Geosynthetics Engineering: In Theory and Practices
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Module - 1
Lecture - 4
Introduction to Reinforced Earth

Dear students, warm welcome to NPTEL phase 2 program, 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 number 1 lecture number 4, Introduction to Reinforced Earth. Now, I will talk about the recap of the previous lecture, what so far we have covered.

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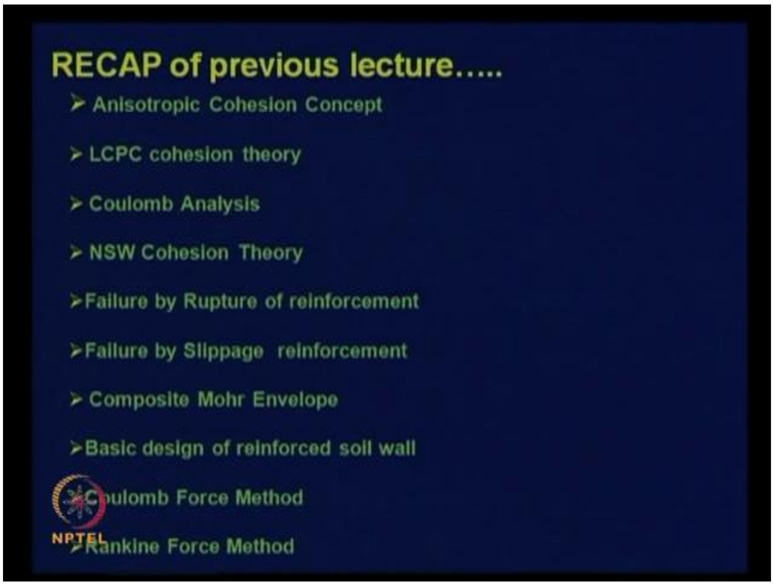

We have covered the anisotropic cohesion concept and we have covered Laboratories Central de Pants et Chaussccs cohesion theory, coulomb analysis, New South Wales cohesion theory and failure by rupture of the reinforcement, failure by slippage of the reinforcement and composite failure envelope, basic design of reinforced soil wall, coulomb's force method and Rankine force method.

So, from this lecture, we have learnt the failure and analysis of the reinforced soil wall and how the structure fail, reinforcement fail. Reinforcement may fail due to the slippage or reinforcement may fail due to the rupture. Therefore, one has to take care the proper kind of the selection of the reinforcing element in order that, it can prevent the slippage as well as the rupture.

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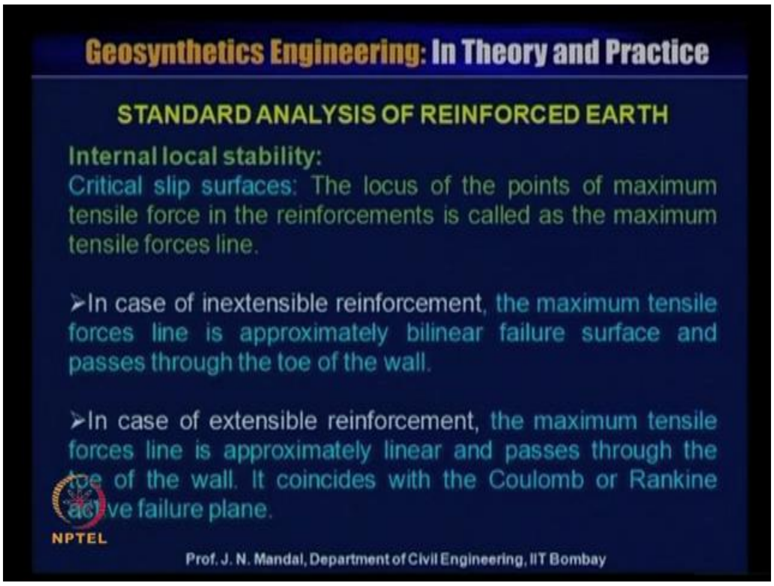

Now, I will discuss some standard analysis of reinforced earth, this is the current reinforced earth system analysis, the internal stability. Now, we should know, what is critical slip surface, critical slip surface can be defined the locus of the point of maximum tensile force in the reinforcement is called as the maximum tensile force line.

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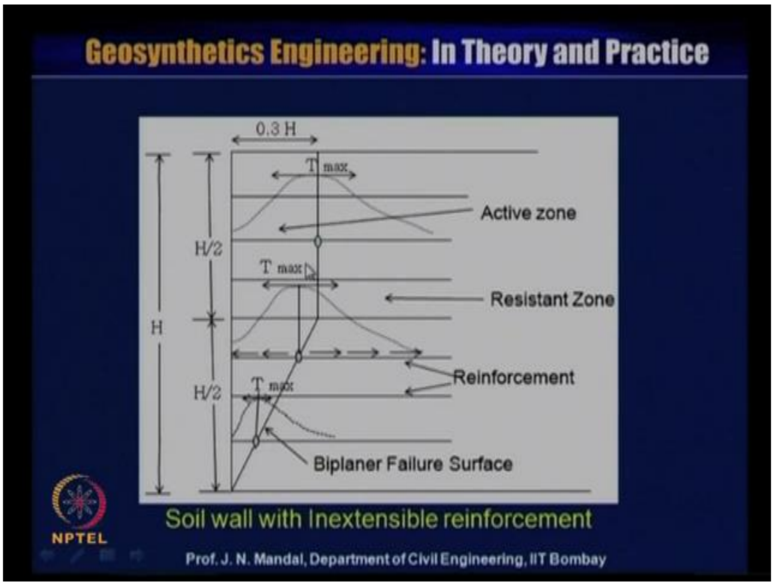

For example, that this is the soil wall with inner inextensible reinforcement, there are 2 type of the reinforcement, one reinforcement is the inextensible reinforcement that means, it is a metallic strip so it is inextensible reinforcement. So, failure mechanism or the locus of the critical slip failure is different from the extensible reinforcement. If we consider extensible reinforcement we can say the geogrid or any polymer material is a extensible reinforcement.

So, failure envelop further extensible reinforcement also different from the failure envelop or inextensible reinforcement. So, in this lecture, we want to show you that, what will be the failure envelope in case of inextensible reinforcement and in case of extensible reinforcement and what is the locus of the point. You can see here, this is the reinforcement material and the tensile force is maximum here T maximum, locus of this point for this reinforcement.

Similarly, you can see for this reinforcement, this is the maximum tensile force little bit away from the facing element and this locus of this slip point is here, like this for this maximum, this is. Now, if you can join, you can see join this point then you can have a biplaner failure surface. So, when the soil wall with inextensible reinforcement that is metallic reinforcement, this failure is biplanar failure surface and if H is the height of the reinforced wall then this distance will be equal to 0.3 times of the height of the wall. Now, this biplanar failure surface has divided into the 2 parts, this is active zone and this is restraining zone. So, you can see that, how the shear stresses moves towards the facing element and what a shear stress is moved away of the facing element.

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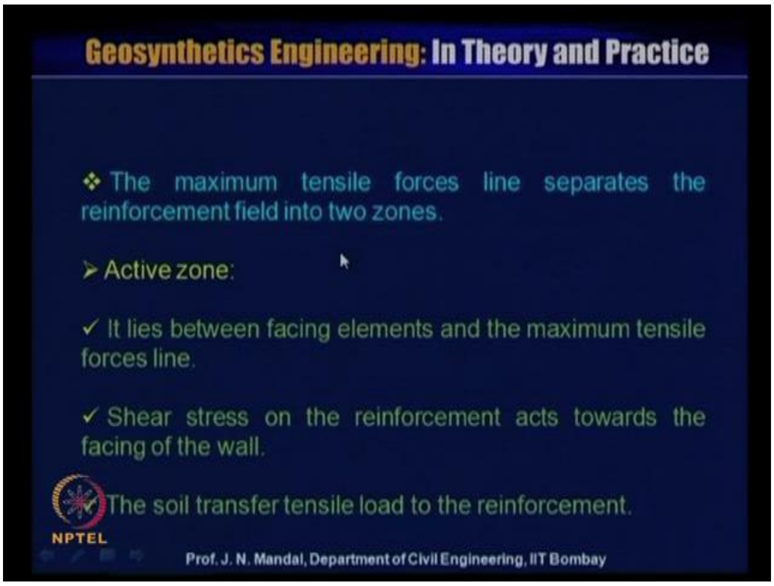

So, in the active zone, it lies between the facing element and the maximum tensile force line. And the shear stress on the reinforcement acts towards the facing of the wall this mean, the soil transfer the tensile load to the reinforcement.

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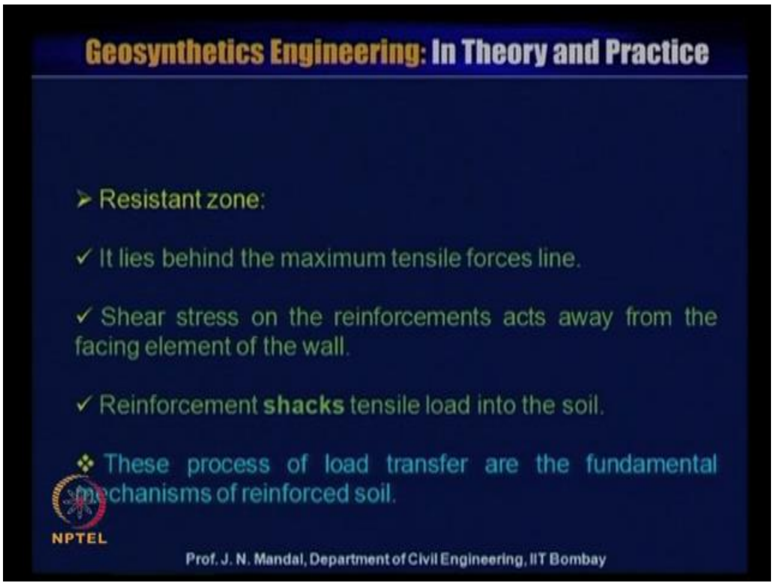

In case of the resistant zone, it lies behind the maximum tensile force line.

