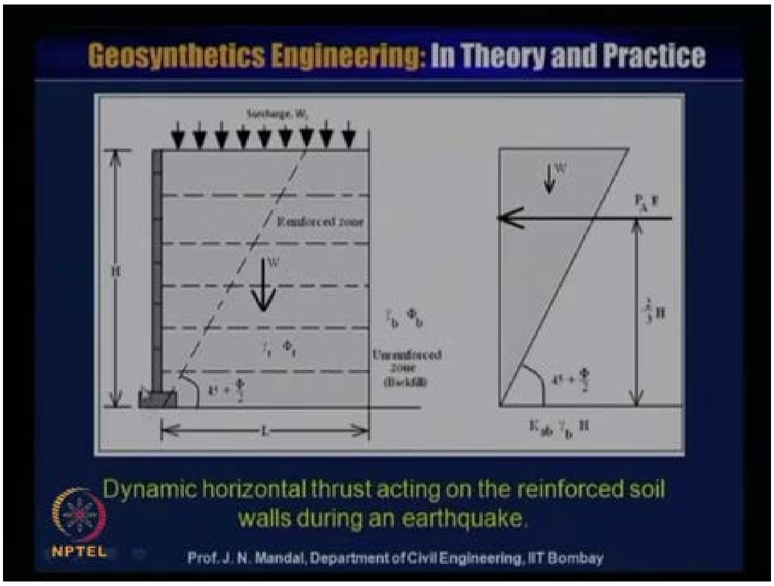

So, this is the reinforced soil wall, as usual there is a surcharge load, this is the length, this is the height of the rain wall. So, this is the dynamic horizontal thrust, which is acting on the reinforced soil wall during an earthquake, here this distribution is slightly different. So, it is inverse, you can see it is increasing like this and this is the dynamic horizontal thrust PAE, which is acting at a distance of 0.66 or two third of the height of the wall.

So, this thrust we will consider two third of the height of the wall, so this you should remember in case of the dynamic horizontal thrust when it is acting on the reinforced soil wall and what the dynamic thrust is acting and what will be the distance from the base of the wall. So, this is two third of the height of the wall, now we have to calculate that dynamic force.

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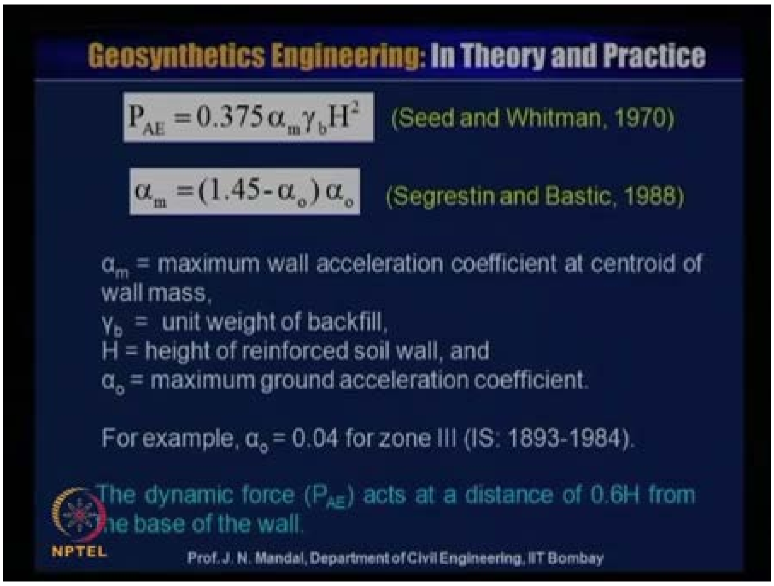

So, dynamic force you have to use the PAE is equal to 0.375 alpha m gamma b into H square, which is given Seed and Whitman 1970. And then, the alpha m is equal to 1.45 minus alpha 0 into alpha 0, this is Segrestin and Bastic 1988, where alpha m is the maximum wall acceleration coefficient at the centroid of the wall mass and gamma b is the unit weight of the backfill and H is equal to height of reinforced soil wall. And alpha m is equal to 1.45 minus alpha 0 into alpha 0, where alpha 0 is the maximum ground acceleration coefficient.

