Geosynthetics and Reinforced Soil Structures
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Lecture - 11
Design Codes for Reinforced Soil Retaining Walls

Hello students, very good morning to all of you. The previous lectures we have been discussing about the different types of retaining walls and their advantages, and now let us continue the discussion in this lecture.

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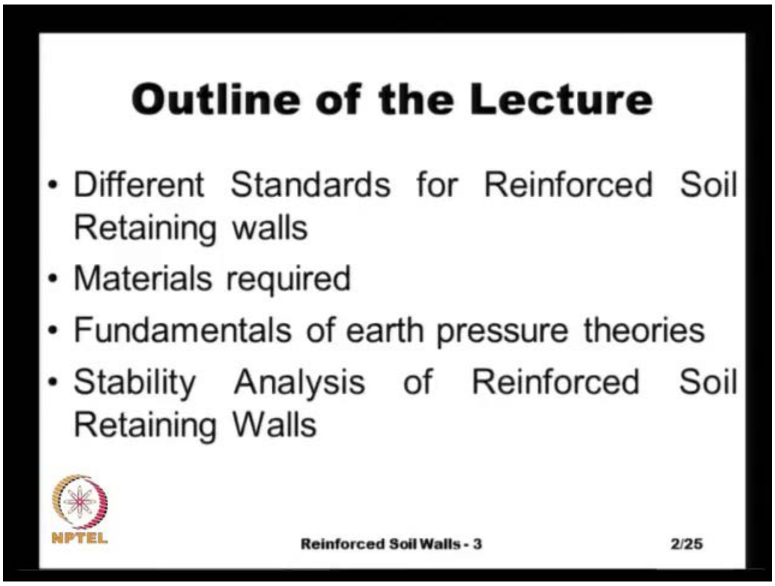

And see what are all the design methods that are available, just a brief outline of today's lecture, different standards for the reinforced soil retaining walls. And then what are the materials that are required for constructing these walls, and then the fundamental of their pressures, and then the stability analysis of the reinforce soil retaining walls.

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There are very large varieties of design methods that are available, and two most popular ones at least as far as the practice of reinforce soil structures in India is concerned; one is the B S 8006, that is the British standard 8006. The title of this is the strengthened reinforced soils and other fills the British code of practice first published in 1995 and significantly updated in the year 2006.

And the other one is the Federal Highway Administration Guidelines and the mechanically stabilized earth walls and reinforce soil slopes design and construction guidelines, this was published in 2001 and frequently updated. Then the one design code that is especially suitable for design of the reinforced retaining walls using modular blocks is the segmental retaining walls.

This was prepared by National Concrete Missionary Association in USA in 2009 the latest version is 2009, the earlier versions they have been publishing this right from 1993, and this particular one is only meant for retaining walls built using segmental block walls. And then the more recent update the Federal Highway Administration is the N C H R P report and the seismic analysis and design of retaining walls buried structures slopes and embankments this was published in the year 2008.

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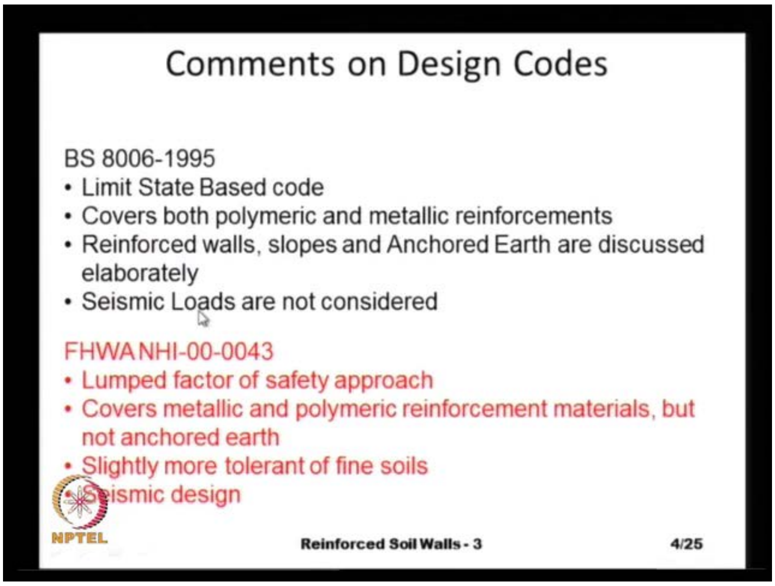

This is actually the most two popular ones are the BS code, that is the B S 8006 and the other one is the FHWA design code, and some of the features in the BS code is that it is based on the limit state approach. That is we look at all the limiting stresses and limiting loads and we look at the load factors, which are invariably linked to the reliability of the designs and so on.

And the BS code is quite extensive and it covers both the polymeric and metallic reinforcements and it is meant for design of retaining walls steep slopes, and also the anchored earth walls, because these are the anchored earth as you have seen earlier these are with reinforcement layer attached with an anchor at the end. So, that we can mobilize higher tensile forces in the reinforcement layers, and unfortunately although this design code is quite extensive it does not discuss the aspects related to the seismic analysis, that is one of the major limitation of this code, whereas the Federal Highway Administration Code is based on factor of safety approach that is very similar to the designs that we normally follow for design of as per the I S codes. So, we are very familiar with the factor of safety approach and it covers both metallic and polymeric reinforcements materials reinforced them anchored earth, so if you want to calculate the passive forces and other things we have to refer to the BS code.

And in terms of the soil requirement the FHWA code is slightly a bit more tolerant, for the percentage of fines that we can allow and the seismic design is also included. So, we can if you have any design along with the seismic activities we can use the FHWA and invariably, because not all the aspects of the reinforced soils are covered in any single code we try to interchange. At least those which are not covered by one particular design code, we try to follow the approach given by the other design codes and we need to combine some of these, and the other design codes that are equally elaborate the French codes and then the German codes.

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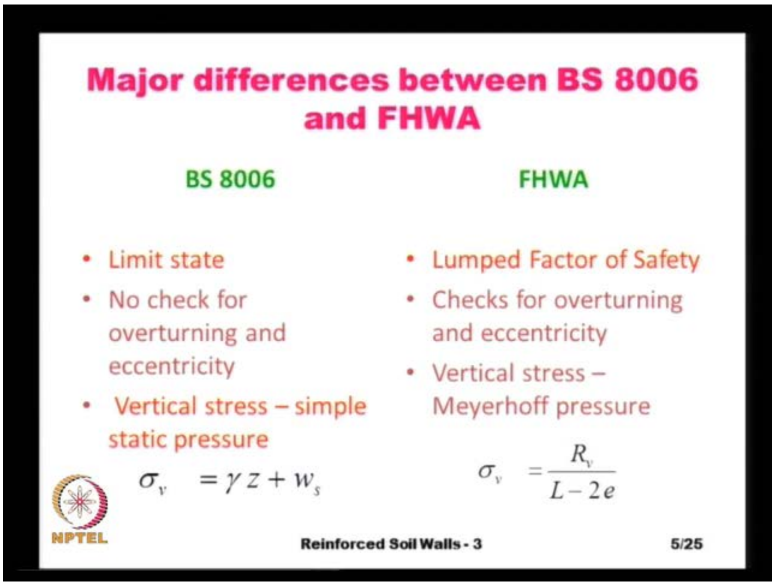

Well, these are some of the major differences between the British standard B S 8006 and the Federal Highway Administration Design code F H W A; one is the limit state design and the other is the lumped factor of safety approach. And in the BS code we do not do check for overturning and eccentricity, that is typically when we design the retaining walls, as you may recall from your geotechnical engineering courses.

We do check for the overturning of the retaining wall, and we also check for the eccentricity in the in the way the vertical load is distributed at the base of the retaining wall, and those aspects are not checked in the British code. Whereas in the Federal Highway Administration code, we check for overturning effect and also the eccentricity, and because of this the resulting vertical pressure calculations are very highly simplified in the British code, we just look at the vertical stress as the gamma z plus the applies uniform surcharge that is gamma z plus w s or q which remains constant.

Whereas in the Federal Highway Administration code the vertical pressures are calculated as per the Meyerhoff's approach, it is assumed that the vertical loads are distributed only over a base width equal to b minus 2 e, where e is the eccentricity. And here since we use l for the length of the reinforcement, and instead of using the b, we use the length of the reinforced block itself as the base width.

And the vertical stress is calculated as R v that is the total load applied per unit length in the perpendicular direction to the one plain of analysis divided by l minus 2 e, where l is the length of the reinforced block and e is the eccentricity, and we will see how to apply this bit later on when we do the calculations.

