Ground Improvement
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Lecture No. #32
Reinforced Soil Walls – II

In this class on Reinforced Soil Retaining Structures are particularly in connection with walls, I will try to explain this example that we covered last time, and further guidelines on the design of reinforced soil walls, we will see today.

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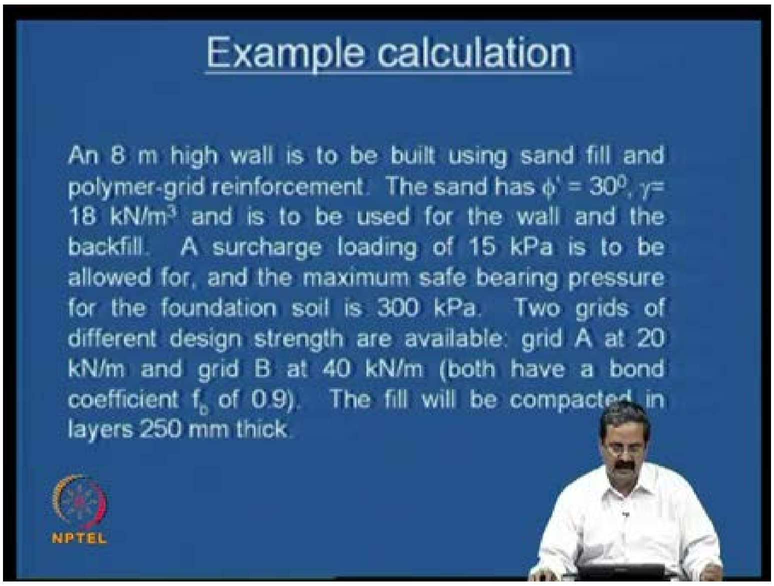

As I just mentioned, we had just discussed this example that we need to construct this in a particular location; we want to construct an 8 meter high retaining wall, with a sand backfill, you know, it is 30 degrees is friction angle and bulk density is also known, and we have a some surcharge that one can use, you know, the like a traffic loading, one needs to consider in some of the in many of the designs, and we also know the bearing pressure of the soil, and assuming that we have two geogrids like grid A and grid B, which have design strength of 20 and 40.

And then, the bond coefficient of the geogrid material is about 0.9, and normally, if the compacted lift thickness is about 250 mm. So, which means, that you have to place this reinforced soil, the reinforcing materials like a geogrids at 250, in the multiples of 250 mm spacing, either it could be 500 or 250 right.

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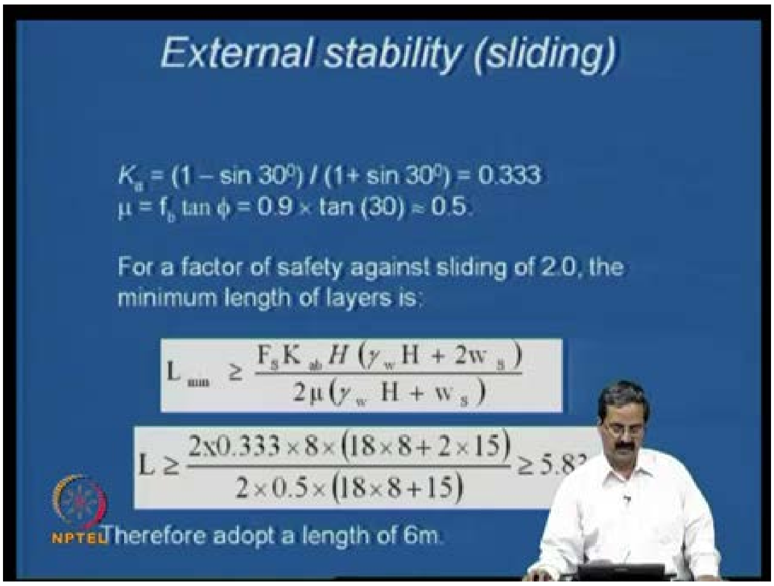

So this, what we already seen that the length of the… We first go with the external stability considerations, and we get the length, you know, corresponding to the factor of safety of 2, say for example, we get this length of about, say 6 meters per 8 meters high wall, considering surcharge, you know, surcharge is also there about on all these equations are already discussed earlier.

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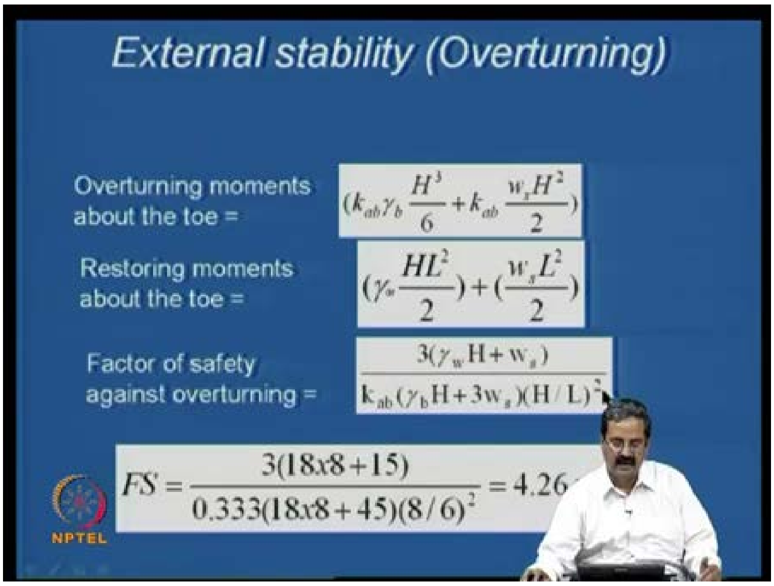

And, we also calculate the overturning moment.

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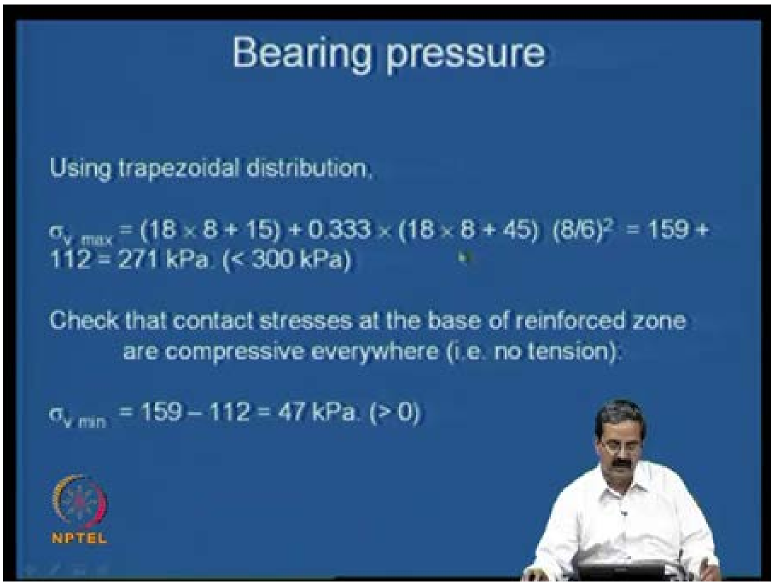

Then, we also check for bearing pressure distribution, and we see that the bearing pressure that is imposed because of the RE wall construction is about 271, and it is less than the bearing capacity of the soil. So, so, we can even calculate, actually, if you assume trapezoidal distribution, you can calculate maximum-minimum distributions, and we also see that there is no tension developed, where the minimum stress is more than 0. So, the other thing is that as I just mentioned, we have another type of distribution, which is called (( )) distribution, one can even calculate the maximum pressure as well using that, and that will be much less than this value as well.