For an example, in a zone 3 as per IS code 1893 to 1984, suppose for a particular zone if that alpha 0 value is 0.04, so you can calculate what is alpha of m, alpha m is equal to 1.45 minus alpha 0 into alpha 0. If you know the alpha m value, you can substitute this alpha m value in this equation and gamma b and H is known. So, you can easily calculate what will be the dynamic force, which is act at a distance of two third or 0.6 times the height of the wall from the base of the wall, so that you can calculate.

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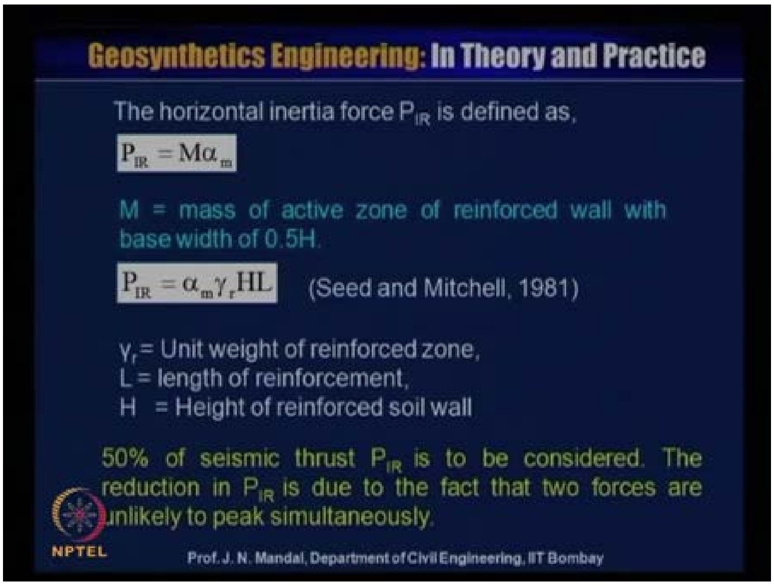

Now, the horizontal inertia force, that is P IR, this defined as P IR is equal to M into alpha m, where M is the mass of active zone of reinforced wall with base width of 0.5 H or P IR is equal to alpha of m gamma r H into L, this is Seed and Mitchell, 1981. So, this is gamma r is the unit weight of the reinforced zone, L is equal to length of the reinforcement, H is equal to height of the reinforced soil wall.

So, here one thing interesting to note that, that 50 percentage of seismic thrust that is, P IR is to be considered it. So, reduction in P IR is due to the fact that, two forces are unlikely to peak simultaneously. So, here you should remember that, 50 percent of seismic thrust P IR is to be considered into the design.

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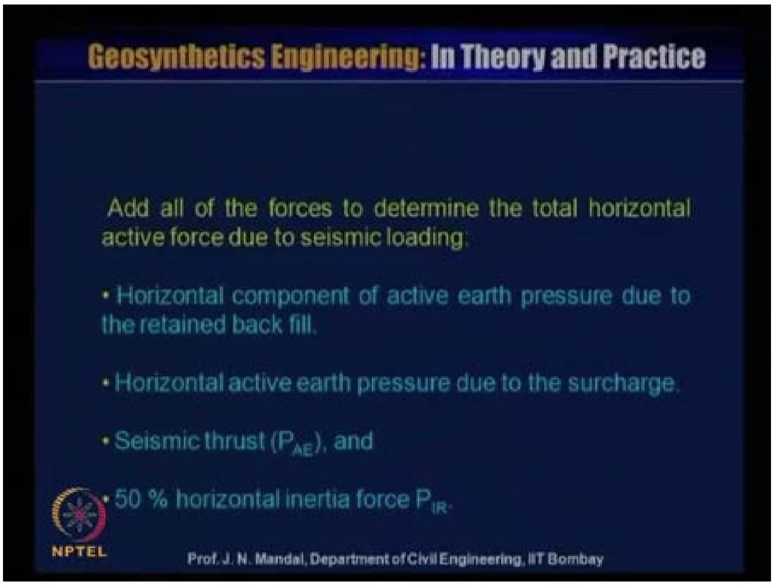

So, you add all the forces to determine the total horizontal active force due to the seismic loading. That means, that what will be the horizontal component of the active earth pressure due to the retained back fill soil, what will be the horizontal active earth pressure due to the surcharge and seismic surcharge that is, PAE. And as I mentioned that, 50 percent of the horizontal inertia force P IR also take into consideration, so all the forces we have to take into consideration.