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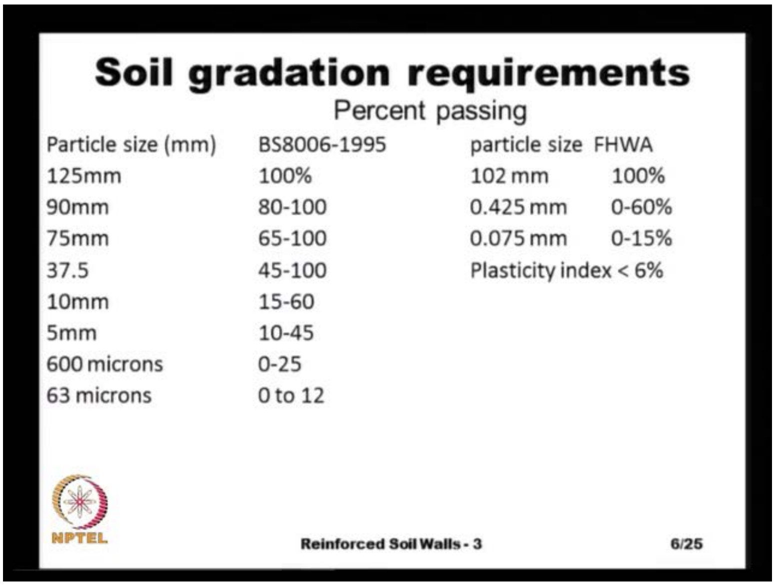

And the soil gradation requirements are listed here, on the left hand side the British code, on the right hand side the American code Federal Highway Administration, and as we have seen earlier we prefer to use highly granular soil because only this granular soils. They have very good interaction with the reinforcement and we have seen theoretically that when the friction angle phi is greater than 0, the amount of mobilized reinforcement forces are much higher and because of that all the design codes they recommend using highly granular soils.

The BS code the requirements are like this, that if you look at the bottom end of the requirements the 600 microns, that is 0.6 millimeters it allows 0 to 25 percent. And then 63 microns is only up to 0 to 12 percent, that is in the BS code they do not use the 75 microns size as the standard in the Indian code and American codes, they go up to 63 microns. And the percentage finds they allow is only 12 percent whereas, the Federal Highway Administration is essential at the top of the gradation requirements are more or less the same.

But at the bottom if you see 0.425 millimeters that is 425 microns up to 60 percent finds are allowed and same the 75 microns size we allow up to 0 to 15 percent finds, find then 75 microns, and the plasticity index that is allowed is less than 6 percent in both the BS code and also the American code.

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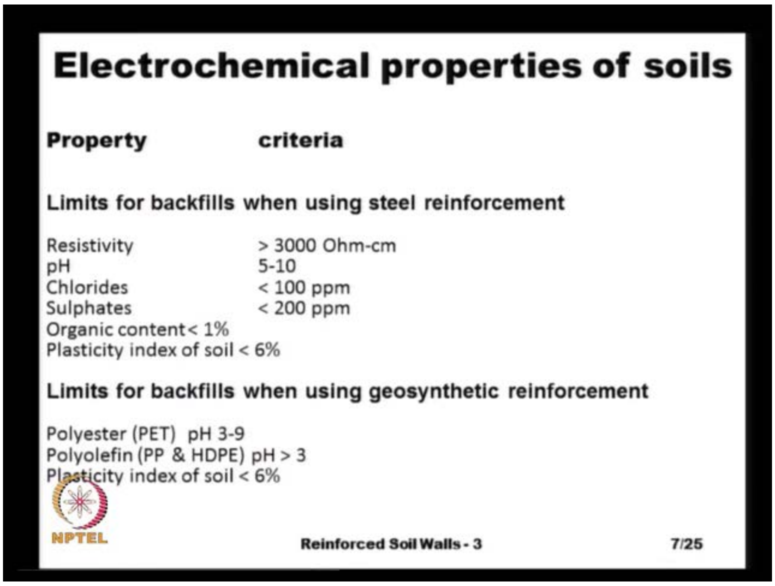

Well along with the gradation requirement all the design codes, they also recommend some other properties that is the electrochemical properties of the soils. The reason why the electrochemical properties are also recommended is that most of the resistant the corrosion of for the metallic reinforcements is because of the electrochemical nature of the soils.

And especially this is very critical when we use steel reinforcement, the resistivity of the soil should be greater than 3000 ohm centimeter, and as we already know the clay soil they have very low resistance, they can allow the electrical currents to pass through because of their the charge that is there on the surfaces. Whereas, the granular soils like sand, they have very high resistance the p H should be in the range of 5 to 10, the chlorides content should be less than 100 ppm, and the sulphates contents should be less than 200 ppm, and organic content should be less than 1 percent, and the plasticity index as we discussed earlier should be less than 6 percent.

And the same limits when we use polymeric type reinforcement the for the polyester the p H is should be in the range of 3 to 9 and the polyolefin, that is the polypropylene or the high density polyethylene the p H should be greater than 3 is actually the electrochemical requirements are more stringent. When we use metallic reinforcement whereas, when it comes to the polymeric reinforcements we do not need to be, so stringent because the plastics they do not interact with the soil directly or indirectly.

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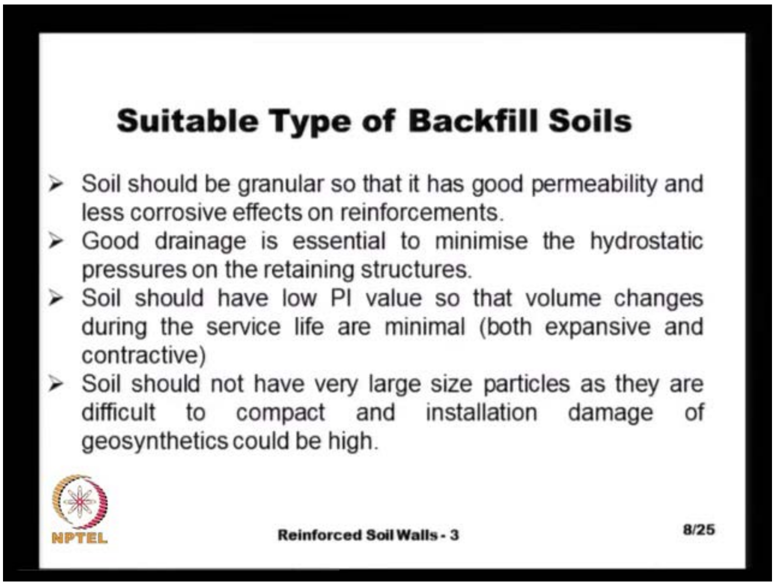

Well what are the suitable types of backfills apart from these requirements, let us look at some other requirements. The soil should be granular, so that it has good permeability and if it is granular, it has lesser corrosive effect on reinforcement, mainly because it has does not have too much of electrochemical properties that will adversely affect the materials that we put in. And the if the soil is highly granular it provides where a good drainage, and it minimizes the hydrostatic pressures on the retaining structures.

And as we know the lateral at the pressures by considering hydrostatic pressures, we find that a very, very high because the lateral at the pressure are constant for the soils is very low of the order of one third to about may be one half whereas, for water it is one because of the hydrostatic pressures. And the reason why we recommend the soils with very low plasticity index value is that the volume changes that a soil undergoes, because of the changes in the moisture contents, they can be directly related to the PI.

That is the plasticity index, because the pI is also dependent on the fines content, and we should not allow too much of both expansive of volumetric strains that is the volume increase or contractive shrinkage. Both could be a disaster or the service serviceability of the structure, may not be satisfied, if there are too much of volume changes, because if there is volume expansion the entire phasing panels they get pushed out. And then the surface may heave up and if there are too many contract too much of shrinkage cracks that happen, there may be some settlements and both should not be allowed.

And the way we put a check on this type of defamation is by controlling the plasticity index, and the although we recommend that the soil should be granular. It should not have too many large size particles mainly, because it becomes difficult compact and we may not be able to achieve very good compaction in terms of the proctor densities. And also the installation damage of the geosynthetics maybe very high, if you have very large size particles that we have seen earlier that the installation damage factors are usually less or low for soils like sand and other things are sills whereas, for railway ballast these installation damage factors are much higher.

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And when it comes to design we need to use appropriate shear strength properties and what properties do we use for design of rein the retaining walls, the codes they recommend that we use the shear strength properties from the direct shear test. Mainly, because the stress state behind the retained walls is very similar to the stress state that exists in the direct shear box test, where in both the cases the strain of the soil along the length of retain the retaining wall is negligible, and the same way in the case of direct shear box test, because of the rigid nature of the box the strain in the outer plain direction is negligible or 0 whereas, there is a shear strain in the direction of the loading. And the we know that there are two types of friction angles, one is the peak friction angle corresponding to the peak of the stress strain curve, and the other one the constant volume of friction angle at very large strain.