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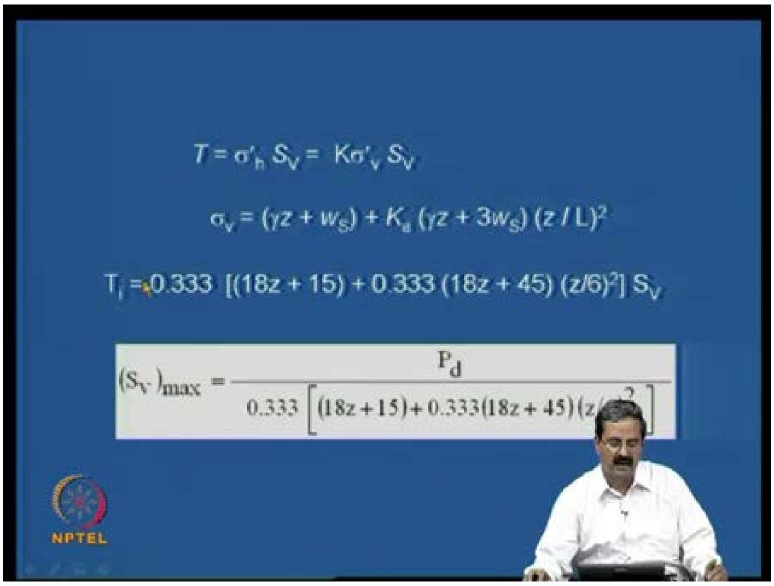

And, this is what I just mentioned. Now, the internal stability when you are trying to deal with that, we should calculate in terms of the tensile force, and we try to… This is tensile force is a given in this expression in terms of the vertical spacing, because the geogrids they are horizontal, they are 1 meter length you consider, and you can, based on this you can get an expression for T i, you know, the reinforcement force required at any section any i section, you know, i level.

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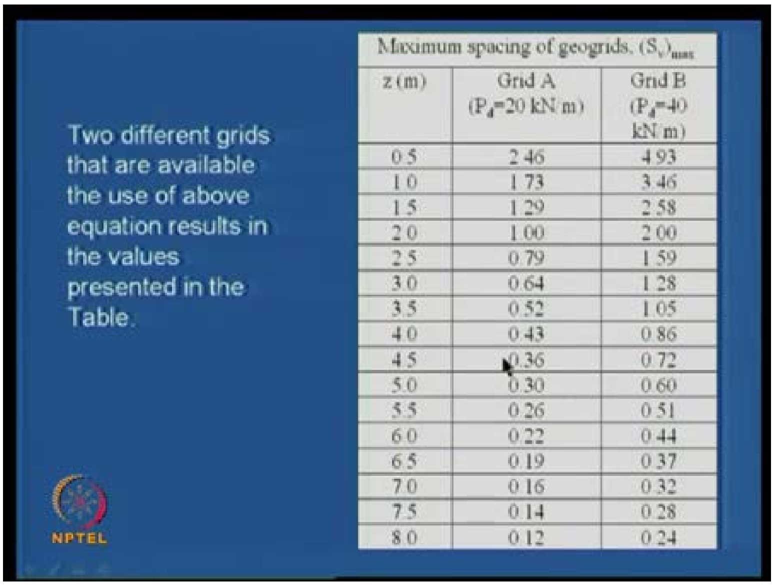

Maximum spacing of geogrids, $(S_v)_{max}$		
z (m)	Grid A (P_d=20 kN/m)	Grid B (P_d=40 kN/m)
0.5	2.46	4.93
1.0	1.73	3.46
1.5	1.29	2.58
2.0	1.00	2.00
2.5	0.79	1.59
3.0	0.64	1.28
3.5	0.52	1.05
4.0	0.43	0.86
4.5	0.36	0.72
5.0	0.30	0.60
5.5	0.26	0.51
6.0	0.22	0.44
6.5	0.19	0.37
7.0	0.16	0.32
7.5	0.14	0.28
8.0	0.12	0.24

So, one can get this and then, once if P d is a design strength of the geogrid, and you just try to put some sort of simple program in an Excel, you will get depending on the two, the strength of the grid, like either it is 20 or 40, one can prepare some sort of results like this.

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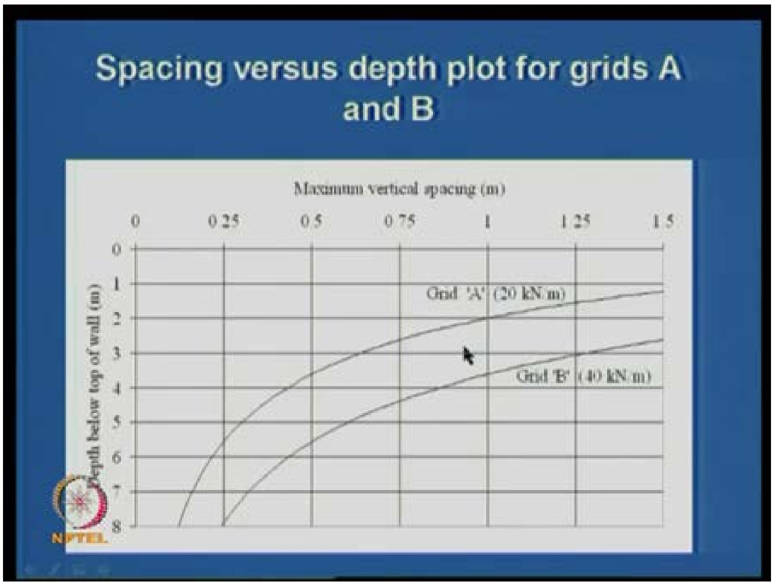

What it means is that, you can see here that if you just plot the grids, the spacing versus the depth plot, this is something very useful to see, at what level the geogrid A will be working? And, what at what level geogrid B will be useful? Like, say for example, if I just said, the geogrid A ((strength)) you know, you can see that, it is 20 kilometer per meter and then, you need to provide at space, it is much less than 0.25 which is not possible. But so, you try to go for 40 kilo ((strength)) you know, at particularly at deeper levels, you have a higher rate pressures. So, you need to go for higher strength of the geogrid.

So, you the way that you see is that up to 2.5, you know, up to this level, up to at least 5.5 meters depth, you can go for this grid the with this, and subsequently, you can use this, that is what it means; essentially, we can use that in multiples and all that that is, what in terms of the spacing and in terms of the availability of the tensile force, this what we do.

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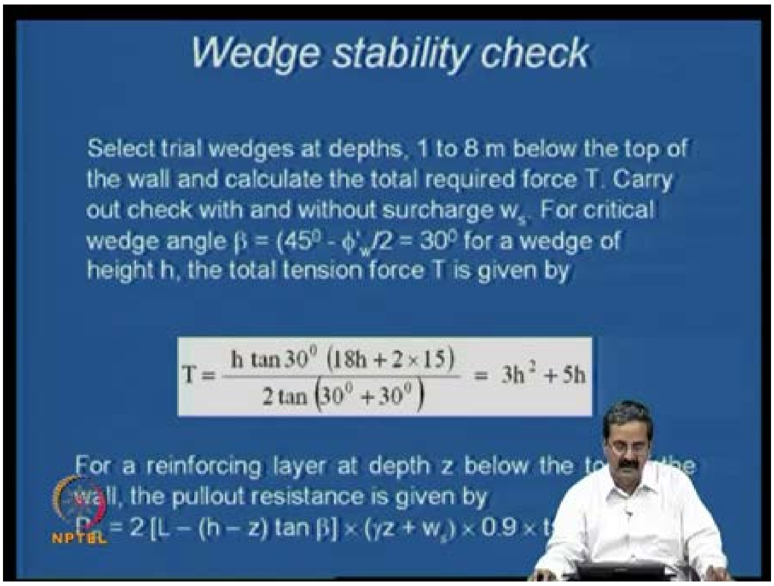

But the apart from it as I just mentioned, we need to go for wedge stability checks, which are, you know, very important and as I just mentioned, you need to draw some force polygons and get this tensile force required to close the polygon, you know, that I just discussed in the last time. And, once you really, even one can do some simple mathematics, simple formulations of minimization and get these equations also. What should be the, I mean, the tensile force required to keep a particular wedge?