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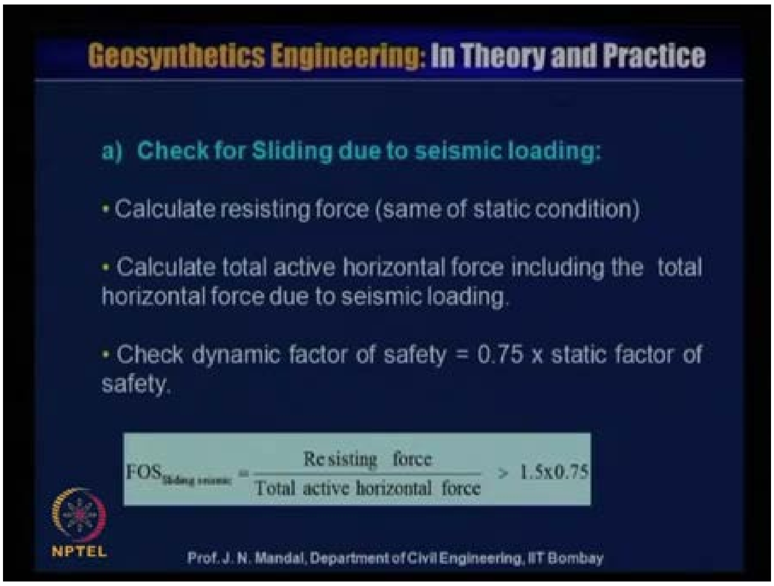

Now, you have to check, due to the seismic effect, you have to check for sliding due to seismic loading. First you calculate, what will be the resisting force same of the static condition then, calculate the total active horizontal force including the total horizontal force due to the seismic loading. Check dynamic factor of safety will be equal to 0.75 into static factor of safety and you can see, this equation, the factor of safety, the sliding due to seismic is equal to the resisting force divided by total active horizontal force and this should be greater than 1.5 into 0.75.

If this is a static case, this factor safety is equal to 1.5, in case of the dynamic, that factor safety will be 1.5 into 0.75. So, you should satisfy this criteria, what will be the factor of safety due to the sliding and for the seismic loading.

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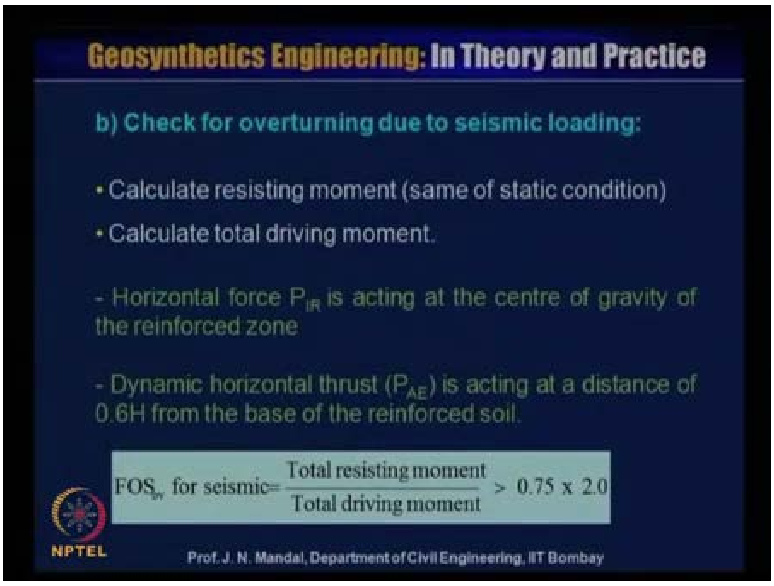

Similarly, we you have to check overturning due to seismic loading, so you calculate the resisting moment, same for the static condition. Calculate the total driving moment then, horizontal force is P IR is acting at the centre of the gravity of the reinforced zone then, dynamic horizontal thrust PAE is acting at a distance of 0.6 times the height of the wall from the base of the reinforced soil.