And the codes recommend the usage of the peak friction angle, mainly because the amount of deformations that we require for mobilizing the active forces is are very small, and because of the provision of reinforcement the lateral deformations are not very high. But, then when you expect very large deformations say for examples if you are using a the reinforcement materials that are very flexible in that case the lateral strains may be high, where we build our structure an extremely soft foundation soil that may lead to large vertical and lateral deformations, we need to use constant volume of friction angles.

And what do we do with the cohesion, because out shear strength properties it consist they consists of cohesion and the friction angle, and cohesion is usually neglected. As it gives us some additional factor of safety in our designs, unless the soil is such that it has very large cohesion and that can be relied upon we should not use the cohesion in out design calculations.

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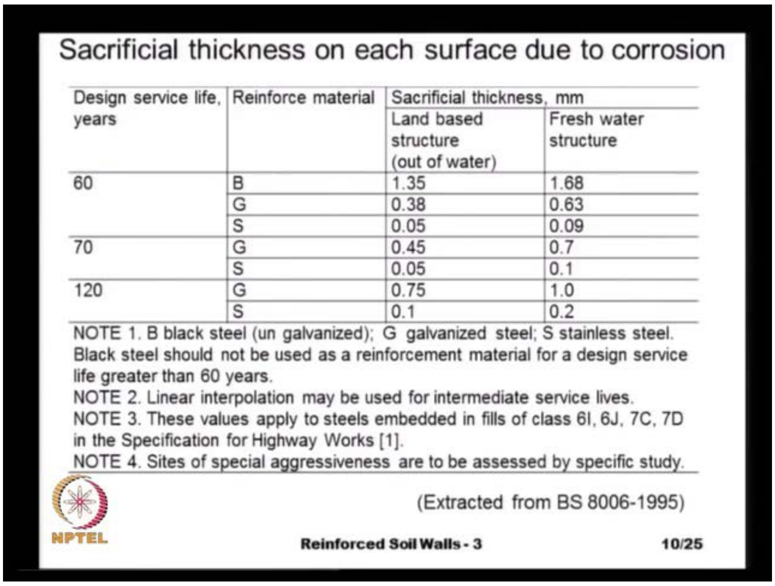

Sacrificial thickness on each surface due to corrosion

Design service life, years	Reinforce material	Sacrificial thickness, mm	
		Land based structure (out of water)	Fresh water structure
60	B	1.35	1.68
	G	0.38	0.63
	S	0.05	0.09
70	G	0.45	0.7
	S	0.05	0.1
120	G	0.75	1.0
	S	0.1	0.2

NOTE 1. B black steel (un galvanized); G galvanized steel; S stainless steel. Black steel should not be used as a reinforcement material for a design service life greater than 60 years.
NOTE 2. Linear interpolation may be used for intermediate service lives.
NOTE 3. These values apply to steels embedded in fills of class 6I, 6J, 7C, 7D in the Specification for Highway Works [1].
NOTE 4. Sites of special aggressiveness are to be assessed by specific study.

(Extracted from BS 8006-1995)

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When we use a steel reinforcement we should expect some corrosion to take place and the affect of corrosion is the loss of thickness of the material that is available, and mole all the design codes their recommend certain loss in the surface thickness. As the time elapses, and a brief extract from the BS code BS 8006 is reproduced here, for different grades of steel.

It is actually B stands for un galvanized steel and the G is with the galvanized steel and S is stainless steel, and then there are two exposure conditions that are given that is for the land based structures which are not directly in contact with the water. And then those structures which are in contact with water, like for example, we may build some retaining walls as lake front structures or as river front structures and depending on the exposure conditions.

And then the depending on the type of treatment that is given to the steel or the metal we have these sacrificial thicknesses, and this thickness should this reduction in the thickness should be applied on all the exposed phases, not just on one phase. Say for example, for 120 year service life for a galvanized steel it is recommended that we reduce the thickness by 0.75 millimeters on each surface, say for example, if you have a 6 mm thick steel strip, the thickness reduction is 6 minus 2 times 0.75, that is in the thickness direction.

And then let us say that the steel strip is 50 mm wide initially and we should apply the reduction in the width on both the sides, so 50 minus 1.5 becomes 48.5. And the same reductions in the case of water exposure is 1 and as you notice for short design lives the British code recommends that you can use un galvanized steel, that is with a index of B. Whereas for the design lives 70 years or more it recommends that we have to use galvanization, and the galvanization usually it should be of the order of about 85 microns on the surface.

Then for a design lives in between the codes says that we can use a linear interpolation between the two design lives that are given, and if you expect more aggressive environmental conditions, then we cannot directly use these tables, but we need to use some site specific analysis. Like for example, if our structure is exposed to marine environment like sea water or ocean breeze, then the corrosion rate could be much higher and we need to consider those extreme events for our calculations.

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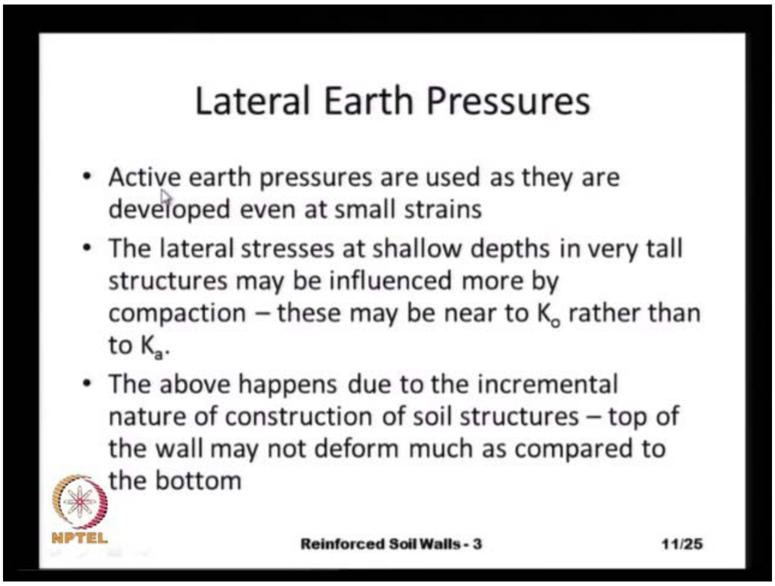

Then what are the lateral earth pressures that we need to consider, as we know we always consider only the active lateral earth pressures, because these are the ones that act on the structure when the structure moves away from the backfill. And these pressures are developed even at very low strains, and the pressures although we in general we say that we use lateral active lateral pressures, but sometimes our structure itself may not deform adequately.

Especially, in the case of very tall structures our pressures may be influenced more by the compaction stresses, because in all these retaining structures we try to achieve a compaction level of more than 95 or 98 percent maximum rate density. And because of that we may have very large locked in stresses, and the codes they say that if you have a very tall structure the lateral earth pressures at the top of the wall may be more closer to k naught, that is the k naught is the lateral earth pressure addressed rather than to k a.

And so we need to consider the different scenarios of the of the type of compaction and the height of the wall, and then whether the wall is allowed to expand laterally or not, while deciding the amount of lateral-th pressures that that we apply. The actually the reason for the different earth pressure scenarios is that all are soil structures are constructed incrementally, we go layer by layer and because of this the top of the wall may not deform.

Although, we assume that there is a rotation, but because we are constructing the soil layers the bottom of the structure is subjected to more number of layers of compaction, and it may deform may have chance to deform laterally or gradually as the structures height is increased. Whereas, at the top the it may not have a change or expand laterally, because the soil compaction does not go beyond the top of the wall. And because of this the deformations at the top are very small, and because of that the lateral earth pressure constant is more closer to k naught rather than k a.