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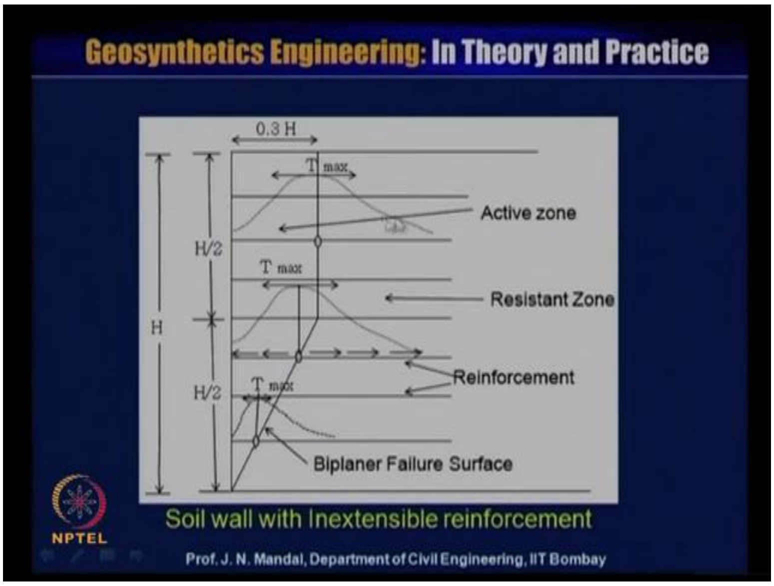

You can see, this is the maximum tensile force line and is lies behind the maximum reinforce soil line. And the shear stress on the reinforcement act away from the facing element. Shear stress is acting away from the facing element and reinforcement set tensile load into the soil. So, this process of load transfer are the fundamental mechanism of reinforced soil so this I already explained that, when the soil wall with inextensible reinforcement and this is the biplanar failure surface. But, what will happen in case of the extensible reinforcement, we will follow up also for the next, what will be the failure pattern for the extensible soil reinforcement. Also, we will check up that, if there is a surcharge load or if there is a slope on the top of the wall for example, that if we...

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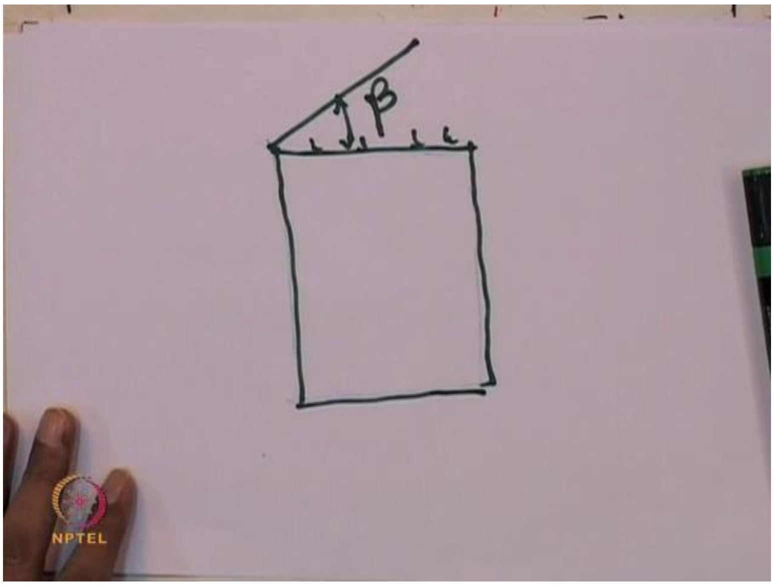

If we consider this is as a reinforced soil wall and also, if you consider this some surcharge load is here also, if there is a some angle, which we call the beta. So, what will be the change of the coefficient of active earth pressure, we can show you.

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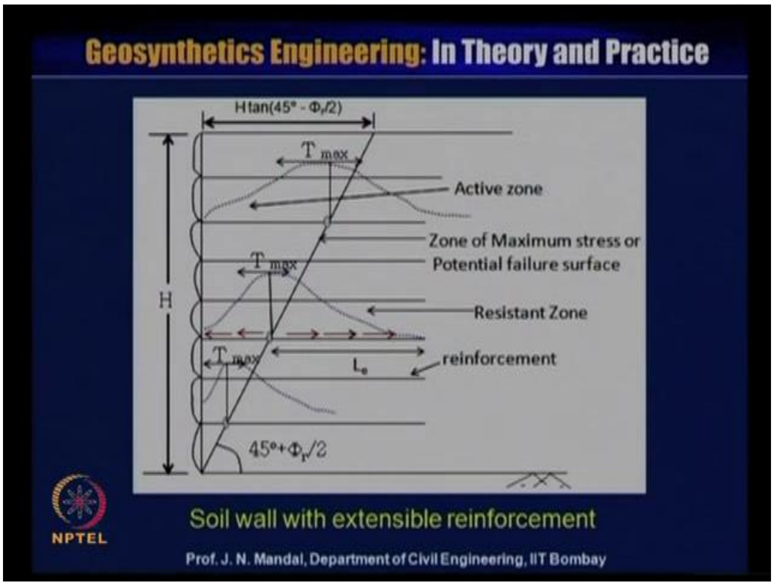

So, for this slope angle, you can calculate the, what will be the coefficient of active earth pressure, when there will be no surcharge load and what will be the coefficient of active earth pressure, when this angle is equal to the beta. Now, if it is a extensible reinforcement that means, if it is a polymer material you can see here that, the failure zone is the linear, it is the linear zone. And this is the zone of maximum stress or it is the potential failure surface, same this is the active zone, this is the restraint zone and this is the reinforcement and this making at an angle of 45 degree plus pi r by 2.

And here also, the shear stress is acting through over the facing element in the active zone and in the restraint zone, the shear stress is away from the facing element. So, you can draw a linear line of failure line so it is the Rankine line and if the H is the height of the reinforcement so this will be equal to H tan 45 degree minus pi r by 2. So, you can look at here, this is the total length of the reinforcement and this is the L e, which we call the, a middle length or bond length and this active zone is equal to L of r. So, you can calculate this L of e by the pull out phase and then you know that, what will be the total length of the reinforcement in. And then you can calculate, what will be length of in the active zone.

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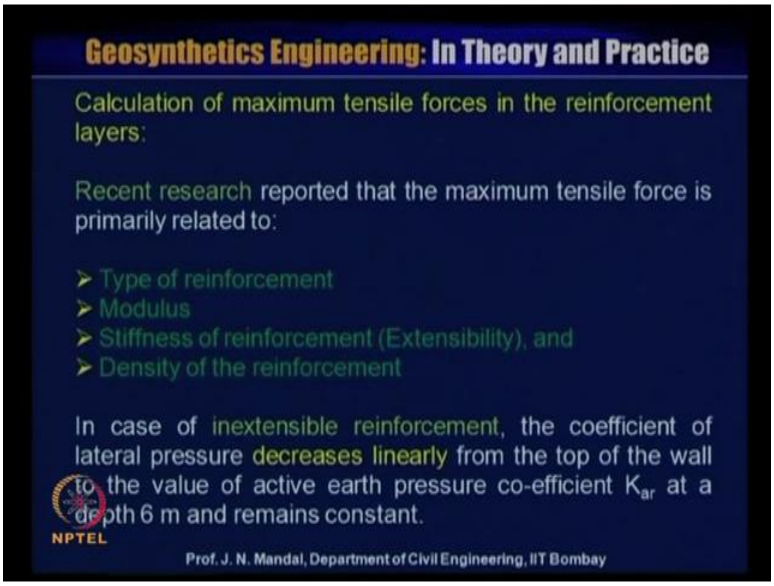

Now, we will discuss the maximum tensile force in the reinforcement layer, recent research reported that, the maximum tensile force is primarily related to the type of the reinforcement, modulus stiffness of the reinforcement, extensibility and the density of the reinforcement. In case of inextensible reinforcement, the coefficient of lateral pressure decreases linearly from the top of the wall to the value of the active earth pressure coefficient K a r at a depth 6 metre and remain constant.

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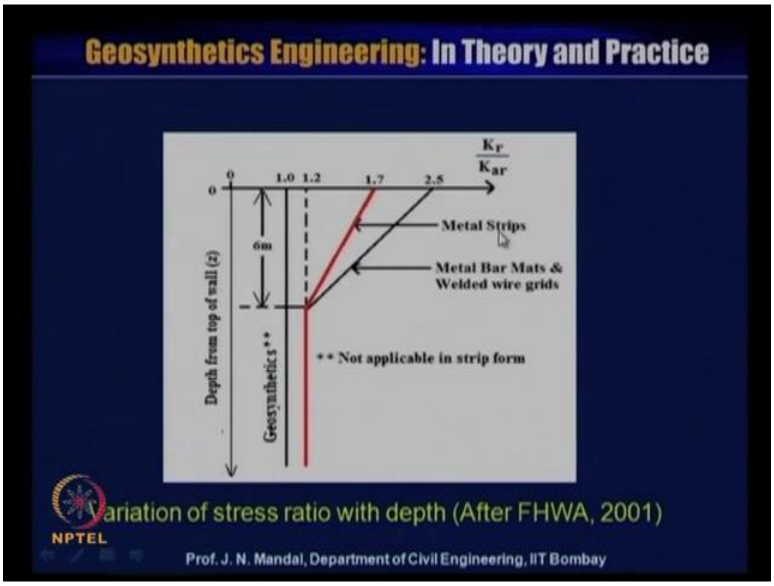

You will look at this figure that, how this lateral pressure is decreasing with the depth and it remain constant when it reaches to the 6 metre. That means, in case of the metallic reinforcement, this value is 1.2 and its lies between 1.2 to 2.5 or 3, depending upon the type of the metallic reinforcement. If it is a metal strip say, you can interpolate and can calculate this, if it is a metal bar or mat welded wire grid so you can also calculate what will be the stress ratio.