The wedge angle is 45 minus phi by 2, the wedge angle is 45 minus phi by 2 and we saw all these expressions, and you get this to ensure the wedge stability, this is one, the total wedge force required to keep that wedge in equilibrium condition, this is what it is. Now, we also have the reinforcement force, I mean at any layer, you know the pullout resistance is also there, you know the thing is that, the two issues that we have, one is the tensile strength consideration, the other one is pullout resistance.

So, the pullout resistance is beyond the failure zone, like you know, 45 minus phi by 2 line beyond that, you write an expression, and beyond that length, you know, on either side top and bottom, there is a resistance that gets provided, which is given in terms of this equation, which is like you know, 2 is on either side and 0.9 is that bond coefficient, we have seen in the example and all that.

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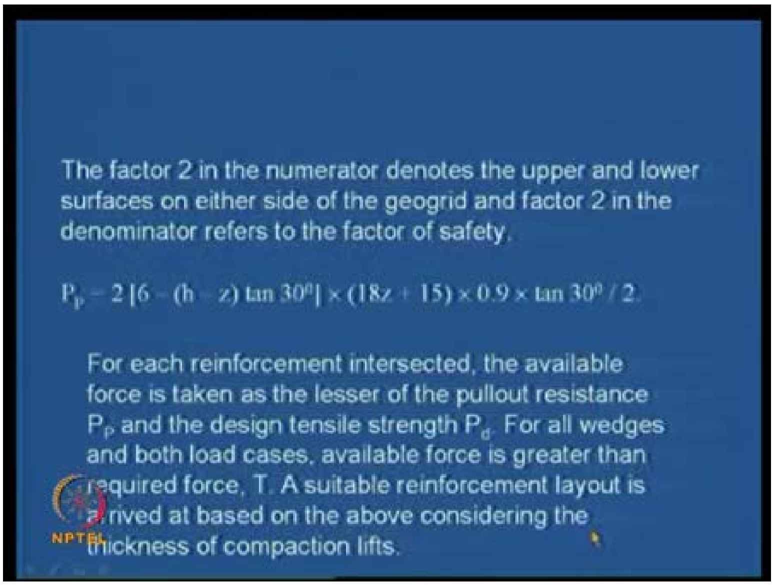

And, once you have that, you have the passive resistance which holds that, you know. So, this is an equation and what we do is that we just check for all the wedges, and you try to see that, at every level you have this adequate force in the member, you know from wedge stability as well as pullout resistance.

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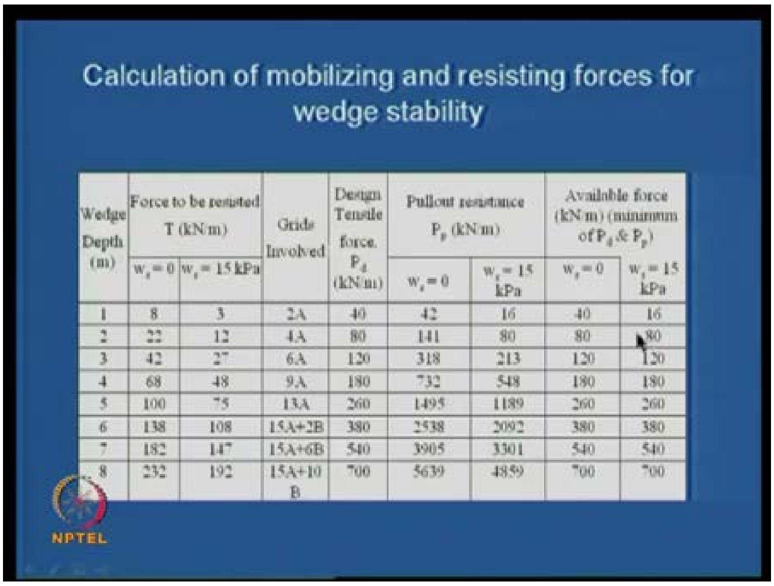

Wedge Depth (m)	Force to be resisted T (kN/m)		Grids Involved	Design Tensile force, P_d (kN/m)	Pullout resistance P_p (kN/m)		Available force (kN/m) (minimum of P_d & P_p)	
	$w_s = 0$	$w_s = 15$ kPa			$w_s = 0$	$w_s = 15$ kPa	$w_s = 0$	$w_s = 15$ kPa
1	8	3	2A	40	42	16	40	16
2	22	12	4A	80	141	80	80	80
3	42	27	6A	120	318	213	120	120
4	68	48	9A	180	732	548	180	180
5	100	75	13A	260	1495	1189	260	260
6	138	108	15A+2B	380	2538	2092	380	380
7	182	147	15A+6B	540	3905	3301	540	540
8	232	192	15A+10 B	700	5639	4859	700	700

And, we select the materials like this, you can see that, say for example, I said A is a 20 kilonewton per meter, and at 1 meter level, you have two grids, because you have, you are providing, why? Because you just make all these calculations, from tensile force considerations may be its just 8 kilonewtons is required, this is without surcharge and with surcharge, you have to calculate two things, because particularly pullout resistance is something like, you know, if there is a surcharge, it is somewhat different, and if there is a pullout, if there is a surcharge, it is lesser. So, you have to take lesser values.

So, what we do is that suppose here, you get 42 right. So, then pullout resistance available actually, this is whatever is calculated value right. So, this is more than what is the two material available right. So, whichever is the lead, so, that way we try to see that at every level this is maintained, like 42 is more than if you provide two layers, it becomes within 1 meter right within 1 meter of the wedge. You are providing a two materials. So, it is fine; like you know, you can the thing is at 0.25 spacing, at 0.5 0.75 spacing, in 1 meter wedge, you can provide at 0.25 spacing and at 0.75 spacing. So, it becomes 2 in 1 meter wedge.

So like that, you can take 2 meters wedge, and you can see that, you will get particularly here, it is all right, but in this case, you will get some 141. So, 141 means you need to get the 80, pullout resistance is higher righ,t for 141 is higher than 80. So, it is fine, 80 into 4; like that you can check up at every level and see at any level, you are normally, this is like that you know, the thing is, we need pullout higher pullout resistance. So that it does not come out, that is how we provide. And, tensile force thing is already satisfied here. So, we can see that, clearly at every level, the pullout resistance is more than the tensile force, tensile force requirement and it is fine; it is stable.

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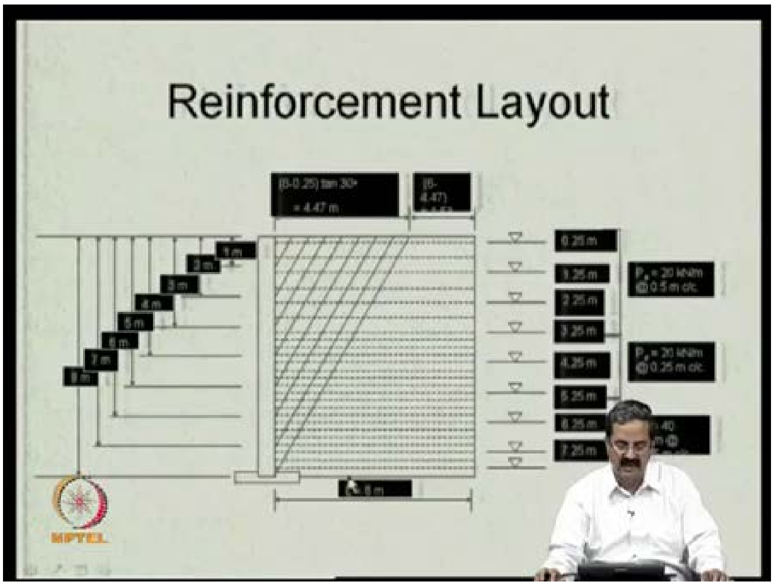

So based on this, you try to come out with some configuration like you know, as I just mentioned, with say for example, 0.25 spacing, some sort of spacing you can provide and you can also provide this materials like this, right you know. This is that failure wedge, I was telling about 45 minus phi by 2 right, you know, all that you can provide and all that; this simple excel program calculation one can do, length is also 6 6 meters; this is a simple structure right.