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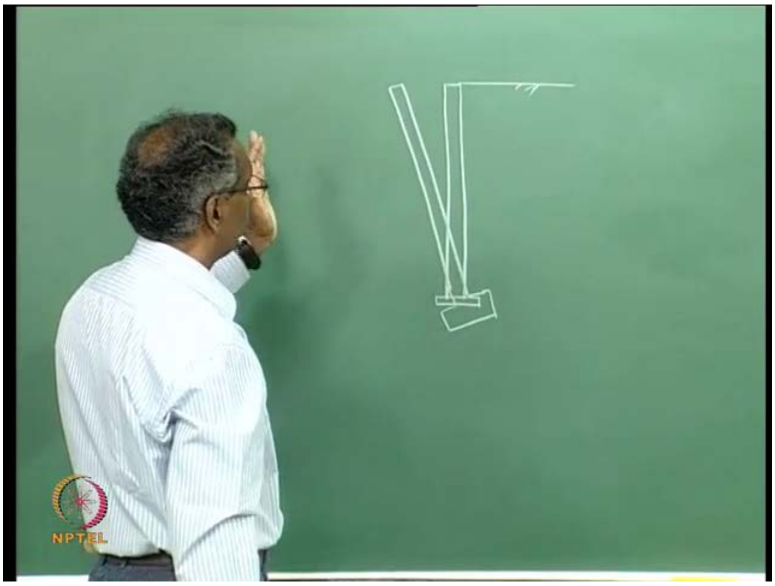

Actually this I can illustrate very simple manner, see for a normal case we assume that the wall the wall rotates like this, and there is sufficient deformation in the soil for the earth pressures to reduce to active earth pressure.

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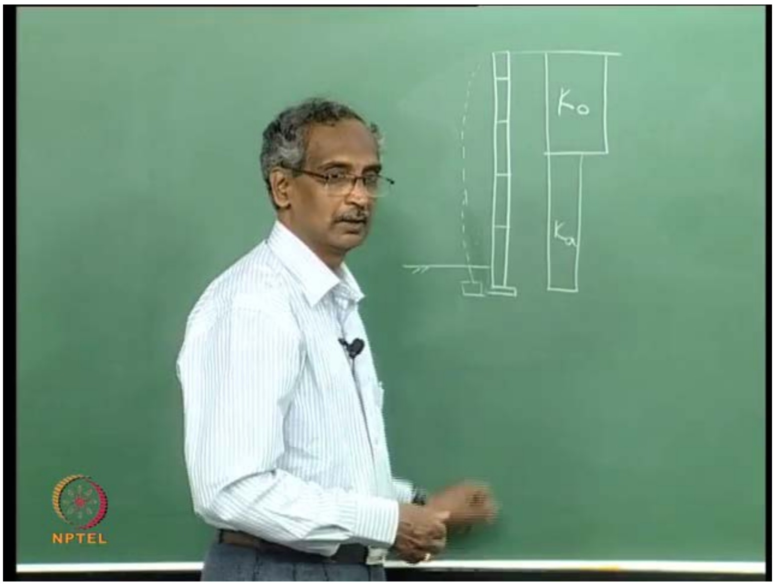

But, the actual deformation of the walls may be more similar to this, because at the top the lateral deformation that takes place maybe very small as compared to the bottom. And so our earth pressures maybe more similar to k naught at the top, then k a at the bottom actually this we will consider when we do the design calculations.

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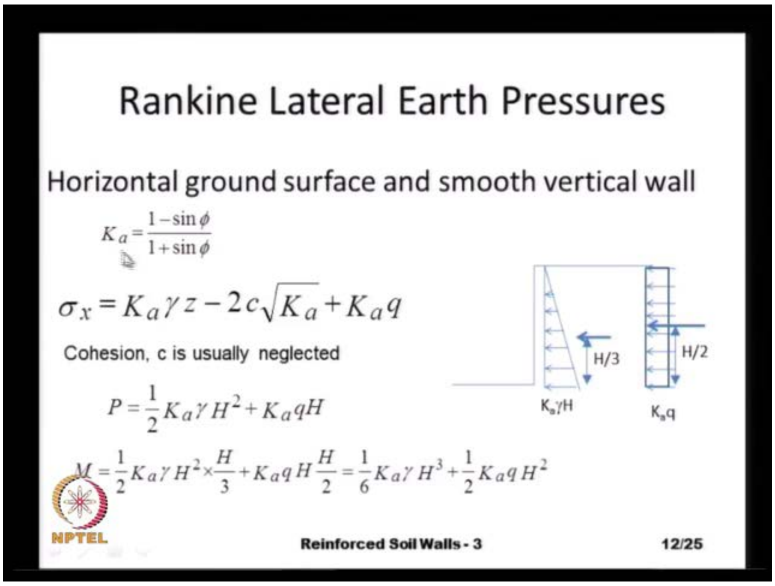

And typically we use the Rankine earth pressures theory for calculating the lateral earth pressures and the overturning moments, and we know that we active earth pressure co-efficient is 1 minus sin phi by 1 plus sin phi. And this sigma x that is the lateral active earth pressure is k a gamma z minus 2 c square root k a plus k a q, where our the self weight stress, because of the unit weight is increasing in a triangular manner, linear increase in the depth.

And at the bottom the maximum lateral earth pressure is k a times gamma h, where h is the height of the retaining wall, and the effect of constant uniform surcharge pressure q is constant with depth k a q, whereas, the self weight has a triangular pressure distribution the surcharge has a rectangular type distribution. And if you see this formula for active lateral earth pressure, the formula is k a gamma z minus 2 c square root k a plus k a cube.

So, if you see the effect of the cohesion, the effect of cohesion is to reduce the lateral earth pressures, and so normally we neglect c, so that we consider higher lateral earth pressures for the design purpose. And because of that we have an additional factor of safety over and above whatever we aim for through the design calculations, triangular pressure distribution acts at height of h by 3 from the base, whereas, this rectangular earth pressure distribution acts at a height of h by 2.

So, our p the lateral force is one half k a gamma h square plus k a times q h and the overturning moment is this triangular force multiplied by h by 3 and this rectangular force multiplied by h by 2. So, it comes out as one by 6 k a gamma h cube plus one half k a q h square, and this is the overturning moment and whatever retaining wall that we design it should be able to support, this much of lateral crust that is acting on the wall and then the overturning moment.

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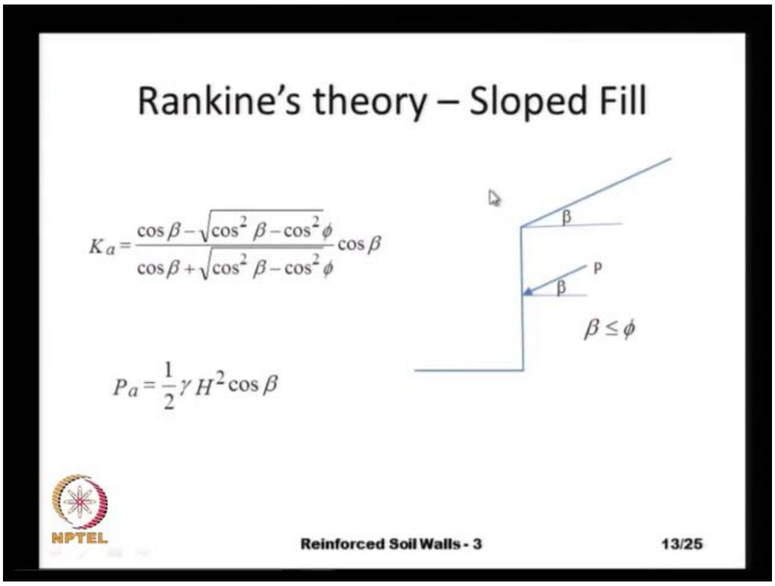

Well sometimes the above formula is for a horizontal backfill, but many times we may have an inclined backfill and the Rankine's theory is gives a very simple formula, wherein k a is given in terms of the slope angle beta. And here this slope angle beta should be less than friction angle phi, because beta is greater than phi becomes the we know that the slope becomes unstable because it is more than the friction angle of the soil.

So, the k a is cosine beta minus square root of cosine square beta minus cosine square phi divided by cosine beta plus square root of cosine square beta minus cosine square phi multiplied by cosine beta, and actually this formula is directly derived by assuming that the forces are in the direction of the slope. We can directly get this is from the mores circle and our resultant force is assumed to act at an angle of beta to the horizontal. So, the horizontal component that we consider for design, that is the P a, the P times cosine beta that is one half gamma h square times cosine beta.