And here, it has been shown that, how the variation of stress ratio with the depth so you look at this variation after 6 metre, it is constant in case of the inextensible reinforcement. So, this is not applicable in case of the strip from for the geosynthetics material, for the geosynthetics material and this K r by K a r will be equal to the 1 that means, K r will be the k of a r. So, you have to be select this stress ratio, K r by K a r based on the type of the reinforcing material, type of the inextensible reinforcing material.

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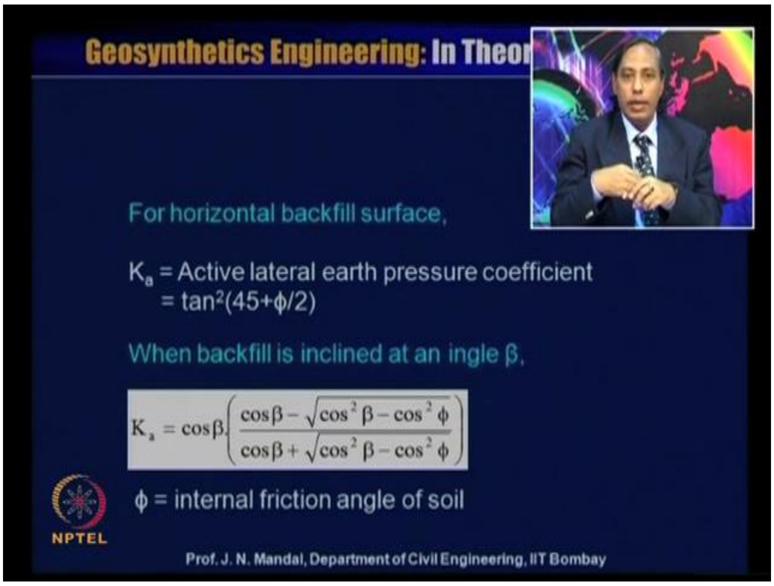

As I mentioned earlier that, if it is a horizontal backfill surface, you have to calculate what will be the active earth pressure coefficient. And then active earth pressure coefficient can be calculated by K a is equal to tan square 45 degree plus phi by 2. When the backfill is inclined at an angle beta then we have to add up this equation that is, K a is equal to cos beta bracket cos beta minus roots of cos square beta minus cos square phi divided by cos beta plus roots of cos square beta minus cos square phi.

While where, phi is the internal friction angle of the soil and beta is the backfill which is inclined at an angle of the beta. So, you have to remember that, it is a horizontal backfill surface so you add up this K a equation is tan square 45 degree plus phi by 2. If this is a inclined with an angle beta so we can add up this second equation that is, K a is equal to cos beta that is, cos beta minus root over cos square beta minus cos square phi cos beta plus root over cos square beta minus cos square phi. So, you remember that, depending upon that, whether it is a horizontal backfill surface or it is an inclined surface.

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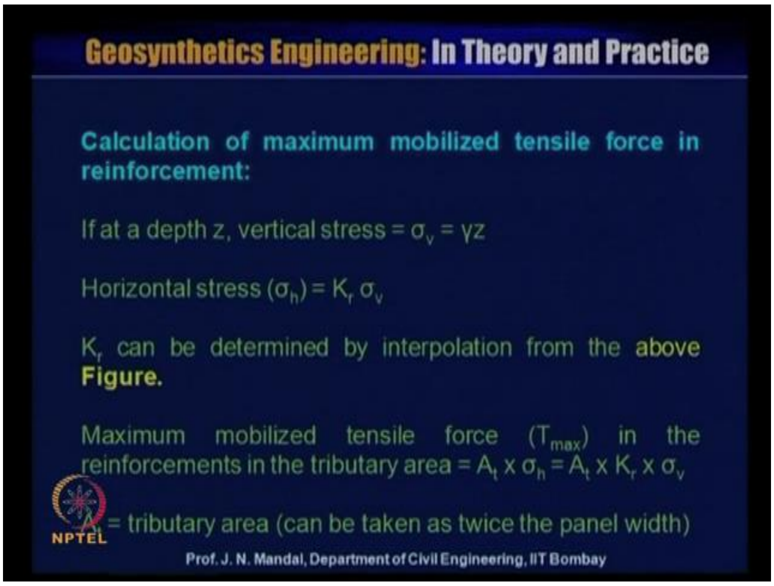

Now, we calculate the maximum mobilized tensile force in the reinforcement at any depth z, vertical stress sigma v is equal to gamma of z.

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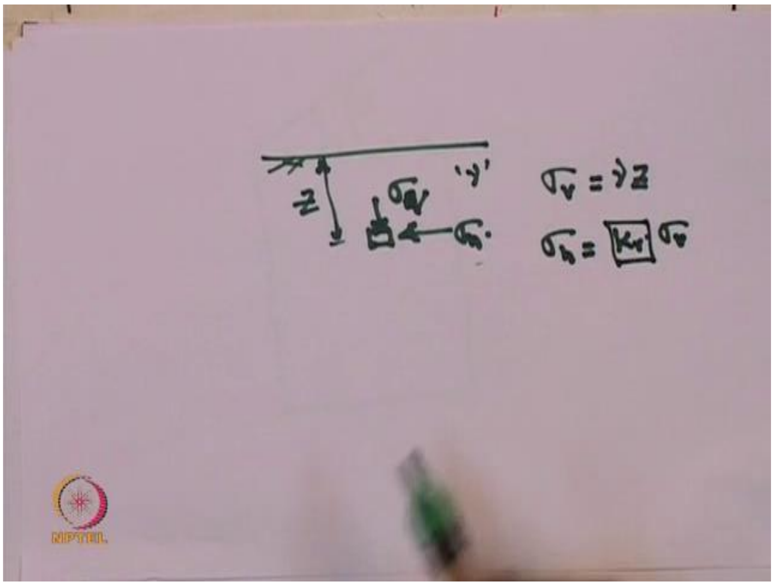

So, if you consider that, this is the ground surface and at any depth so you can calculate that, what will be the sigma of z and also you can calculate that, what will be the horizontal stresses. So here that sigma if it is a sigma of v; that means, if this depth is equal to the z. So, you can write that, sigma v is equal to gamma into z and gamma is the unit weight of the soil and the horizontal stress is sigma of h. So, sigma of h will be equal to K r into sigma of sigma of v so this K r can be interpolate from the figure.

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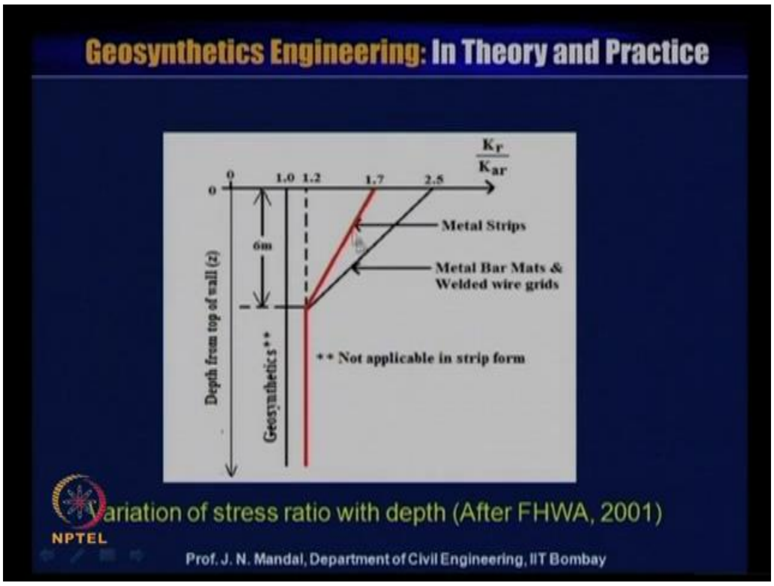

This figure K r by K a r from this, you can interpolate and can determine that, what will be the stress ratio. That means, if you know that K r by K a r is equal to let us say, 1.7 so it will be known to you.