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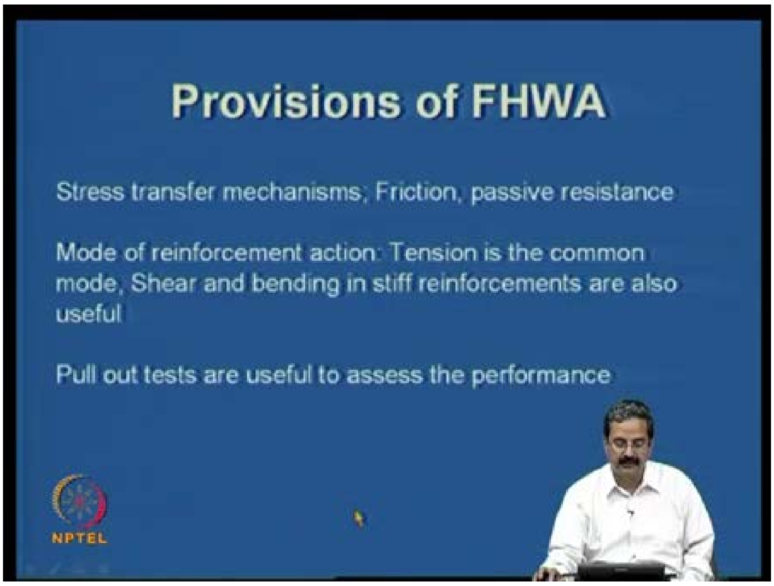

So, this is in a way simple understanding, you know, but then, when you are trying to look at, you know certain guidelines, you should be much more rigorous, and many of these guidelines particularly, Federal Highway, you know from USA we have, BS 8006 we have, we also have Indian Roads Congress provisions to some extent, and there are many codes that we have, even NCMA codes, what we I just want to highlight you some provisions here and just this will summarize some things that we already discussed.

So, this stress transfer mechanisms are: one is friction, the other one is passive resistance; because of the friction only the reinforcement force is developed and because of the passive resistance only, you know that you are able to mobilize this bond resistance and all that. And, mode of reinforcement action, maximum it is only a tension, you know, the way that reinforced soil is acting is that it is just only the tension, but then suppose, you have a stiffer reinforcement.

Now, we have two types of materials, in fact, there are many nowadays; like you know, you can even have composites, composite reinforcement also. What it means is that the you can have see, I told you the geogrids is an extensible type of reinforcement, geotextiles is an extensible type of reinforcement, whereas the steel is not extensible compared to the stiffness that you have in the case of geotextiles, it is much stiffer. So, you may call it non extensible, but then, you also have a combination of what is called anchor plates - sometimes you know, anchor plates also can be provided to reduce the length - pullout length, you know as we saw the example, in the case of bearing capacity problem, in which if you only take friction alone, the length of reinforcement will be higher.

But the in moment, some sort of provide some sort of bearing, which provides passive resistance, the length can be reduced. So, sometimes you may even try to provide anchors and all that. So, mode of reinforcement in reinforced soil is essentially tension, you know, that is a main thing; but then, if you can also take advantage of shear and bending in stiff reinforcements.

That is you know, if you are that is also useful sometimes, you know, for example, even confinement action geocells, geocells is one material. So, one can do lot of composite reinforcements one can do, but what it means is that essentially, we can understand some of these things in a better way and then, design better structures.

Then, another important test that we need to conduct in most of this test is that - pullout tests. So, pullout tests are very important, in fact, geogrids, geotextiles anything in the field, you can pull out and see, pullout load verses deformation is what you get actually, you know.

Then, you will be able to assess this long term performance and short term performance also; short term performance is, in terms of its force mobilization right; in the long term performance, say for example, some materials like, you know, particularly geosynthetics they have a tendency for creep.

So, because if the creep, there will be changes in the tensile forces and all that. So, people may even do creep the pullout test, may be after say 5 years or 10 years to see whether the geogrid or geotextile is all right? and What is its tensile resistance? What is its pullout resistance? One can calculate, just based on some of this information. Right? So, they are quite useful.

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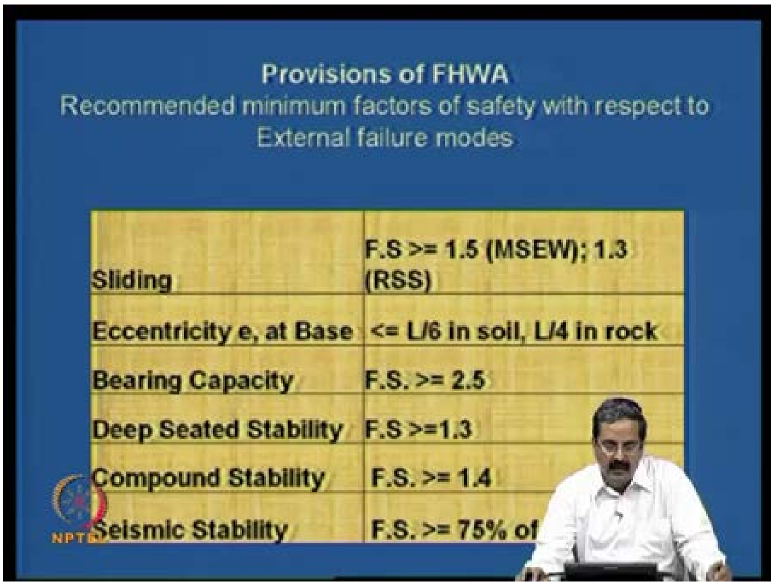

So, some some more information that you know, like we already saw it with reference to the example, what should be the factors of safety? Here, with respect to MSEW means, Mechanically Stabilized Earth Walls; this is a standard terminology that they use, the factor of safety has to be more than 1.5, and then 1.3 in the case of reinforced soil slopes.

Then, that is for Sliding, Eccentricity at the base like, these are all, you know, what we we did not discuss this, but in the codes, in some codes it is there. So, like b by the L by 6 is something that we should, you know the middle third rule that we know already, we have to check that.

And in a codal provision, it is clearly mentioned, bearing capacity factor of safety should be more than 2.5, deep seated stability like 1.3, compound stability like number of failures another this thing so 1.4, seismic stability like, the factor of safety is can be reduced to 75 percent, provided the earthquake force is considered in the design; that we will see that, how much how do you consider that you know, static factor of safety is how much it is here, it is a say for example, we have said 1.5 here.

Then, that is without any earthquake force, but if you consider the earthquake force into calculations, you say 0.75 of static factor of safety, 1.5 into 0.75 will be the value that you should get.