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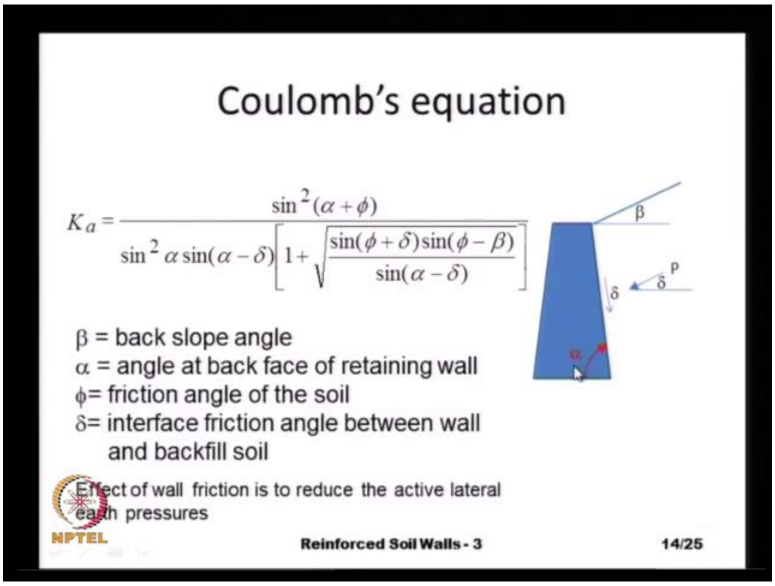

And then you can also consider a more generic case of a retaining wall like this, wherein the this phase is not vertical, but its inclined at some angle alpha and let us say that the backfill slope is inclined at a beta at an angle of beta. And then the back surface of the retaining wall need not be smooth, in the Rankine's theory is assumed that the shear stresses that are generated, along this the backfill soil to the retaining wall phase is smooth and because of that there are no shear stress is developed.

Whereas, in the Coulomb's theory it is a bit more general and Coulomb assume that there could be some friction that is developed along the height of the retaining wall. And the generalized formula for that is given like this k a is sine square of alpha plus phi, this entire thing divided by sin square alpha sin alpha minus delta that multiplied by this whole bracket to the square, actually the square is missing here in this equation.

And beta is the in this equation is the back slope angle alpha is the angle at the back phase at the retaining wall, when alpha is 90 degrees this back phase is vertical and phi is the friction angle of the soil. And delta is the interface friction angle between the wall and the backfill soil, and the effect of the wall friction is always to reduce the active lateral earth pressures.

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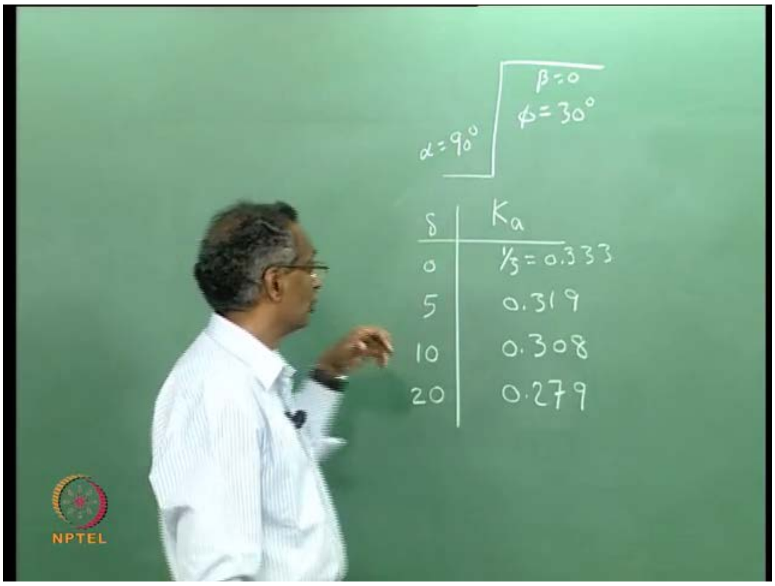

Let me just list out some typical k a values as a function of data, here I have listed the influence of a delta in the k a, for a typical friction angle of 30 degrees with a vertical wall and horizontal backfill slope. And when delta is 0 the k a is one third that is the simple Rankine's formula that is 1 minus sin phi by 1 plus sin phi that is equal to 0.333 and let us see the effect of delta on the k a as it gradually increases.

So, when the delta is increased to phi degrees the k a falls down to 0.319 and when it increases to 10, it has reduced 0.308 and when the delta is increased to 20 degrees the k a is 0.279 and the effect of the delta is always to reduce the pressures as we have seen. And in the case in order to get more conservative results, is always a good design practice to reduce to neglect the effect of delta on the earth pressures, because by neglecting delta we get a higher k a for design purposes as we have seen there.

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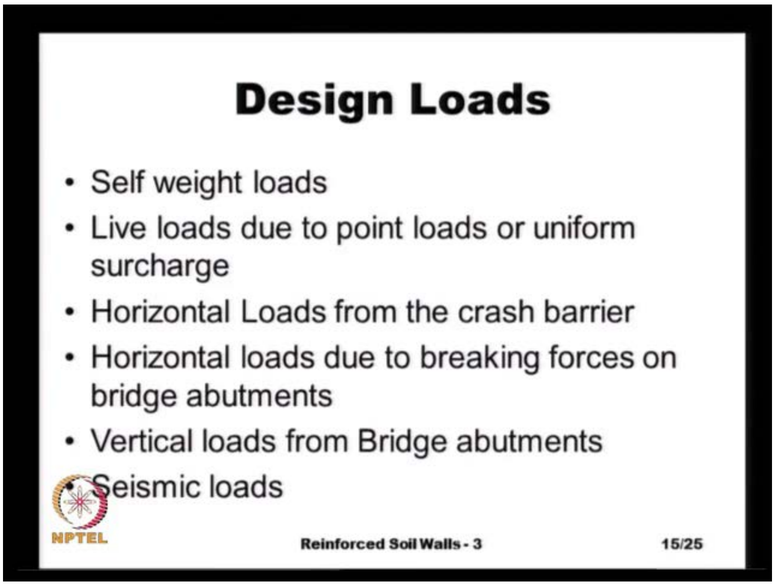

Well for design purposes we need to consider very large number of loads that act on the structure, the two of these loads we have seen earlier, one is the self weight of the loads self weight of the of the soil, that is a triangular distribution of the of the earth pressures. And then the uniform loads, because of the live load that acts on the structure its either because of the point loads or uniform surcharge.

The point load could happen when we have a bridge abutment sitting directly on top of the retaining wall, and the bridge abutment will have some roller support. And the load that is transferred into that supportive it will act like a point load, then we could have a horizontal load that is transferred from the crash barrier. It is when there is any impact of the vehicles on the crash barrier during an accident, there will be some lateral crust and that load gets transferred into the retaining wall.

Then there could also be the horizontal loads due to breaking forces on the bridge abutment especially on highway bridges or on the railway bridges the traction forces could be very high. Then apart from these we need to also consider seismic loads that act because of the earthquake excitations.

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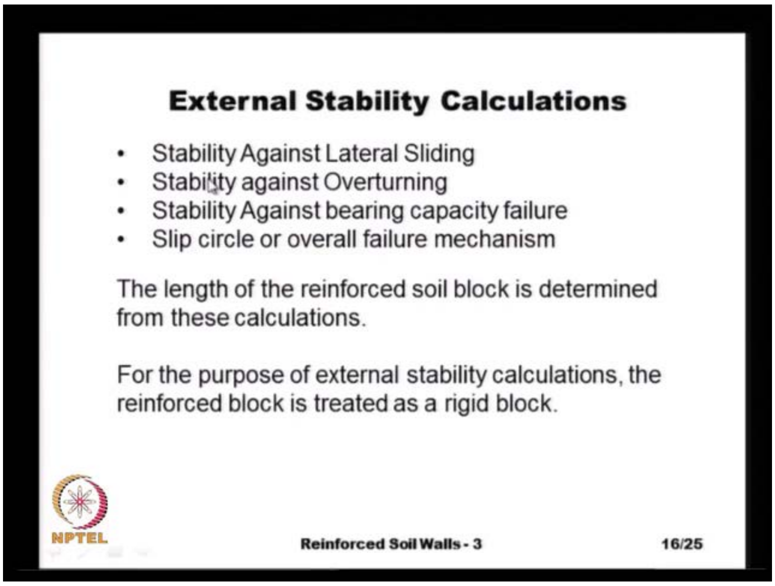

Well, let us look at the design process now, and there are two different calculations that we do for the design of the reinforce or retaining walls one is the external stability calculation, and then the other one is the internal stability calculation. And there are four different steps that we do under the external stability calculations, one is to check for the stability against lateral sliding and the other one is to check for stability against overturning. And then the stability against bearing capacity failure or the settlements and then the slip circle failure or the overall failure mechanism.

And usually these calculations the external stability calculations, they fix the length of the reinforcement in this reinforced soil retaining wall, and as we have seen earlier the parameters that are to be designed the length of the retaining walls, and then the vertical spacing and then the strength of the reinforcement layers and so on. And the length of the retaining walls is obtained by doing this the external stability calculations and for the purpose of the external stability calculations, we treat the entire reinforced block as a homogenous block, as a rigid block, as a monolithic block, for the purposed of design calculations.