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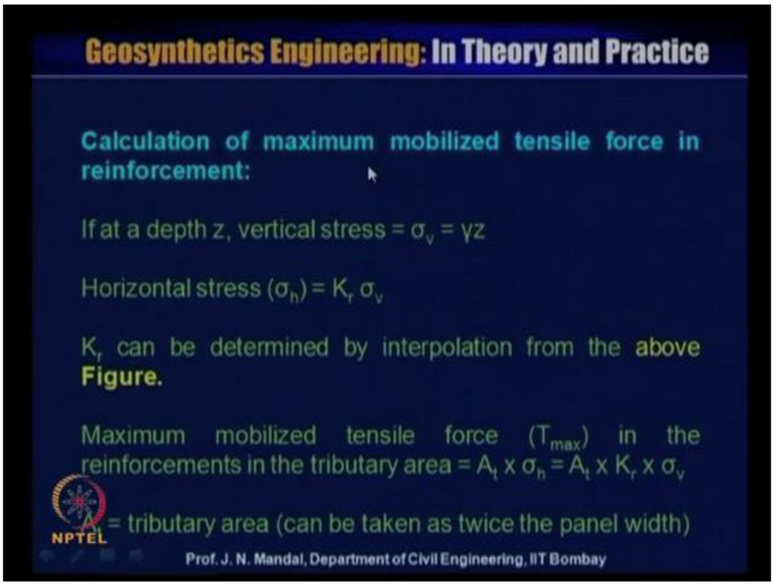

So here, how we are calculating this K r value so maximum horizontal mobilized tensile force, which is designated at T of maximum and this maximum horizontal force in the reinforcement is rely on this tributary area. If that area is equal to A of t and this is sigma of h so T max, maximum mobilized tensile force in the reinforcement in the tributary area will be equal to A t into sigma h then sigma h is equal to K r into sigma v. So, A of t is the tributary area, which can be taken as twice the panel width so from this, we can calculate that, what will be maximum mobilized tensile force.

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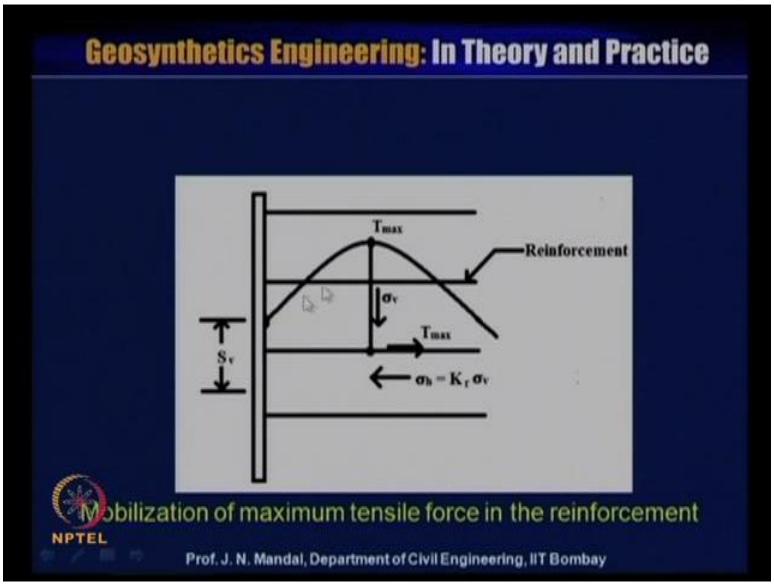

Now, this at any point you can see here that, if it is the sigma of v and this is the sigma of h that is, K r into sigma v and this is the T of maximum. Here, the tensile force is acting here T of maximum, this is the mobilization of maximum tensile force in the reinforcement and this is the reinforcement.

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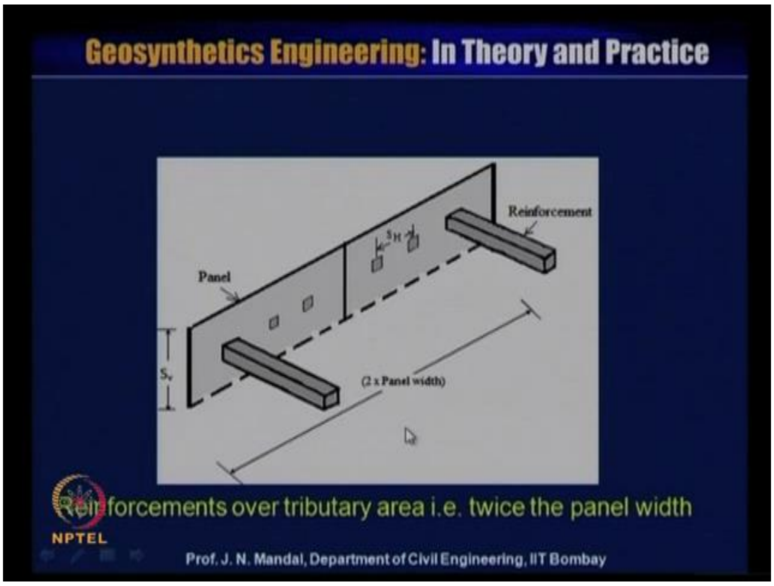

So here, that some explanation is given for the tributary area that means, reinforcement over tributary area. This is the reinforcement and this is the panel you can see, this is one panel, this is one panel, this is half of the panel, this is bottom of the panel, this panel is length and the height is almost 1.5 metre and this is the S of v. This is the S of v that is, the spacing and the tributary area will be equal to 2 into panel width. And this is the horizontal spacing between the reinforcement that is, S of h and this is the vertical spacing between the reinforcement, it will S of v. So here, it has been focused on the reinforcement over tributary area; that means, twice the panel width.

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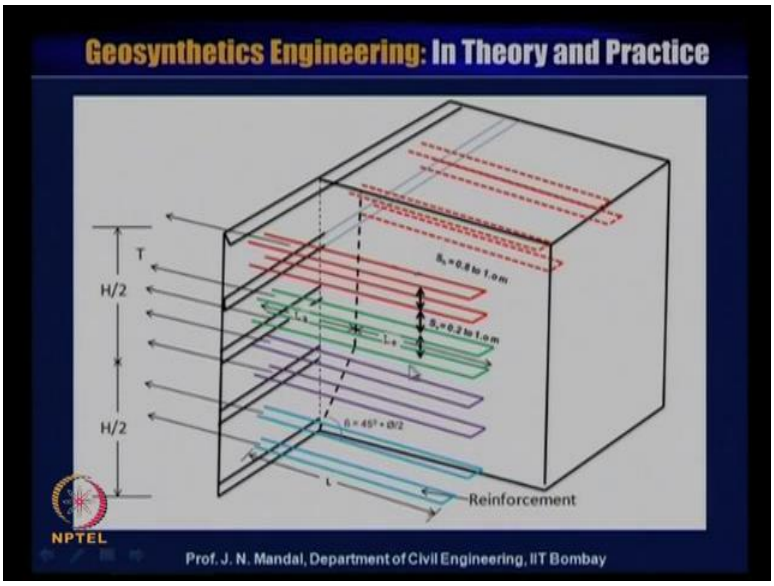

Here also same, in case of the metallic reinforcement you can see, what is this bilinear type of the failure surface and this also the vertical spacing, which is lied between 0.2 metre to 1 metre. So, you can change that vertical spacing also, you can change the horizontal spacing, which is lies between 0.8 to 1 metre. So, you can change the spacing and you can optimize and can design accordingly.

And here, this is the length of the reinforcement, if it is length of the reinforcement is L and this is the middle length or the bond length L e and this is the L e is equal to active zone length. So, you can calculate this, what will be the total length and this failure making at an angle of 45 degree plus theta by 2.

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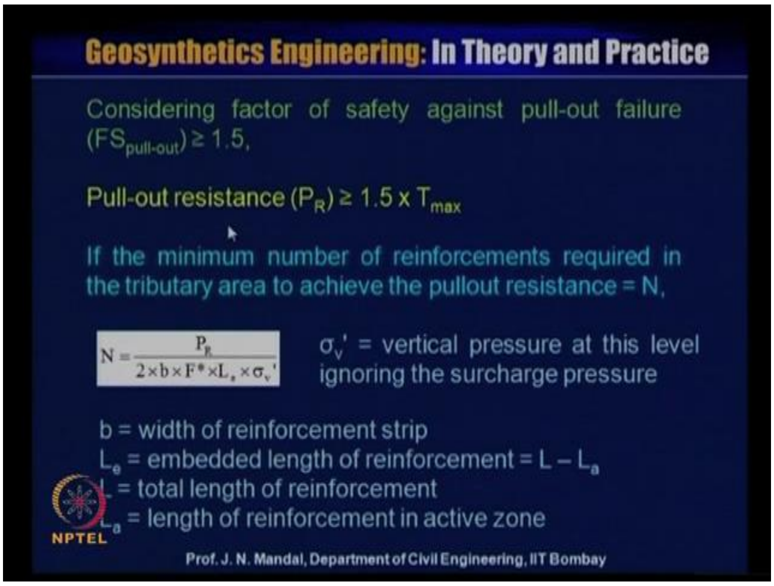

Now, considering the factor of safety against pullout failure, it should be factor of safety against pullout will be greater than equal to 1.5. So, pullout resistance P R will be greater than equal to 1.5 into T of maximum, if the minimum number of the reinforcement required in the tributary area to achieve the pullout resistance is equal to N then N will be equal to P R divided by 2 into b into F star into L e into sigma v dash.

So where sigma v dash is vertical pressure at this level ignoring the any surcharge pressure and b is the width of the reinforcement strip. And L e is the embedment length of the reinforcement that is, L minus L a or L is equal to total length of the reinforcement. L a is equal to of the reinforcement in the active zone so it is like this, if I draw a failure line.