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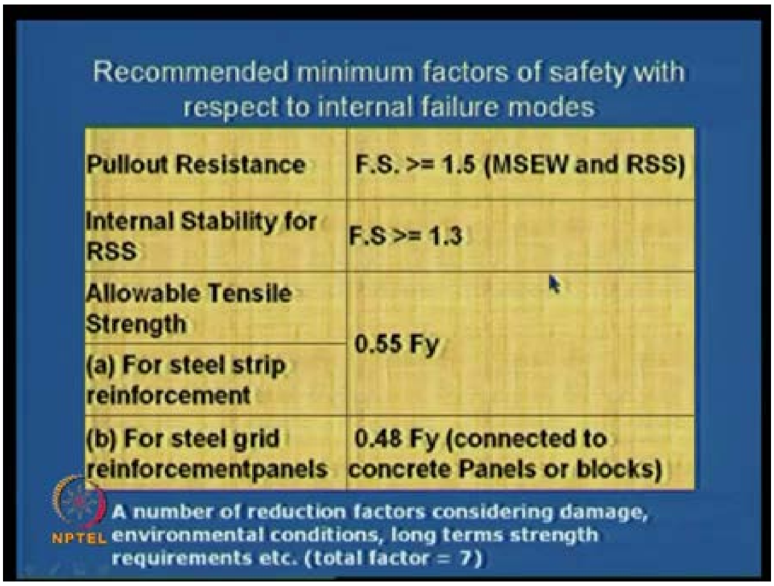

So, internal stability also, like pullout resistance the factor of safety should be minimum 1.5, internal stability for reinforced slopes about 1.3, allowable tensile strength, you know, allowable tensile strength of all these materials is something very high, you know, is it not? Like we have, we know the yield stress of the steel and geogrids or whatever.

So, you can see that 0.55 is the allowable stress. Then, for steel grid connected with reinforcement panels, it is 0.45. So, this is all in a connecting with steel, but then suppose you have geogrids, you have a number of reduction factors that I already discussed, and we it can go up to about, you know as I said, because of damage it could be 1.3, because of this environmental conditions, it could be 1.5. So, long terms long terms strength requirements and all 1. you know, it depends on say 50 years or 100 years, it could be 2, 2.3 like that; if you multiply all of those factors, it may come down to total factor could be 7.

Say for example, 1.3 into 1.5 into 1.2 like that; if you just multiply, all that correction factors could end up as 7, and suppose the design strength of that material, you know, we got you know, the earlier we used design strengths of 20 and 40.

So 20 into 7, may be 20 into 7 means 140 kilo newton per meter, should be the value of the geogrid or the grating of the geogrid immediately now; now, if it it has done, immediately you take the sample and test it and if it shows 140 kilo newton per meter then, it is fine.

Then, you also have information about all these reduction factors and use those reduction factors correctly, and then you will get the correct long term strength and all that; and you can say that yes, the design is satisfactory.

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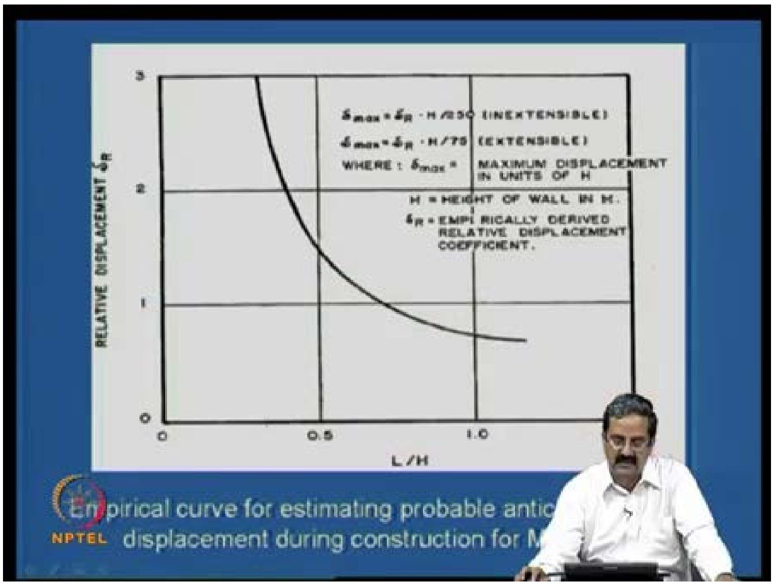

This is another important figure; like see, the estimate of deformations, you know, because reinforced soils are all flexible structures, like come come the when you compare with the reinforced concrete structures, which are rigid, you know; the reinforced soil walls are flexible structures, because of their flexibility, like you know essentially, because of the interaction between the soil and back fill, there is some movement and then, what is that movement? How much it can happen - is something that one should understand.

And see the thing is, delta max is nothing but it is in terms of the the… It is called relative displacement coefficient they have given here, it is called a relative displacement coefficient, which is an again given in the codes and in the case of inextensible reinforcement is H divided by 250.

And in the case of extensible means geogrids delta R into H divided by 75. So, the height of the wall in meters, say for example, if 10 meters is the height of wall and you know, normally, you know L by H ratio will be in the case of about 0.7 or 0.65 or something like that.

Even you have seen in the other day, just now, 6 meters is the length of the reinforcement; 6 divided by 8 will be 0.75; like that normally, the codes says that it should be about 0 .7 H. So, when you take it to 0 .7 H, this relative factor is about 1, and if use that 1 here, 1… So, this 1 into that H is, say for example the 10 meters, 10 meters divided by 250. So much of mm will be the the units of the displacement allowed.

I have we have seen that we have measured also; like, it is a very important property, because to understand normally, you know, you have to measure deformations in reinforced earth wall. So, it is very important; and otherwise, the problem would be that you will not be able to understand to what extent these relationships are valid.

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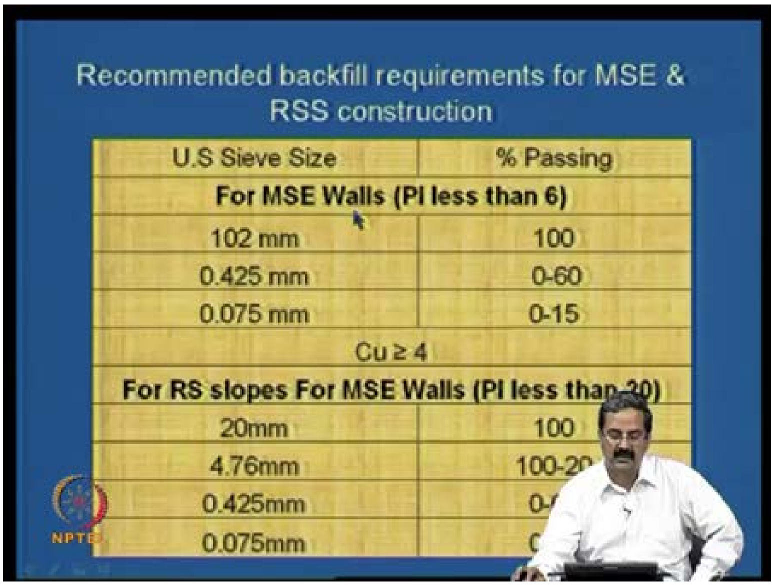

Of course, this back fill requirements, I just mentioned earlier, in the factors influencing reinforced soil, but anyhow, I will just highlight a few more again; MSE walls - it should plasticity, index should be less than 6, and the gradation characteristics are given like this; like, you know, 102 mm - 100 percent, 0.425 - 0 to 60, 0.075 - 0 to 15.

So, more than not the clay, you know, 0.075 size, you know, it should be more than 15 percent all the time; it it cannot be less than this, you know; like you know, the you cannot allow here an bigger number, it should be in the range of 0 to 15; it cannot be say for example 25 percent, which means that it is more like a clay right; 0.92 is a clay, but then it is also little finer fraction, so you do not allow them a material to be too finer.

Then, Cu is the coefficient of uniformity is less than or equal to 4 and for slopes PI, you know, there is slopes, it is this is another one.