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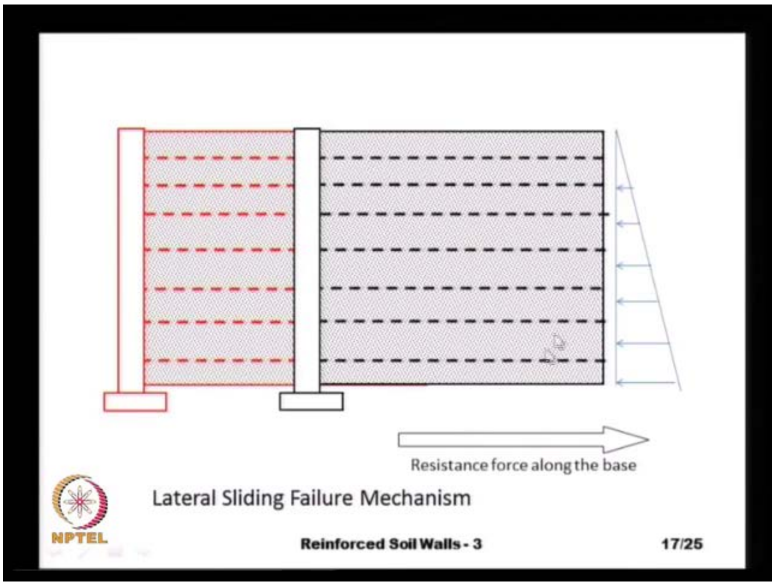

Well the let us look at retaining walls something like this, and here we have a soil of certain height and with number of reinforcement layers, and it is acted upon by lateral force that comes from the from the backfill. And when this force acts let us see what happens, the tendency is of the lateral forces is to push this wall outwards like this as shown here and during this process, we have some resistance force is developed along the base.

And this failure mechanism is one of the failure mechanism that we also considered in the case of the reinforce concrete ((Refer Time: 40:32)) concrete walls, and this fixes the amount of mass that we need to have in the reinforced soil block. So, that there is an adequate resistance that is developed at the base to contract the forces that are acting on this reinforcement block.

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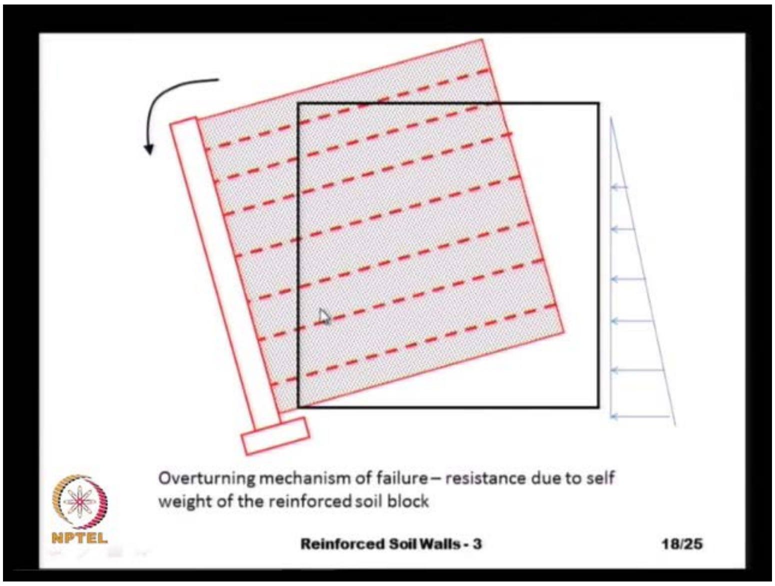

The other one is the overturning effect the block should be wide enough that the overturning forces that act on the block or lesser than the counter acting moments, and in this failure mechanism is checked at the Federal Highway Administration code and other design codes. Whereas, the BS code does not recommend the checking for this and the same way the Japanese code also does not talk about the overturning, because the Japanese code and the British code they treat this as a flexible soil structure where the entire structure may not overturn.

Whereas, the American codes they consider this as an entire rigid block and there could be some overturning and the self weight of the reinforced block is, so designed that there is a adequate fact of safety against overturning.

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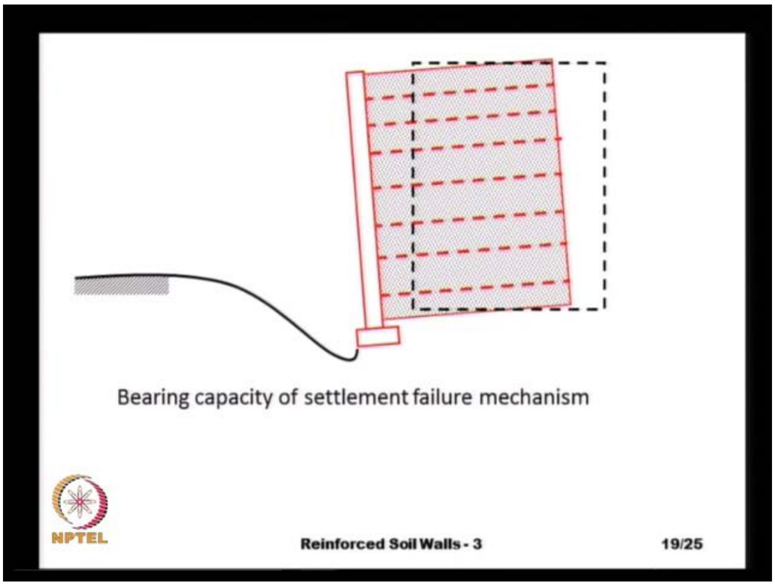

Well, the other possibilities is the bearing capacity failure or the settlement excessive settlements and we need to check for the bearing capacity of the foundation soil and also the settlements of the foundation soil. And the settlements that we have under the because of the construction should be within reasonable limits, so that the serviceability of the structure is not impaired, and at the same time there should be adequate fact of safety against bearing capacity failure.

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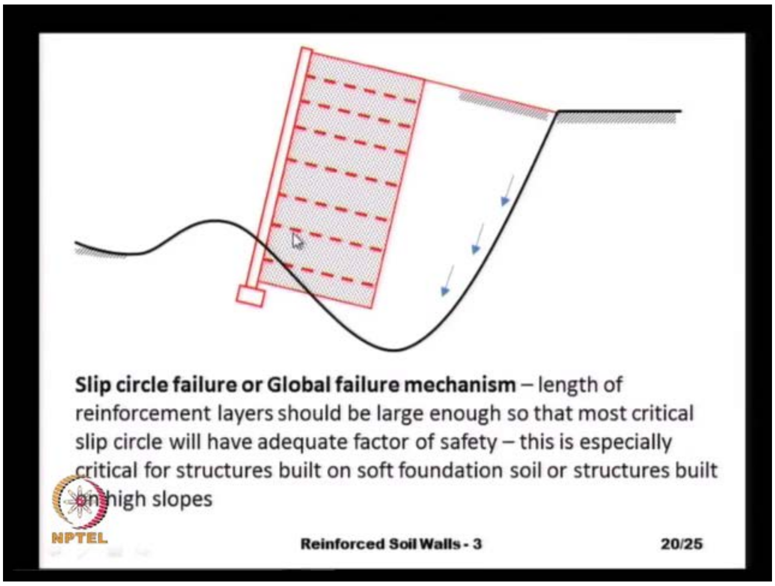

And the other type of failure mechanism is the slip circle failure mechanism and the slip circle variably forms behind the reinforced the soil block. And this is a very critical failure criteria, especially when we have ah the structure delta extremely soft soils, where we can have a deep seated type failure or whenever structure is built on a steep slope something like this.