So, you check what will be the factor of safety, again it is overturning due to the seismic will be equal to total resisting moment divided by total driving moment and that should be greater than 0.75 into the factor of safety due to overturning in static is 2. So, it should check that, it should satisfy the criteria factor of safety against the overturning due to the seismic effect.

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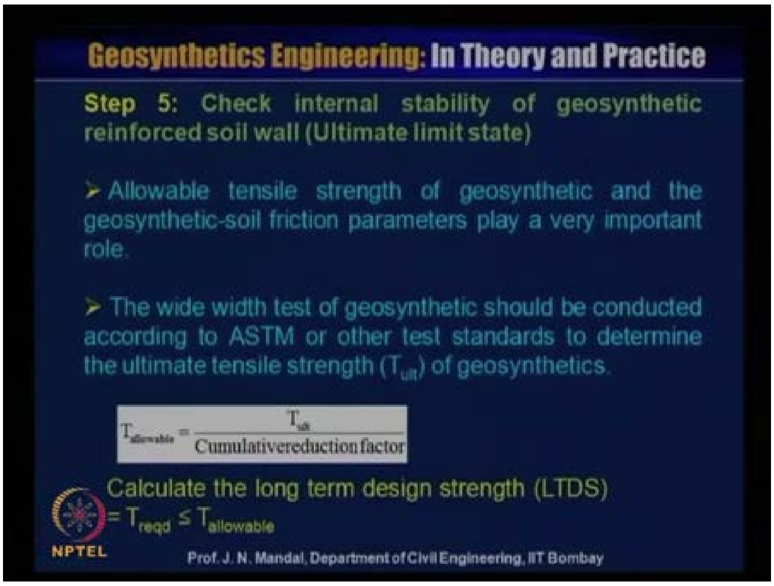

Step 5, check internal stability of the geosynthetics reinforced soil wall, ultimate limit state. So, allowable tensile strength of geosynthetic and the geosynthetic soil friction parameter play a very important role. The wide width test of geosynthetics should be conducted according to the ASTM or other test standard to determine the ultimate tensile strength of geosynthetics. So, you know the ultimate tensile strength then, you have to calculate, what will be the allowable tensile strength that means, that will be equal to ultimate tensile strength divided by cumulative reduction factor.

You know that, cumulative reduction factor that is, the reduction factor for the deep, reduction factor for the installation damage, reduction factor for the biological degradation, reduction factor for chemical degradation. So, all those factor you have to take into consideration and then, you have to calculate, what will be the allowable tensile strength of the geogrid material. Now, if require that long term design strength that is, LTDS, so that is T required should be less than equal to T of allowable, it should satisfy.

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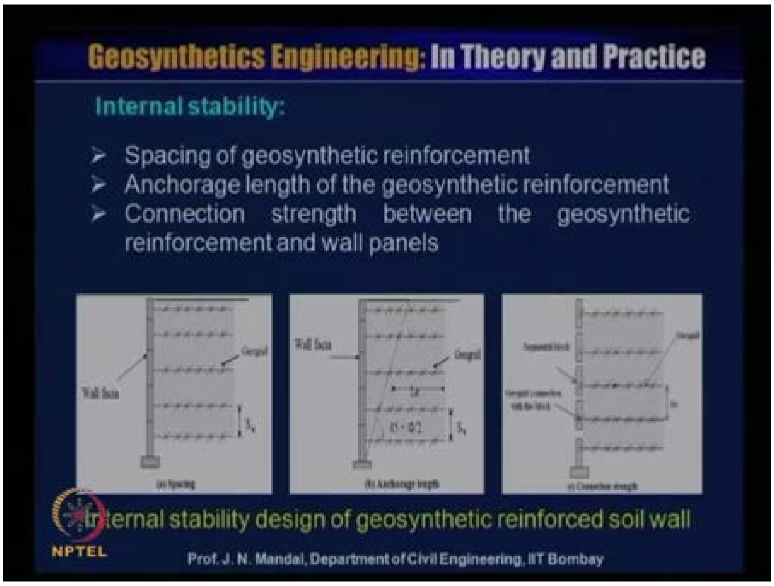