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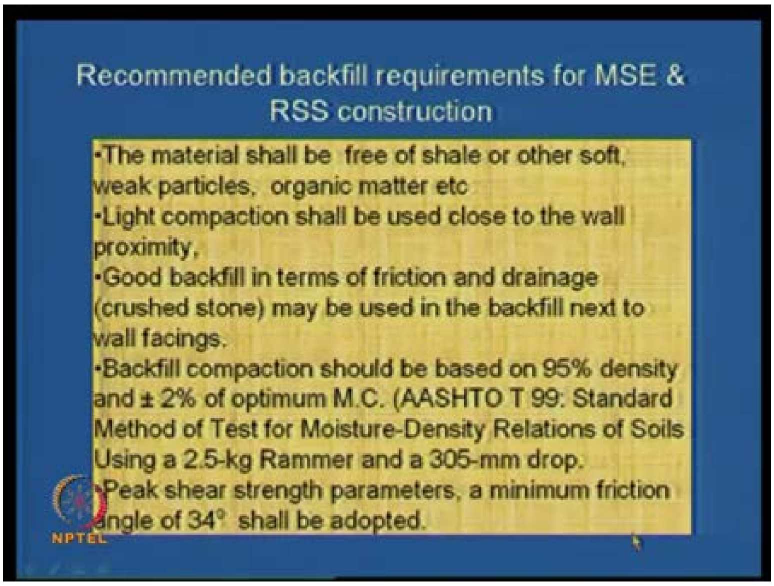

Some more important like, the back fill material should be free of shale or other soft materials or weak particles or organic matters; you know, because the back fill should not get degraded, you know or it should not become softening, you know some materials like, you know, talk and all that, if you just have a saturation with them, they may become little soft. So, we do not want that.

Then, light compaction like you know, the thing is backfill compaction is all right, but when it comes to close - close to the wall; then, you have to have a simple light compaction method - light compactors that you have, one should use them, because what happens? If you use the heavy compaction equipment, the lots of stresses come onto the wall, and even the compaction control is difficult. So, they exert additional stresses.

So, best is to have a light compaction equipment and also good backfill, in terms of the friction and drainage; like sometimes, very good material they use next to the backfill and the wall facings.

And then, the backfill should be compacted to 95 percent density - bulk density and 2 percent of the… plus or minus 2 percent of the moisture content, like you know, standard proctor right.

And peak shear strength parameters should be used, like you know, you try to take the sample, you know, reinforced soil you are trying to use it as a material there for wall fill; you know, you try to do a direct shear test or a triaxial test, and then get the shear peak shear parameters, residual stress parameters.

What it means - here is that they recommend that you should take peak shear parameters; then a minimum friction angle of 34 should be obtained actually; it cannot be more than- less than this, that is what, you know, that is, some of these specifications even in IRC we have.

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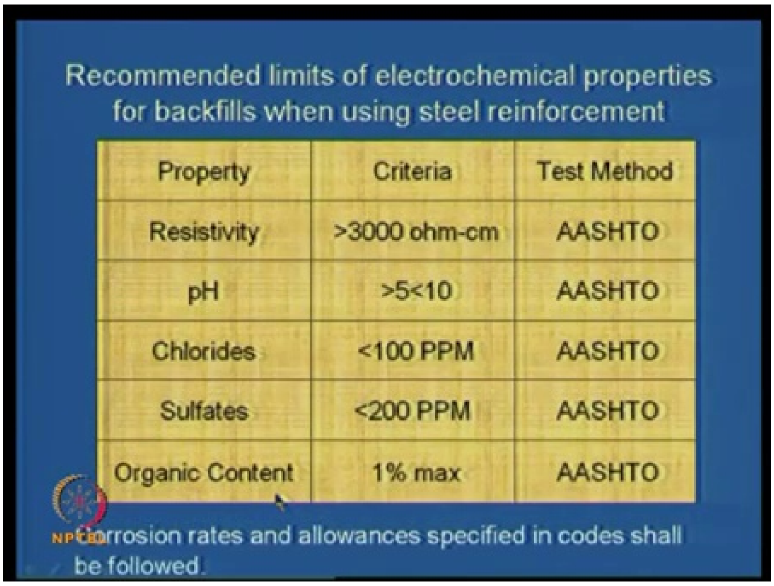

And some of the backfill materials, one should be careful that they are not liable for corrosion effects. So, what you should do is that you should find out the electrochemical properties of the backfills, particularly when you are using steel reinforcement. So, you have some the parameters like resistivity, pH, chlorides, sulfates and organic content; you have permissible limits here. So, one should gets, and then you have a standard method - AASHTO methods one can use.

And you have to see that in this particular backfill or the wall fill that you are using, you do not have… You have the properties less than these limits specified, particularly when steel reinforcement is present.

And, there are some cases, you know, people also provide coatings for the reinforcement, and in fact, the the other way is that people also provide corrosion, you know, allowances; you know, like you should be able to know, what are the rates of corrosion in a particular environment? Say for example, if the pH is this much, what is the corrosion rate?

You know, so one should be able to see that; and these rates of corrosion and allowances that we need to provide or the thicknesses we need to provide are specified in codes; that you should see, for example, BS 8006 code – it is very good. So, it gives information.

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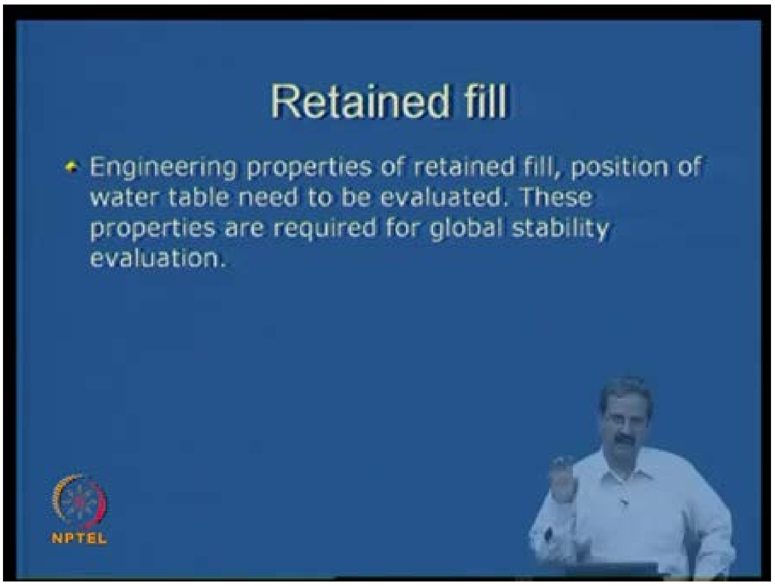

So, this is about reinforced soil wall fill; but there is some material that is next to the retaining wall, which is called retained fill you know; so that retained fill, you know next to that if it is weak, then again there is a problem; you know, whole material should collapse, it it can collapse right.

So, you need to be very even the back with the foundation soil, you know retaining RE wall is fine, but the backfill or the you know backfill means, next to the retaining wall and the foundation soil have to be really good, you know, then only the whole structure stands.

So, you need to see see that the properties of the retained back fill or the retained fill as well as even the foundation soil are reasonably satisfactory, and so you should go for standard testing, you know - standard testing of all these materials and the position of water table.

Say for example, you are constructing a wall here, next to some slope, and you need to know, what are the drainage channels that are likely to be intersected; so that, you can provide proper drainage in the RE wall. So, these are all required from global stability point of view.