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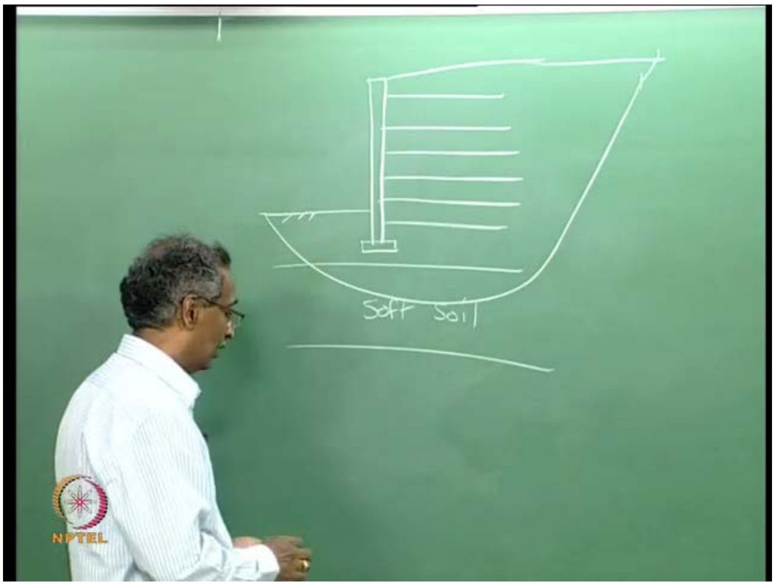

Let us say that we build our retaining wall on an extremely soft soil, there could be a possibility for the or for the formation of the slip circle through the soft foundation soil. And that has to be checked apart from the earlier a 3 conditions like the lateral sliding or overturning, the bearing capacity failure.

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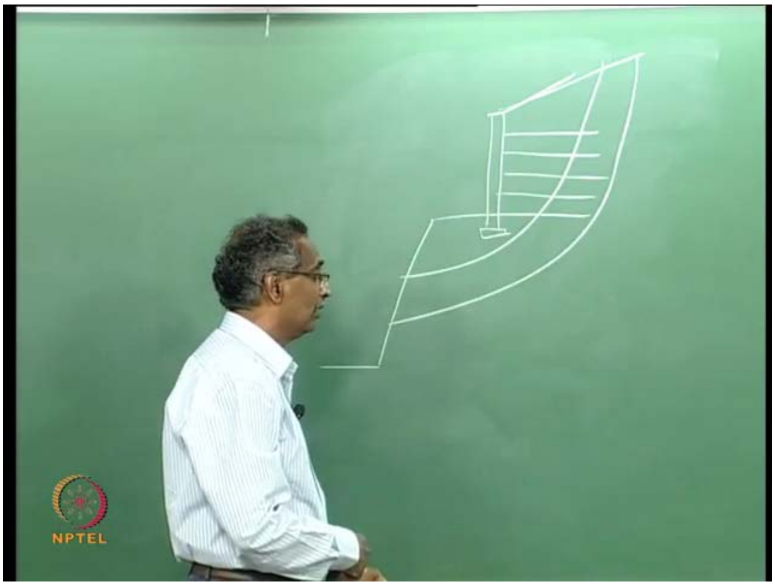

And another case where from this type of failure could be critical is, let us say we build a very high retaining wall on a on a slope, we need to consider the possibility of slip circle directly forming either through the reinforce block behind the rein or behind the reinforced block and cutting through the cutting through the slope like this. And so in such cases this failure mechanism may govern the design rather than the lateral sliding or overturning or the bearing capacity type failures.

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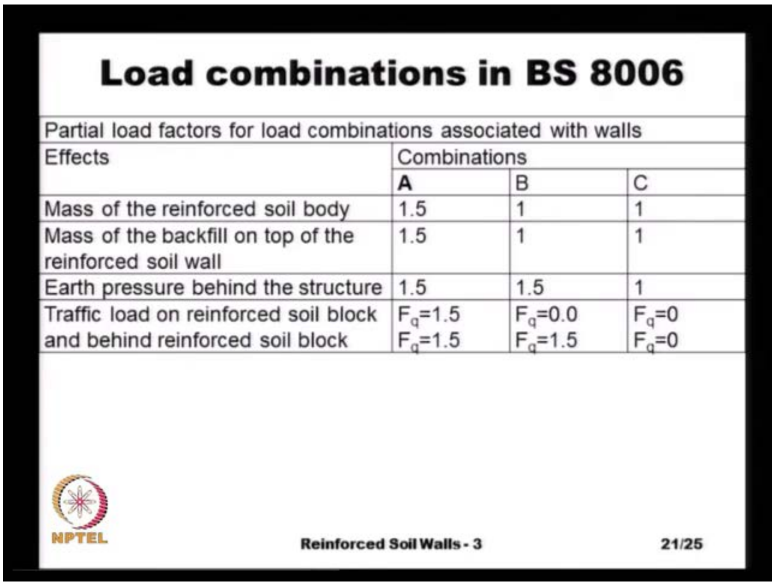

Load combinations in BS 8006

Partial load factors for load combinations associated with walls			
Effects	Combinations		
	A	B	C
Mass of the reinforced soil body	1.5	1	1
Mass of the backfill on top of the reinforced soil wall	1.5	1	1
Earth pressure behind the structure	1.5	1.5	1
Traffic load on reinforced soil block and behind reinforced soil block	F_q=1.5 F_q=1.5	F_q=0.0 F_q=1.5	F_q=0 F_q=0

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All these failure conditions there are very well described in the BS coding and the BS code through the different load combinations, and the BS code it gives three different load combinations A B and C. And they assign some factors that we need to consider for achieving different critical conditions, and these combinations are given separately for normal reinforce or retaining walls, where there is no external loading at the top. And another case, where we have a reinforce retaining wall that is directly supporting a bridge abutment.

See in load combination A fact of 1.5 is applied on the mass of the reinforce soil body and then the mass of the backfill on top of reinforce soil wall is also applied with a factor of 1.5 Then the earth pressure that is coming from the backfill is also applied with a factor of safety of 1.5 and so on in the traffic load. And then whereas in the and is actually in the combination a applies a factor of 1.5 on all the loads that we have and it creates very critical conditions.

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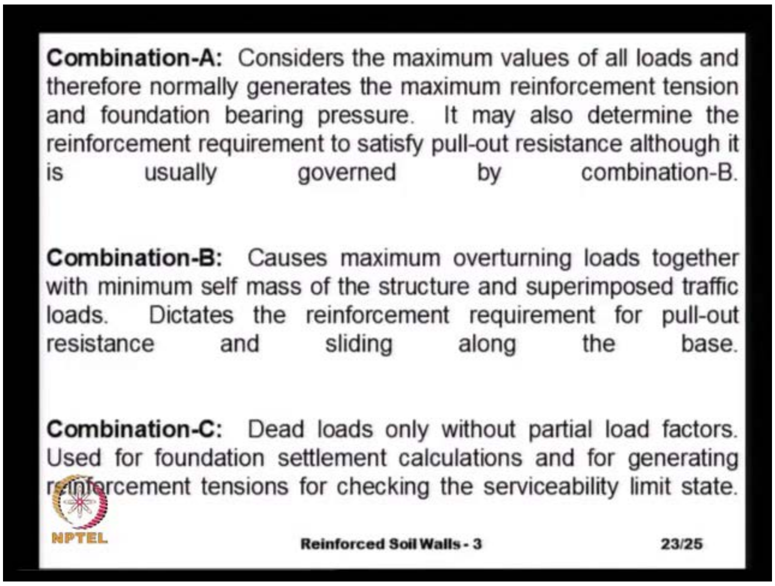

Basically, this combination A it considers maximum possible values of all the loads and this generates the maximum reinforcement forces, that we have and then the maximum foundation bearing pressures. And this is basically to rent of the reinforcement layers and then the factor of safety against the foundation bearing failure, and it also checks for reinforcement against pullout.

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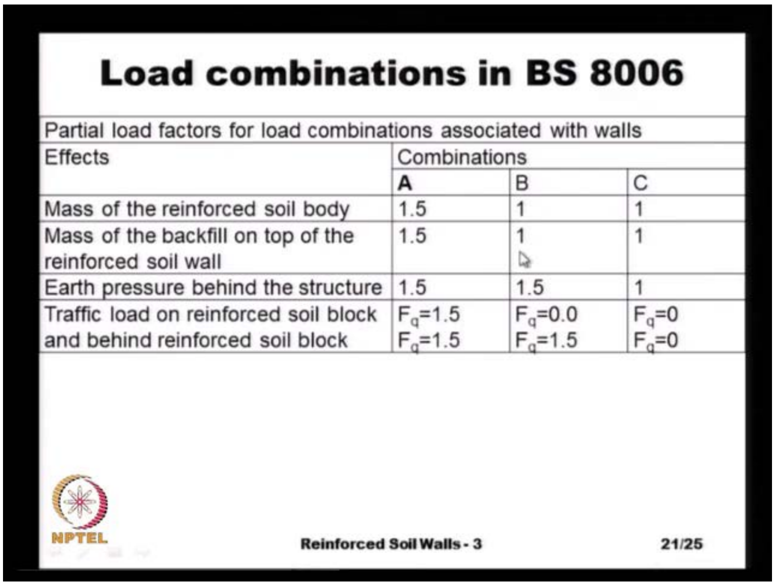

Partial load factors for load combinations associated with walls			
Effects	Combinations		
	A	B	C
Mass of the reinforced soil body	1.5	1	1
Mass of the backfill on top of the reinforced soil wall	1.5	1	1
Earth pressure behind the structure	1.5	1.5	1
Traffic load on reinforced soil block and behind reinforced soil block	F_q=1.5 F_q=1.5	F_q=0.0 F_q=1.5	F_q=0 F_q=0

In some load cases whereas in the other cases the combination B maybe more predominant whereas, in combination B we increase the forces that are acting while reducing the resistance forces. See in the combination in load combination B we apply a factor of one and the mass of the soil within the reinforced body and mass of the backfill, directly resting on top of the reinforced body reinforce soil we apply a factor of one.