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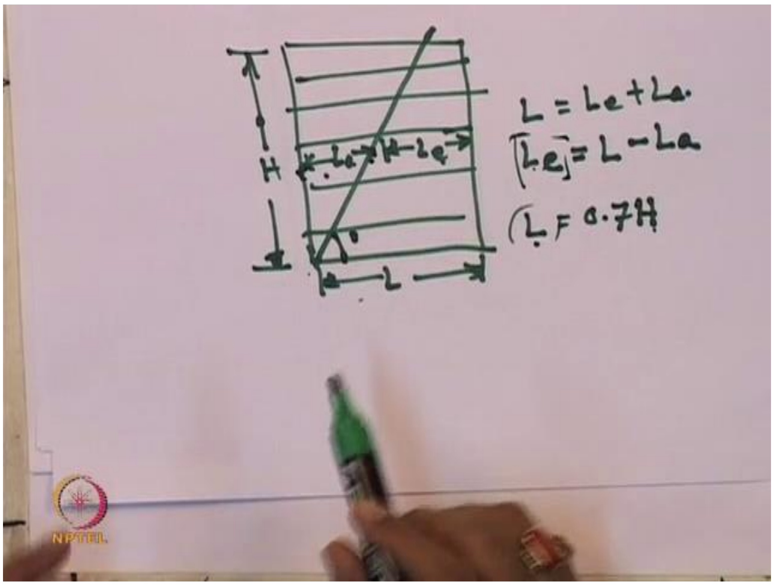

If it is the wall and if this is the reinforcement and you can draw a failure line like this and let us say, failure line like this and this is the embedment length L and this length is equal to L of a and this total length is equal to L. So, L is equal to L e plus L a, this is L e plus L of a so we require what should be the value of L e so this will be, L e will be equal to L minus L a. If you know that, what will be the height of the reinforced soil wall and L is generally considered for the design is 0.7 times of the edge.

So, you know what will be the height so you can calculate, what is L and from here, if you know the angle. So, you can calculate, what will be this length and then we can calculate what will be the embedment length. So, we can calculate this embedment length from this.

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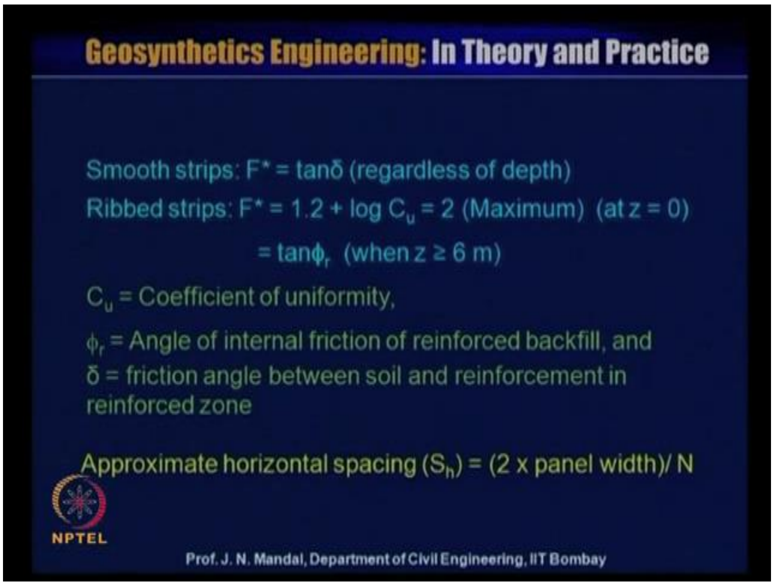

Now, this smooth if it is a smooth strip, this F star will be equal to tan of delta that is, regardless of the depth for delta is equal to friction angle between the soil and the reinforcement in the reinforced zone. And if it is a ribbed strip, F star will be equal to 1.2 plus log of C u that is, 2 is maximum at z is equal to 0 is equal to tan phi r when z is greater is equal to 6 metre, for C u is the coefficient of uniformity and phi r is angle of internal friction of reinforced backfill.

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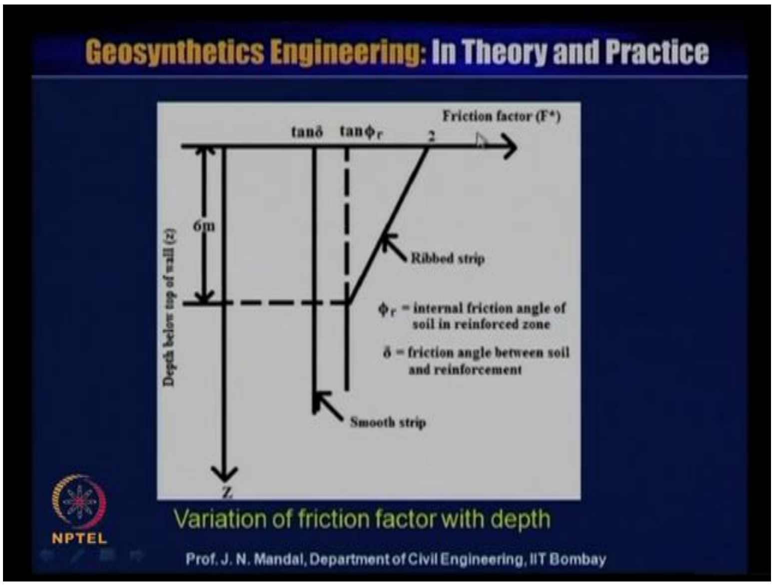

So, if we look this figure, this is the ribbed strip and this figure is variation of friction factor with the depth, this is friction factor with the depth. So, this is tan phi r, this is tan phi tan delta, phi r is internal friction angle of soil in the reinforced zone and delta is friction angle between the soil and the reinforcement. And this is the friction factor, you can see friction factor which is denoted as F of star.

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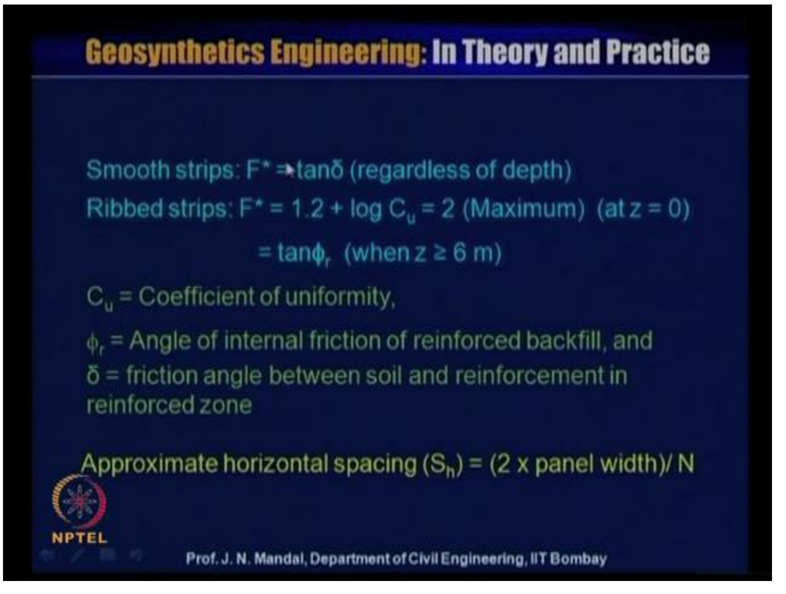

This friction factor value depend upon the type of the reinforcing element, if it is a smooth strip, F star is equal to tan delta and regardless of depth. And if it is a ribbed strip, F star will be equal to 1.2 plus log of C u or 2 maximum value. But, C u is the coefficient of uniformity and if you know that, what will be the coefficient of uniformity of that soil. So, you can directly determine, what will be the F star for ribbed strip and this I say that, maximum value is 2 at a depth of when z is equal to 0.

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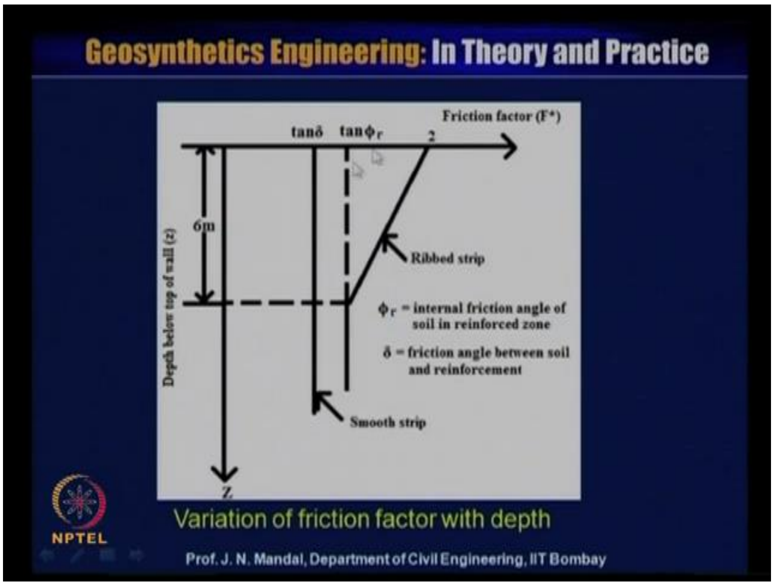

And then the F star will be equal to tan phi r, when z is greater than equal to the 6 metre you can see here, when this is the 6 meter, when it will leads to this 6 metre, greater than equal to the 6 metre. So, we have shown these two, figure 1 is in terms of the lateral stress that is, K r K a r what ratio you should take into consideration into the design for the inextensible reinforcement. And the earlier slide shows that, what should be the friction factor that depend upon the type of the inextensible reinforcement and it is goes on up to the 6 meter and after that, almost this constant.

So, also we conclude that, how the F star factor also depend upon the coefficient of uniformity of the soil. If you know the coefficient of uniformity of soil then also, you can calculate this friction factor. And this also, when you can calculate at a depth of z is equal to 0, at a depth of z is equal to 6 meter and above.