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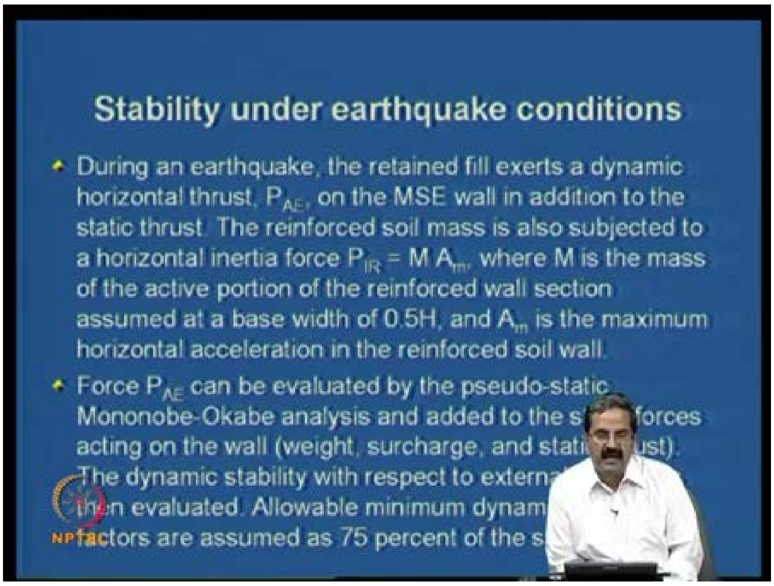

Then, when you are trying to study that behavior in dynamic conditions, what is going to happen? During an earthquake, the retained fill exerts a dynamic horizontal force, like its P AE, you know like the active earth pressure due to earth pressure earthquake; on the M S E wall and in addition to the static test, in already the horizontal force is there and when earthquake comes, there is a horizontal force that gets created, and the reinforced soil is also subjected to a horizontal inertial force.

Like you know, we say P IR which is nothing but M A m is a mass of the soil and its acceleration right, how much is that force - that its gets subjected to. So, these forces you should know, and the the active portion of the reinforced soil is assumed to act at a base width of 0.5H and A m is the maximum horizontal acceleration in the reinforced soil wall.

So, what we do is that - we calculate these forces like active force due to earthquake and also the horizontal inertial force due to in the reinforced soil mass, and at so, then actually the force P AE, you can evaluate by Mononobe-Okabe method; I am sure that you must have learned this procedure in earthquake geo technical engineering, where you you gets you you gets some information about how much is the… If you know the horizontal force or the horizontal earthquake coefficient, you can calculate the earthquake force acting.

But earthquake force should be added to the static forces, and including all static means, weight, surcharge and all that; and then the dynamic stability is evaluated; allowance of about 75 percent of the static factor of safety is allowed; that is what I we discussed already.

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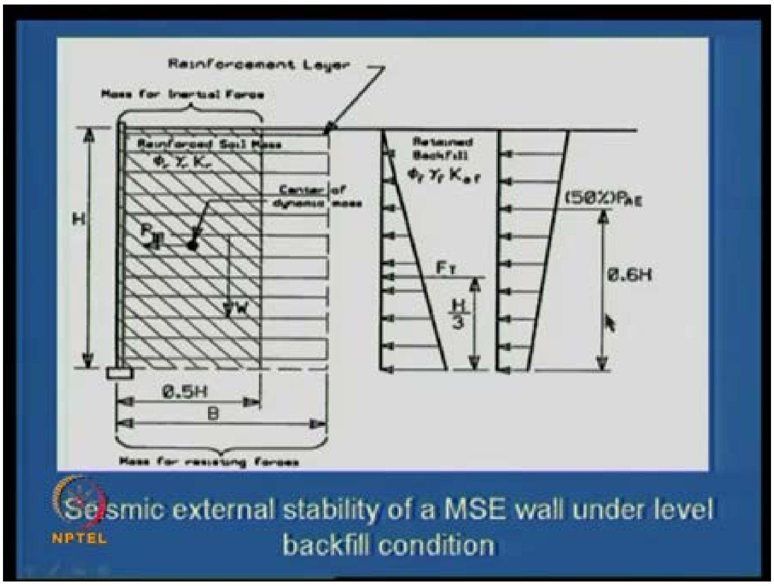

This is the weight, it is like this, you know; like as I just mentioned, and we take that this much of 0.5H you know, this is a mass that gets subjected to dynamic force, and this is center of the dynamic mass, and mass for inertial force, how to calculate the inertial force? This much of soil participates in the the movement. So, P IR, you know, this is the one and this is what you calculate like this.

Then, we assume that we take 50 percent of the AE and it acts at a at a. 0.6H; this static force acts as H by 3. So, these are all some, you know when you are trying to calculate what are the things? We have to calculate sliding forces, factor of safety with respect to sliding and over turning right.

You have to calculate when you are looking at, and then all that calculations you should make even bearing capacity check and all that. So, this one is very important, when you are trying to assess the the stability of the reinforced soil under earthquake conditions.

So, of course, the codes give much more detail matter and then we have software as well, but one should be very careful in understanding these provisions properly, and then applying this some of these rules.

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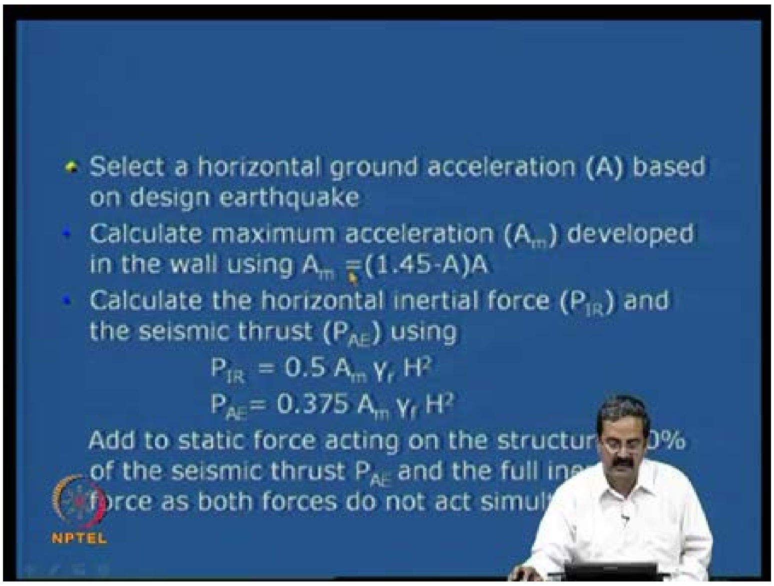

So suppose, the material is subjected is locate the… Reinforced soil wall is located in some area, where we know the horizontal ground acceleration based on design earthquake, and so, we calculate the maximum horizontal acceleration A m is in in terms of 1.45 minus A into A; actually, you know about amplification factors being in earthquake the that comes based on this, this lot of research done on this, but this is the way that it is given in the Federal Highway code. So then, the P IR and P AE is given by these expressions, like 0.5 A m gamma r means reinforced soil and then H square, and then, 0.375 A m into gamma f fill H square.

So, you add to the static force acting on the structure, 50 percent of the seismic force and the full inertial force as both forces do not act simultaneously.

So, as I just mentioned, we just follow this particular diagram what we discussed; and then, calculate all the forces and see, if the materials or the factors of safety are acceptable.

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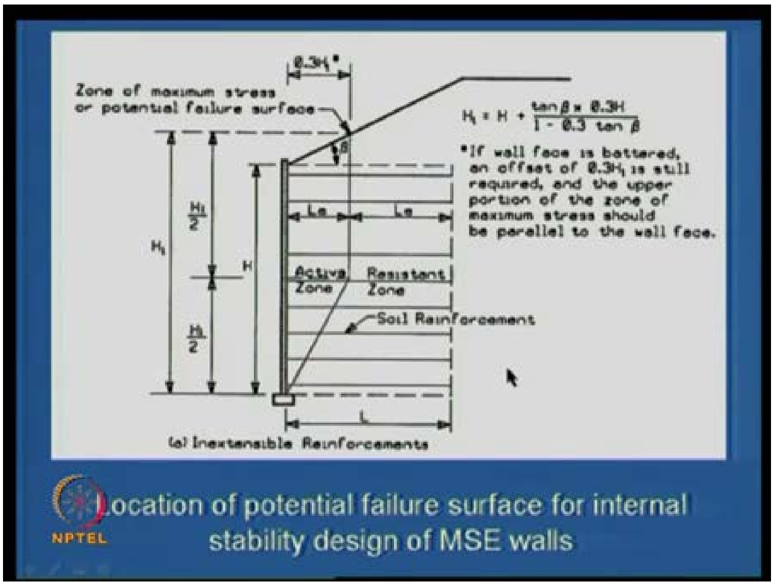

A few more additional points that we should understand, if this is a wall structure like this, and there is a, you know, this slope angle beta you know, like in the case of particularly in embankments, you should get this particular condition.