Whereas we apply a factor of 1.5 and the pressures that are acting behind the reinforcement block that is the backfill, then the traffic load directly applied on the reinforces block we do not consider. So, our f q is 0 and whereas, the traffic load that is acting on the backfill soil, it is multiplied with a factor of 1.5 and this combination B is very critical for lateral sliding and overturning.

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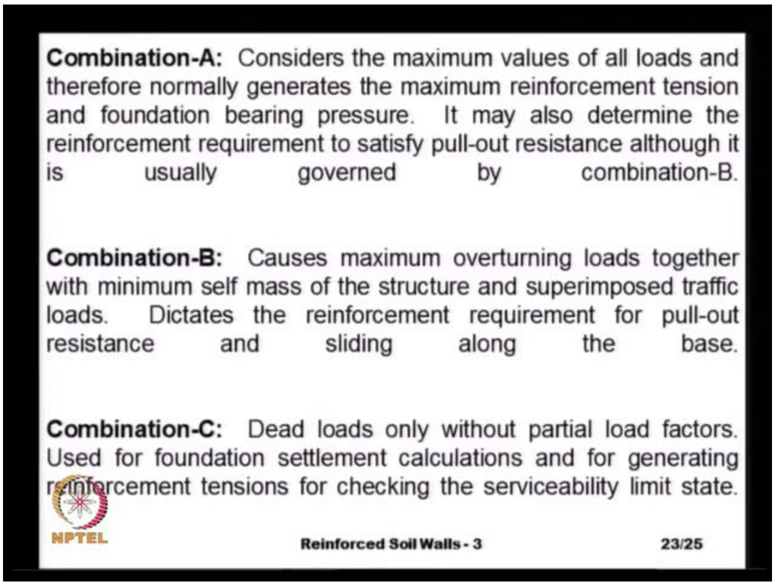

And is actually this combination B causes maximum overturning moment while the mass that is resisting these forces is minimum, and the dictates the reinforcement requirement for pull-out and sliding along the base. And it is actually it is a very critical case for the length of the reinforced block to resist the force of that are acting on the block.

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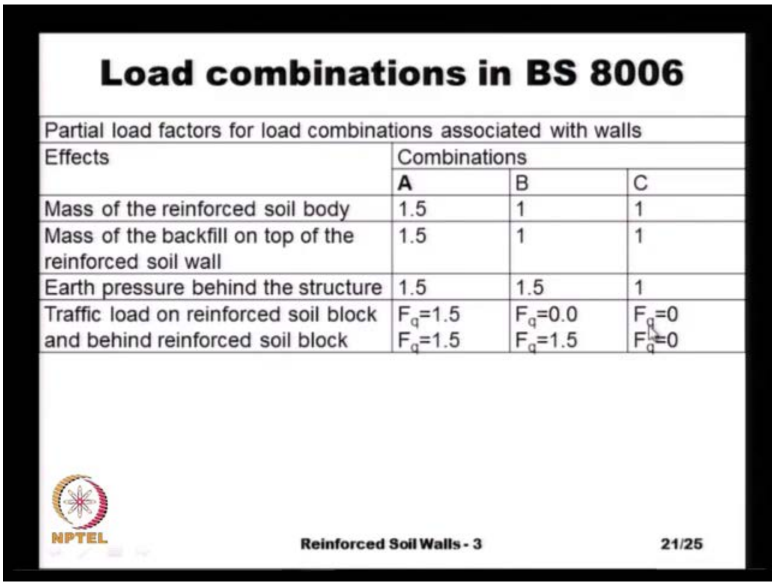

Partial load factors for load combinations associated with walls			
Effects	Combinations		
	A	B	C
Mass of the reinforced soil body	1.5	1	1
Mass of the backfill on top of the reinforced soil wall	1.5	1	1
Earth pressure behind the structure	1.5	1.5	1
Traffic load on reinforced soil block and behind reinforced soil block	F_q=1.5 F_q=1.5	F_q=0.0 F_q=1.5	F_q=0 F_q=0

Then the combination C is actually all the self weight forces there applied with a factor of one, and we do not consider any external loading due to surcharge.

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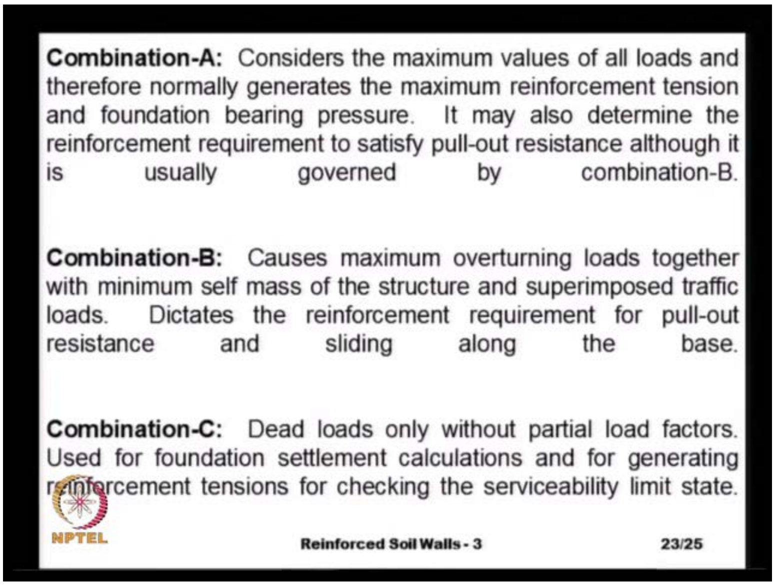

And this is actually this combination C we consider only the dead loads without any partial load factors, and this combination C is used for calculating the foundation settlement, and for generating the tension forces within the reinforcement layers during the serviceability limit state.

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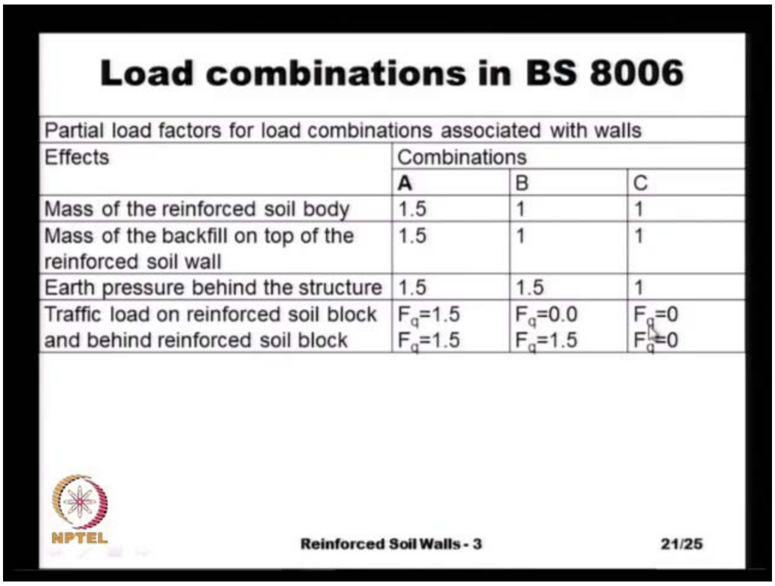

Partial load factors for load combinations associated with walls			
Effects	Combinations		
	A	B	C
Mass of the reinforced soil body	1.5	1	1
Mass of the backfill on top of the reinforced soil wall	1.5	1	1
Earth pressure behind the structure	1.5	1.5	1
Traffic load on reinforced soil block and behind reinforced soil block	F_q=1.5 F_q=1.5	F_q=0.0 F_q=1.5	F_q=0 F_q=0

It is actually in all these cases we consider extreme events, the combination C is for a limit load whereas, we can think of combination C for serviceability limit state. That is within the working stress levels and we need to do some more calculations that we will look at in the next lectures.

Thank you.