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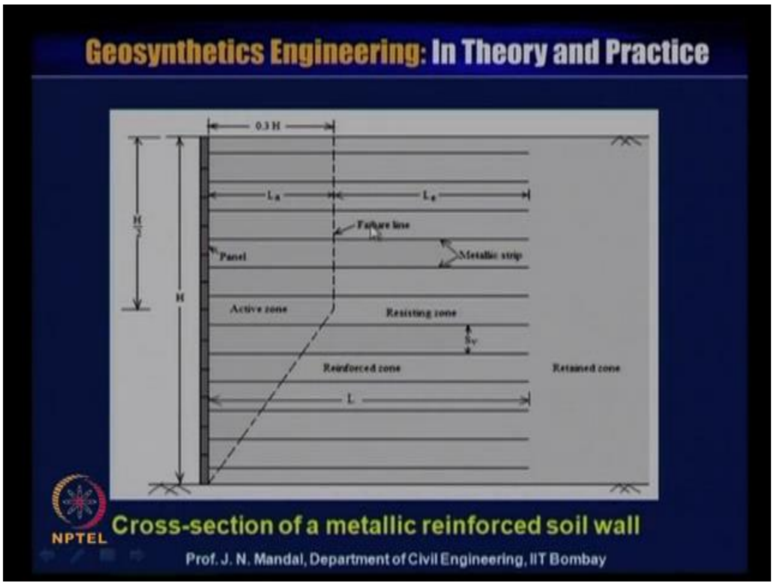

This slide shows the cross section of the metallic reinforcement so this is the we know that, in case of the metallic reinforcement, failure pattern by linear failure and this is the height of the wall and this is the spacing between the two reinforcement S v. This is the length of the reinforcement, this is embedment length L e and this is L a, and this distance is about 0.3 times the height of the wall.

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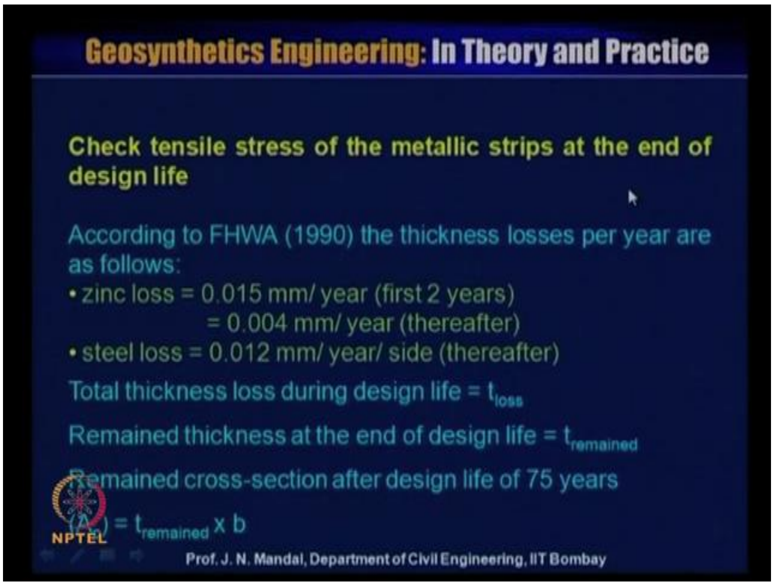

Now, because we are using the a metallic strip reinforcement and that was the reason that, we should also study that, what will be the effect of the moisture, what will be the corrosion effect of the reinforcing material and what should be the longevity and durability of this material. So, we should know that, how many years the reinforced soil structure can last, whether it is 75 years, 120 years, like this. We have to be very careful about the corrosion effect of the reinforcing material, this is one of the most important point here.

Because, the most of the cases we use the metallic reinforcement or galvanized metallic reinforcement, which we will come in contact with the moisture content or water content. And then reinforcing material may deteriorated, there will be a corrosion effect and then there is a possibility for the collapse of the structure. So, we will see that, how the tensile stress of the metallic strip at the design life so there is a specification for the Federal Highway Administration FHWA, 19902.

And then you can calculate that, what will be the thickness loss per year so it has observed that, zinc loss is equal to 0.015 millimetre per year, first two years and then zinc loss is equal to 0.004 millimetre per year thereafter. Now, steel loss 0.012millimetre per year per side thereafter so we have to check that, what will be the total thickness loss during the design life, that mean T loss. And remained thickness at the end of the design life is equal to T remained, the remained cross section after the design life of 75 years is the cross section remained is designated at A of c. So, A of c will be equal to, what will be the thickness remained and the v so you can calculate, what should be the remained cross section after design life of 75 years.

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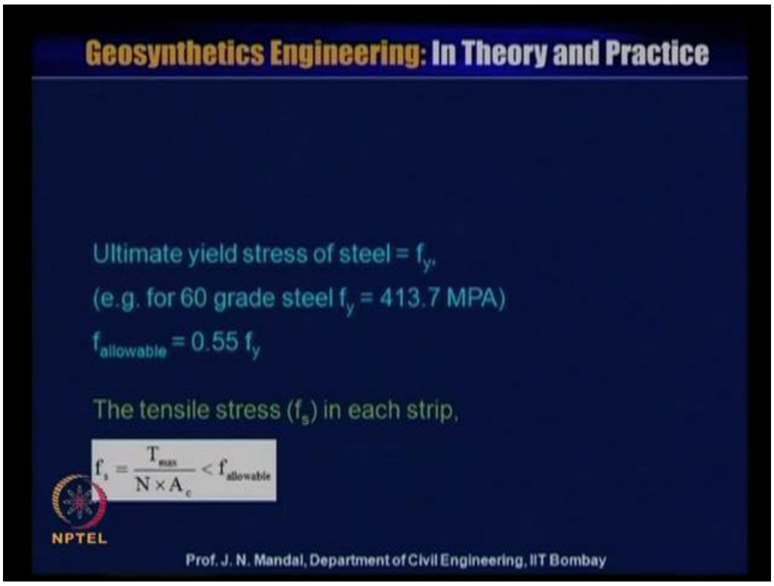

Now, because it is a metallic strip reinforcement or inextensible reinforcement and it is universally well known about the yield stress of the steel and we know that, ultimate yield stress of the steel which can be designated as f of y. And generally, if we consider the 60 grade of steel so f y will be equal to 413.7 MPA and we have to consider for the allowable ultimate yield stress of the steel, if it is designated as f allowable.

So, f allowable will be equal to 0.55 f of y so tensile stress f s in each strip can be calculated with this equation that is, f s is equal to T of maximum divided by N into A c and these value should be less than the f of allowable value.

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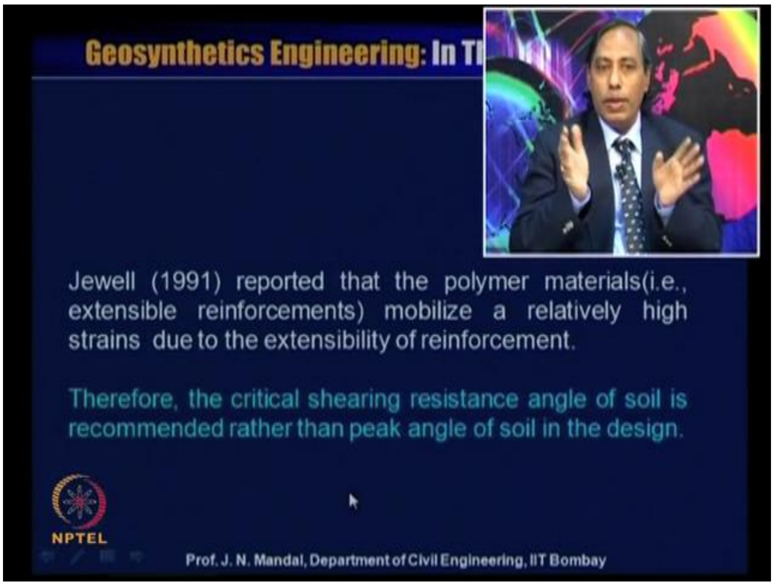

If it is less then it is ok June 1991 reported the polymer material that is, extensible reinforcement mobilized relatively high strain due to the extensibility of the reinforcement. Therefore, the critical shearing resistance angle of the soil is recommended, rather than the peak angle of soil in the design.

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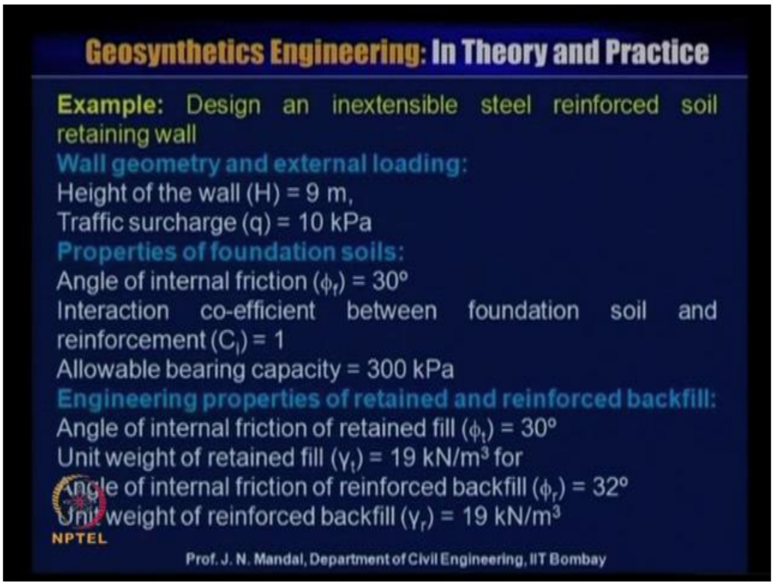

I will now give you some example, designed example of inextensible steel reinforcement for the retaining wall. So, let us consider that, wall geometry of the and the external loading. So, height of the wall is about 9 metre and traffic surcharge q is equal to 10 kilo

Pascal, angle of internal friction phi r is equal to 30 degree and interaction coefficient between foundation soil and the reinforcement C i is equal to 1. Allowable bearing capacity of the soil is 300 kilo Pascal, the engineering properties of the retained and the reinforced backfill that is, angle of internal friction of retained fill is 30 degree.