Now, we will discuss the internal stability, for internal stability you require spacing of the geosynthetic reinforcement. What should be the anchorage length of the geosynthetics reinforcement, what should be the connecting strength between the geosynthetics reinforcement and the wall panel, these are very important. Most of the time we do not consider the connecting strength, because structure may fell if you do not consider the connecting strength between the reinforcement and the wall panel or the block.

So, there is a possibility for the failure, failure due to the slip rate, failure due to the connection, so you have to be proper design for the internal stability. So, you need the spacing, if this is the wall, you need what will be the spacing between the two reinforcement, this you have to design for internal stability of a geosynthetic reinforced soil wall. You should also require, what will be the length of the reinforcement, so you have to calculate what will be the anchorage length.

If you know the anchorage length of the reinforcement then, you know that, what will be the total length then, you can deduct or you can determine this then, you can determine the total length of the reinforcement, knowing this, this angle is 45 plus phi by 2. So, internal angle 45 degree minus phi by 2, so this portion also you can calculate at any depth you can calculate. So, if know this and if you know anchor length from the pullout and then, you can calculate what will be the total length of the reinforcement.

So, you require what will be the total length, you require what will be the spacing and at the same time, you require that, what should be the connecting strength, this you can see how the geogrid is connected with the panel or the block. So, this is the segmented block, so geogrid is connected with this, so there is a possibility for the failure, so these all you have to check.

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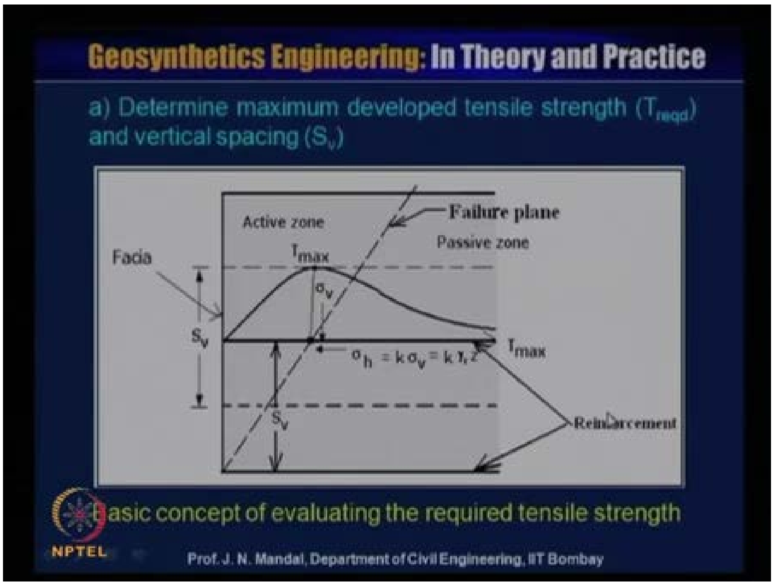

So, determine the maximum developed tensile strength, T required and vertical spacing, here this is a basic concept of evaluating the required tensile strength and this is the reinforcement here and also it is here, you can check this is also reinforcement here, if you take in between. So, from here to here, so this is the S of v, spacing between the reinforcement and this is the facia and this is the reinforcement and this is the maximum tensile force, the T maximum is accessing.

And this you know the failure plane and this is active zone and this is the passive zone, where there is a vertical force is sigma of v is acting. So, sigma h will be equal to k into sigma of v and sigma v you know at any depth, you know the unit weight of the soil in the reinforced zone, so sigma v will be equal to gamma r into z. So, sigma h will be equal to k into gamma r into z, so this is the basic concept for evaluating the required tensile strength of the geogrid material.