And unit weight of retained fill gamma t is 19 kilo Newton per metre cube, for angle of internal friction of reinforced backfill phi r is equal to 32 degree and unit weight of the reinforced backfill gamma r is equal to 19 kilo Newton per metre cube. These are the data is given for a inextensible retaining wall here it is given that, what will be the wall geometry, what will be the properties of the foundation that means, you should know what would be the properties of the foundation is very important. And you should know, what should be the engineering property of the retained and reinforced backfill.

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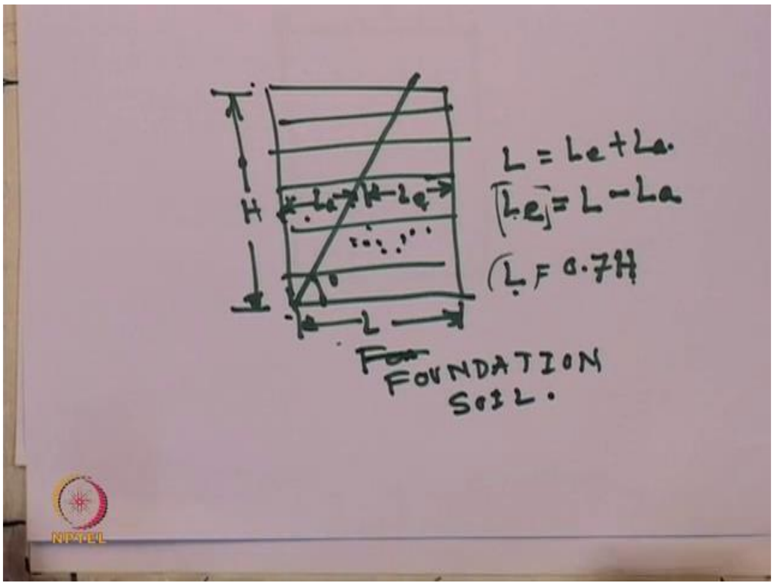

So, if I can show like this, if this is the foundation soil so you should know that, what will be the properties of the foundation soil, you should know that what will be the properties of the retained soil, you should know that what will be the height, these are the properties given for the design for the reinforced soil.

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Now, when you will design this reinforced soil wall then you require some factor of safety so you require for the design for the external stability, you require for the design for internal stability. So, you have to check up, what will be the factor of safety against the sliding and then factor of safety against sliding should be 1.5. What should be the maximum foundation pressure and that should be less than equal to allowable bearing capacity. And at the same time, due to overturning, there is a possibility for the failure so you have to consider the eccentricity, that measure of earth pressure distribution.

So, eccentricity e is given, is equal to less than equal to L by 6 and we have to check up the global stability, this should be greater than equal to 1.3. And for the internal stability, you have to check what will be the factor of safety for pullout resistance, that should be greater than equal to 1.5. And allowable space because for this is a inextensible reinforcement, which will be equal to 0.55 f of y and we consider the design life for the 75 year.

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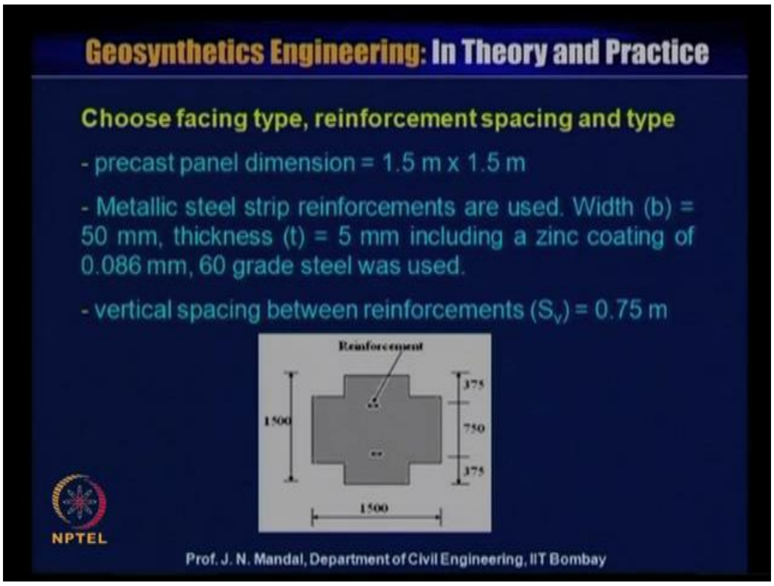

So, we have to check that, what will be the design life, what should be the factor of safety for the external stability as well as for the internal stability. And when you will design this metallic reinforced soil retaining wall, you have to choose the facing element. So, there are different types of the facing elements, I am just showing one cruciform facing element whose, dimension is about 1.5 metre by 1.5 metre, every 3.75 millimetre spacing or 750 or 3.75 like that spacing, you can connect the reinforcing material with the facing element.

So, we also have to check up that, what will be the size of the panel, we can also check up the local stability of the panel and what will be the dimension of the panel. Let us say, that dimension of the panel is 1.5 metre by 1.5 metre, different manufacturer have their different types of the panel. But, in case of the metallic reinforcement, majority use this cruciform of the panel, precast concrete panel and also we should know, what will be the metallic strip of the reinforcement, and each and every metal strip of the reinforcement have a width.

So, width b equal to 50 millimetre, thickness of the metallic strip reinforcement is 5 millimetre, including a zinc coating of 0.086 millimetre and 60 grade steel was used, vertical spacing between the reinforcement S v, we consider 0.75 metre. So, we can see, this is one of the facing element in crucishape form and this is 1.5 and this is also 1.5 meter and this reinforcement is connected with this spacing element here and here, and this spacing is 7.75. So, this vertical spacing S v is 0.75 then you have to place another panel here then you can see, half of this panel is 0.375, the another 0.375. That means, spacing will be equal to 750, like that you can construct these reinforced soil retaining wall.

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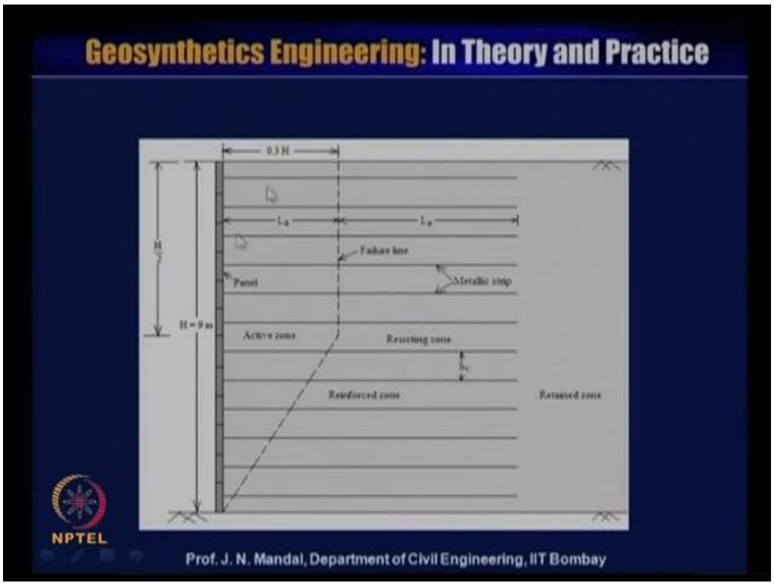

So, these are the some data, which is given for the design of this kind of a wall.

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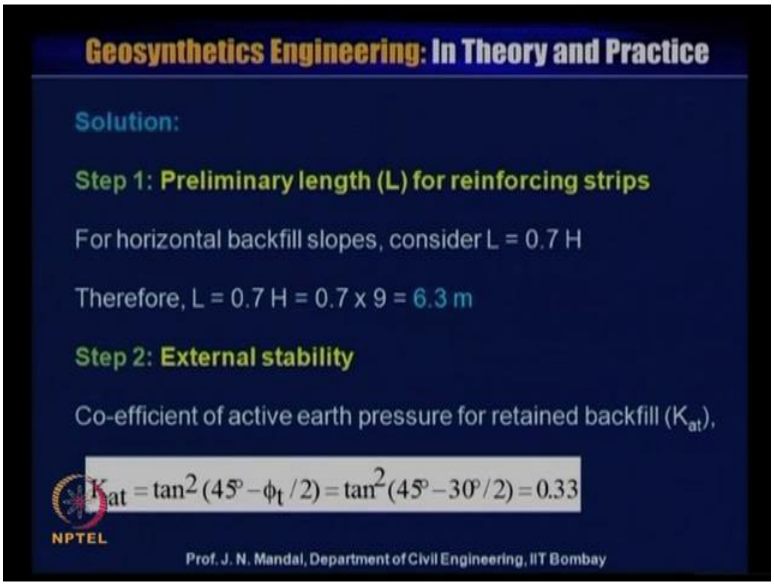

Now, we will give you a solution for this, when you design the metallic reinforced retaining wall you have to assume that, what will be the length of the reinforcement. I said that, if the height of the reinforcement is H and then the length of the reinforcement is 0.7 times of the H. So, for general purpose design of reinforced soil wall, so length we can consider is 0.7 times the height of the wall. So, first step, preliminary length for reinforced strip you have t to consider, L is equal to 0.7 H.

You know that, height of the reinforcement is 9 metre so length is equal to 0.7 of H that mean, 0.7 into 9 is 6.3 metre. Step 2, we will move on to external stability, if now the coefficient of active earth pressure for the retained backfill that is K a t, K a t is equal to tan square 45 degree minus phi t by 2 and phi t is given 30 degree. So, if you substitute this value, K a t we can calculate that tan square 45 minus 30 degree by 2 is equal to 0.33.

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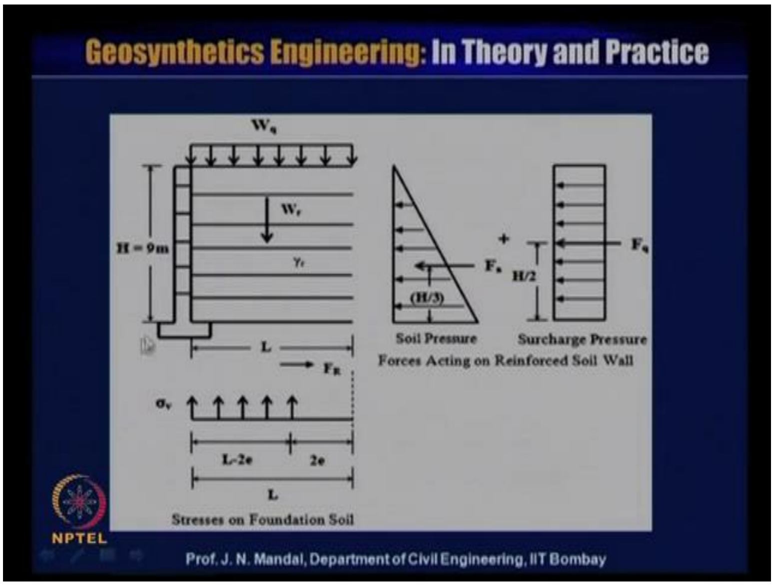

Now, look here this is the wall, the height of the wall is 9 metre and there is a surcharge that is, W of q and this is the reinforced zone width, which is designated as W of r and gamma r is equal to the unit weight of the reinforced soil zone here and this is the length of the reinforcement. Now, this reinforcement may fail due to the sliding, you can see that is why, you need the resisting force which is designated by F of R. So, when you will design this kind of the wall, you have to check what are the pressure inserted into this reinforced soil wall.

So, this is the backfill here so here, the forces acting on the reinforced soil wall is the what will be the soil pressure. So, soil pressure you can see that, triangular distribution and this pressure forces, which is acting at a height of H by 3, if H is the height of this reinforced soil wall. So, this horizontal forces for the soil pressure will act at a distance of H by 3 from the base of this soil.

So, this is a triangular distribution and due to the surcharge load you can see, this is a surcharge pressure that is uniformly distributed. And this is force F of q, which is acting at the middle height of the reinforced soil wall that means H by 2, H is the height of the reinforcement. So, you have to first consider, whatever the forces is acting into the wall, the forces acting due to the soil pressure, forces acting due to the surcharge pressure, if suppose, there is any live load, that also you have to take into consideration into the design.

If there is a earthquake also in the seismic zone, that also you should consider into this design but here, in this example, only we are considering the soil pressure and the surcharge pressure. So, you have to check that, what is the pressure is acting, what are the forces are acting on the retaining soil wall. At the reinforced soil wall, the rest on the foundation soil, here foundation soil so foundation soil may be very poor so you wanted to improve the foundation soil.

If you wanted to improve the foundation soil, there are various system, we will cover during our geosynthetics mechanically stabilized reinforced soil wall. But, we have to determine that, what should be the stresses on the foundation soil so we will adopt this measure of pressure distribution. So, if L is the length and this is the vertical pressure is sigma v and this distance is L minus twice e, e is eccentricity and this distance will be twice e so total length will be the L e.

So, when we will design for the, what will be the factor of safety against the bearing capacity and the vertical forces, which is acting upward, that length we should consider L minus 2 e. And this is the measure of earth pressure distribution, for all cases I should recommend that, you should follow up the measure of earth pressure distribution. So, A L minus 2 e zone will be the active zone.

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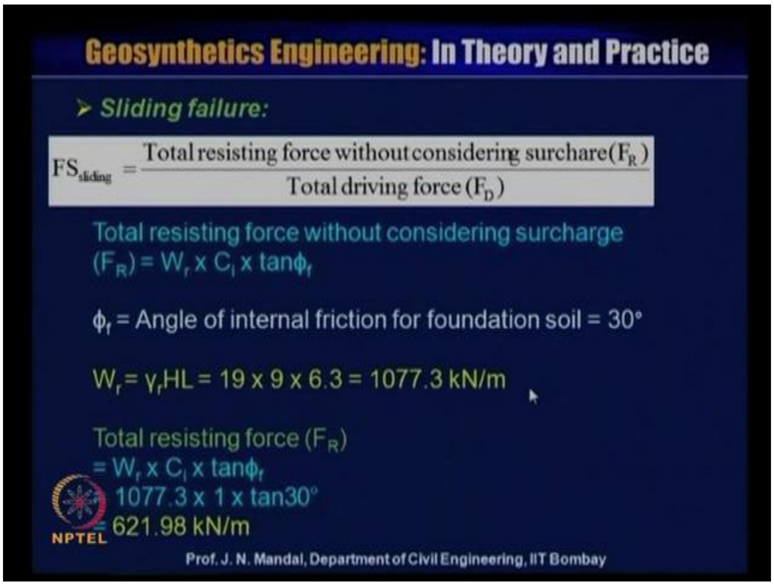

So, we have to check up for the factor of safety against the sliding, if this wall fell due to the sliding. We can see that, wall removed and you have to resisting with the force so there is a possibility for fell for the sliding. So, factor of safety sliding in the ratio of total resisting force without considering the surcharge here, divided by total driving force F D. Total resisting force without considering the surcharge F R is equal to W r C i into tan phi r. If you look here that, this is W r and this frictional force is acting here so this frictional forces is tan of phi r.

So, this is C i, C i value is equal to here 1, so C i is equal to 1 that is, F R will be equal to W r into tan of phi r, for phi is equal to angle of internal friction for foundation soil, which we consider as 30 degree. So then we have to calculate what will be the weight of the reinforced soil zone so we know that, what will be the length of the reinforcement, we know that what will be the height of the reinforcement, we know that what will be the unit weight of the reinforced soil zone.

So, weight can be determined by the unit weight of the soil in the reinforced zone into length into height. So, that is why, we have calculated W r is equal to gamma r H into L, gamma r is equal to 19, height of the wall is 9 and L is equal to 0.7 times of height that means, 6.3. So, you can calculate W r is equal to 1077.3 kilo Newton per meter so total resisting force F R will be equal to W r C i into tan phi r. That is, W r is equal to 1077.3, C i is 1, tan phi is 30 degree so total resisting force will be 621.98 kilo Newton per meter.

So, at the same time you know the resisting force, also you should know that, what should be the driving force. So, driving force also can be retained, as what should be the active pressure force from the retained field.

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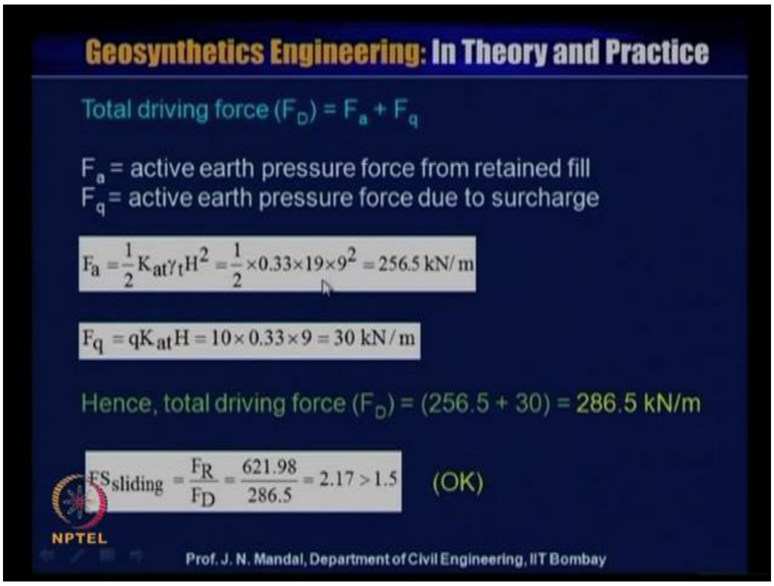

And what will be the active pressure force due to the surcharge load so here, this active earth pressure from the retained fill is equal to half K a t gamma t into H square, half into K a t value is equal to 0.33 and gamma t is 19, H is equal to 9, this is 9 square. So, this F a that means, active earth pressure force from the retained field is 256.5 kilo Newton per meter and F q is the active earth pressure force due to the surcharge that is, F q is equal to q into K a t into H because due to this is a surcharge pressure.

So, 10 is the surcharge load and gamma K a t is 0.33 and H is equal to 9, it is equal to 30 kilo Newton per meter. Hence, total driving force F D will be equal to 256.5 that is, F of a plus F q is equal to 30. So, total driving force will be summation of F a, and F q that means, 256.5 plus 30 will be equal to 286.5 kilo Newton per meter. Now, we have to check that, what would be the factor of safety against the sliding that is, the resisting force divided by driving force.

So, resisting force which we have already calculated that is, F R is equal to 621.98 divided by driving force is equal to 286.5 kilo Newton per meter. So, this ratio is equal to 2.17 and we have to check that, this factor of safety against sliding should be greater than equal to 1.5. So, if this factor of safety greater than equal to 1.5 that means, it is ok structure is in stable condition, with this I ended up this lecture.

Thank you for listening.