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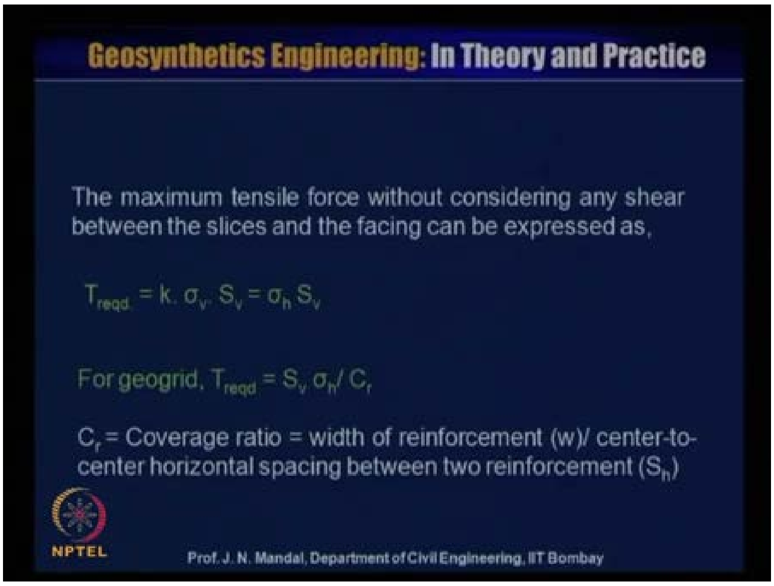

The maximum tensile force without considering any shear between the slices and the facing can be expressed as T required is equal to k into sigma v into S v, we know k into sigma v is equal to sigma h and S v is the spacing between the two reinforcement. For geogrid, T required is equal to S v into sigma h by C of r, this is important C of r, where C r is called coverage ratio that is, width of the reinforcement W, center to center horizontal spacing between the two reinforcement that is, S of h.

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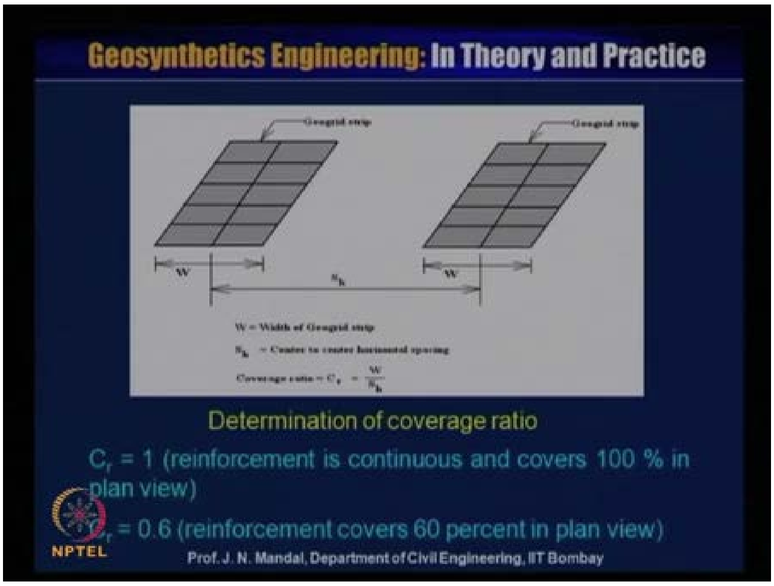

So, I will just show you that, what is the coverage ratio, so you can see here, this is the geogrid strip and this is the W, is the width of the geogrid. This is also width of the geogrid and this is the S h that means, S h is the center to center for horizontal spacing of geogrid. So, you are placing the geogrid strip like this, so coverage ratio this is important, the coverage ratio which is designated as C r, is equal to width of the geogrid strip is W divided by this center to center horizontal spacing S h.

So, coverage ratio C r is equal to W divided by S h, so when you say that, C r is equal to 1 that means, the reinforcement is continuous and cover 100 percentage in the plan view. So, entirely you are placing the reinforcement, so it is continuous over is 100 percentage in plain view. Whereas, if the C r value is equal to 0.6 that means, reinforcement are covering partly that means, 60 percent in plan view. So, in case of 60 percent plan view, you can provide the reinforcement in the form of geogrid strip.

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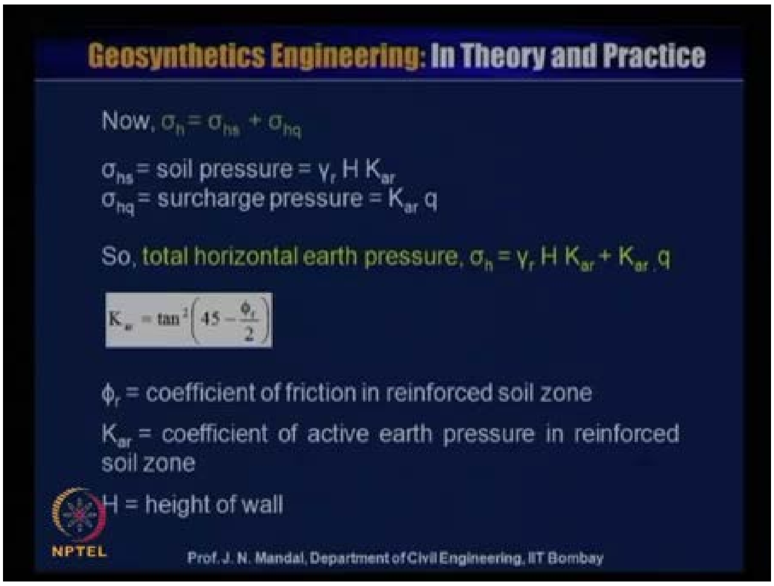

So, you can reduce the quantity of the geogrid when you are using this coverage ratio, so you can set the amount of the geogrid material. So, this coverage ratio, because this is very important when we will put some sample, so when you will design this, so we will consider this coverage ratio C r. So, you can design that, when C r value is equal to 1 we can design, for C r value is equal to 0.6 you have, one can go for the different C r value, may be 0.5, 0.4, etcetera 0.7, but you have to see that, which can give the proper stability of the reinforced soil wall under what coverage ratio. So, that also I will show you with some example.

Now, sigma h is equal to sigma h s plus sigma of q, where sigma h is equal to soil pressure that is, gamma r H into K a r, sigma h q is equal to surcharge pressure that is, K a r into q. So, total horizontal earth pressure sigma h is equal to gamma r H into K a r plus K a r into q, where K a r is equal to tan square 45 degree minus phi r by 2, where phi r is equal to coefficient of friction in the reinforced soil zone, K a r is equal to coefficient of active earth pressure in the reinforced soil zone and H is equal to height of the wall.

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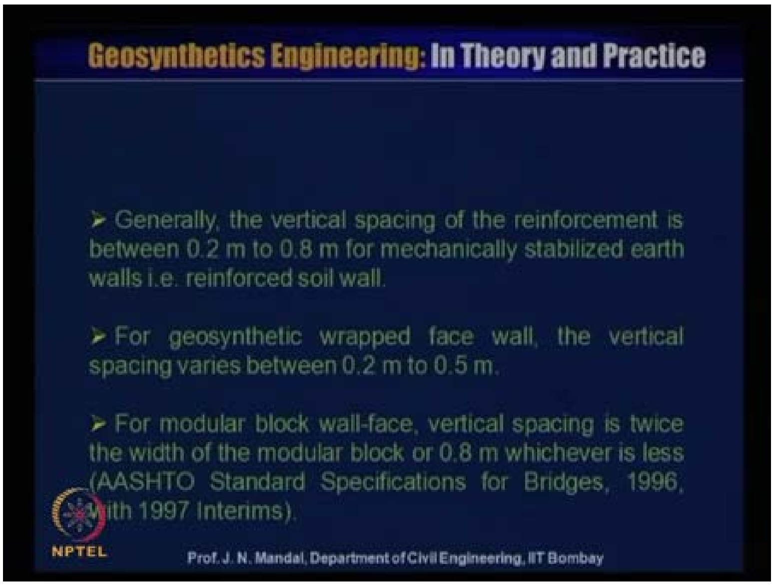

So, generally the vertical spacing of the reinforcement is between 0.2 meter to 0.8 meter for mechanically stabilized earth wall or reinforced soil wall. You can go 1 meter also, but it is always preferable that, you can go for the 0.8 meter from stability point of view. For geosynthetics wrapped face wall, the vertical spacing between 0.2 meter to 0.5 meter and for modular block wall face, vertical spacing is twice the width of the modular block or 0.8 meter, whichever is less. This as per AASHTO standard specification for the Bridge, 1996 with 1997 interim.

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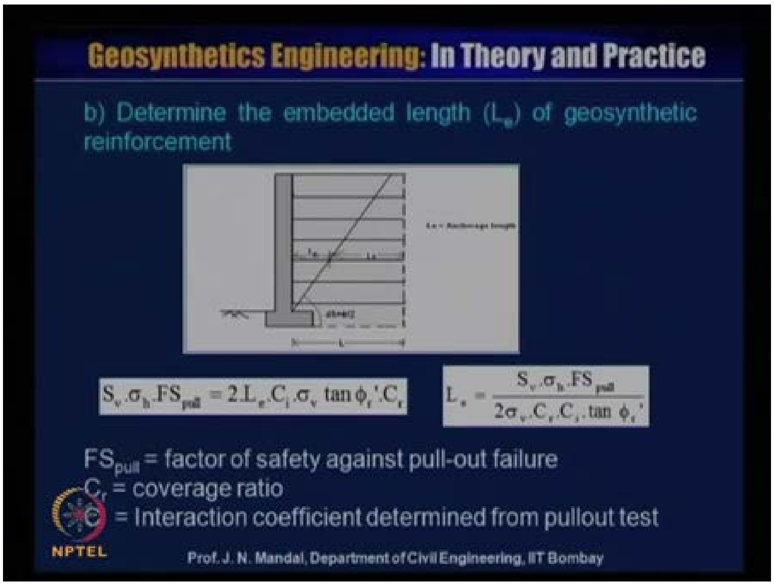

If you require to determine the embedment length L e of the geosynthetics reinforcement, so here you can see, this is the reinforcement, length of the reinforcement is L and this is the Ll of e or which we call anchorage length. So, from the pull out, you can calculate that, what will be the anchorage length L e. So, you know that, S v into sigma h into F S pull, main factor of safety against pull out failure will be equal to 2 into L into e C i sigma v tan phi r dash into C r, here C r is the coverage ratio and C i is interaction coefficient determined from the pull out test.

So, you can calculate this interaction coefficient from the pull out test, suppose if C r value it may be 1 and then, from the pull out test, you can calculate the what is C i value. You can conduct the direct C r test of the soil and determine, what will be the phi r and C value then, you can perform the pull out test, from where you can calculate that, what should be the anchorage length. So, if you know this anchorage length that means, from this equation, L e is equal to S v into sigma h into F S pull out divided by 2 sigma v C r C i into tan phi dash.

So, from the pull out test, you can calculate C i and C r is the coverage ratio that depend upon, whether you are using that 100 percent planer or 0.6 or 0.5, etcetera. So, if you know then, you can calculate, what will be the anchorage length, which is important to us. You know the, how to calculate spacing S v, you know the how calculate the sigma of h and then, you consider what will be the factor of safety for pull out, so you can calculate L e.

So, if you can calculate the L e then, you can calculate L r, because if this angle is 45 degree plus phi by 2, so this angle will be 45 degree minus phi bar by 2. So, this length at any distance, so you can calculate L r, so if you calculate L r then, you can calculate the total length, L is equal L e plus L of r. So, you have some idea about the design of geogrid reinforced soil wall, how you have to determine the external stability, internal stability.

And also, how you can calculate the, what will be the sliding resistance, what should be the factor of safety against the sliding, factor of safety against the overturning, also factor of safety against the bearing capacity and factor of safety against the deep seated failure or the global stability. Also, for this reinforced retaining wall is have learnt that, what will be the spacing length between the two of the reinforcement, what should be the length of the reinforcement, what is the anchorage length. So, you will be partly able to design the geosynthetic reinforced soil retaining wall, so with this, I have ended up the lecture today.

Thank you for listening.