You should be able to know, how do calculate the maximum tension force and all that? In the case of extensible reinforcements, this is a simple for a illustration only, you have lot of guidelines on this, you know, particularly Federal Highway is full of illustrative examples and calculations; this is a typical diagram, in which say for example, you have to calculate H 1.

H 1 is you have to calculate like this; suppose, there is a, you know, you have an RE wall like this and then, there is a 1 is to 2 slope may be, and then there is a road here, and then all that; How do you do that in the case of… How do you design? So, how do you take the active force, active trust or the active zone? So, that H 1 what is the height you have to take, you know, sometimes most of the time the question is that there is a there is a fill here, how do you take the height, so that you can go to the design.

So, H 1 is H plus this tan beta into 0.3H divided by 1 minus 0.3 tan beta. So, that H 1 will be the height, and so, that is how, you know, the classification of the this zones all that would be done; you know this particular thing where this to be divided this H 1 by 2 and H 1 by 2, and this how it is done, and this is in the case of steel reinforcement, please remember that; then this is the active zone, this is a resistant zone right. So, these are all some guidelines and how to do that?

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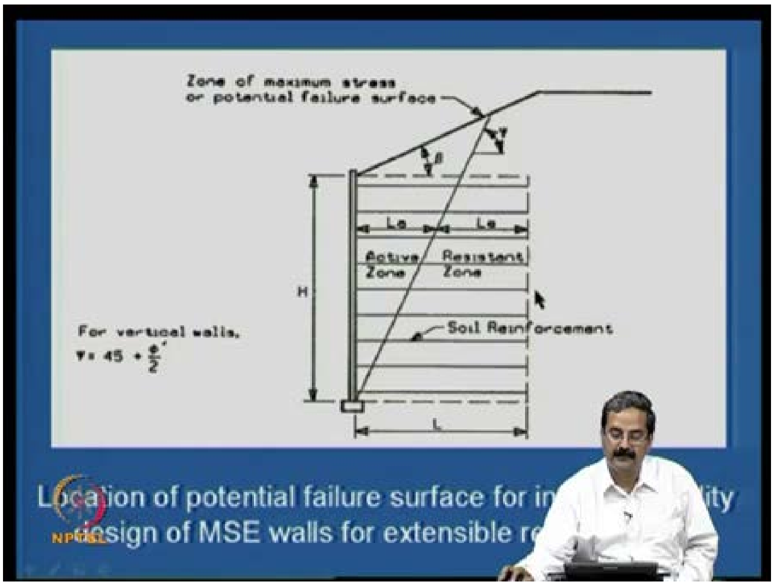

And when you have extensible reinforcement, you have a line like this, which is like 45 minus 5 by 2 line, beta is different. So, in in this case, it is just the H, and the zone of in the previous case, the zone of maximum tension is like this, in this case like this.

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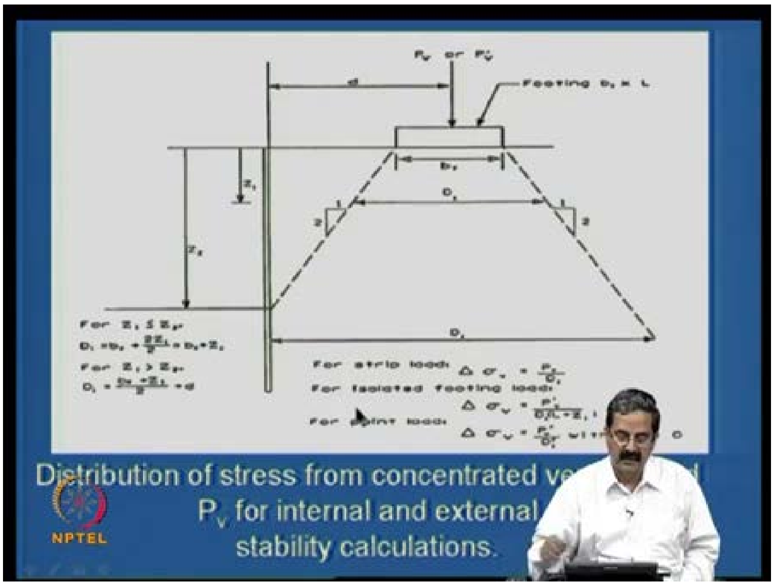

And suppose, there is a surcharge, you know P v, you know some load, you know - concentrated load, at some at the top of the road; how do you take it? It is also that, that is given; like you know say for example, there is some load here, footing load.

And then, there is RE wall you have to construct. So, how do you how do you take this forces as it is given here; if there is a load here, it is has a 1 is to 2 distribution, which is common in soil mechanics, and for isolated strip load and for all these loading conditions are given.

And once you know this, you can calculate the, you know, the stress; this is actually, the you know, the thing is - if you have the reinforcement here, it it will have maximum stress right.

And then, if you could have reinforcement here, there is a distribution. So, how much of force is coming? Like you know, given that you have an area you know, say for example, D f is a footing foundation D f into L, you know; then the load P v divided by D f into L will be the total stress acting at this point.

Now, you want to reduce that length; so, you have to proportional reduce this thing this one is to distribution, and then design the reinforcement properly, you have to design reinforcement properly, and you know, the thing is that just we we saw that, its k a times you know, sigma v right.

How do you calculate a tensile force in the reinforcement? Essentially, what is the horizontal stress? How do you calculate? You are calculating the tensile force, and it is over some spacing and say, you need to essentially calculate horizontal stress.

So, horizontal stress is always a fraction of or the multiple of vertical stress. So, when you have a surcharge here, and you need to have this, you know, vertical stress and multiply by k 0 or k a whatever right; then you will get the horizontal stress and then, knowing the horizontal stress you can design for tensile force required.

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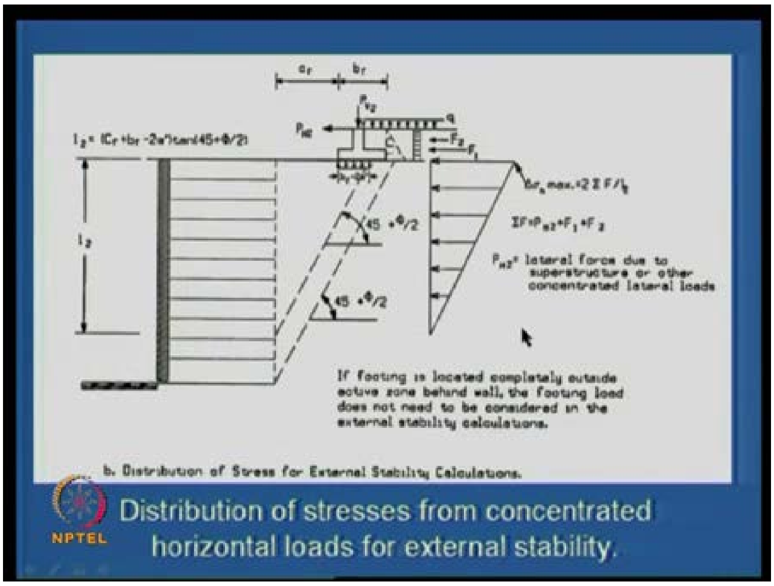

There is another case, where you know, your your RE wall is on a curvature; so there could be some horizontal force acting like this, what we saw was - the vertical load and even for horizontal force also one can completely, I mean check this; and they have some appropriate formula for this, what should be the lateral force that one can expect, you know, when you have a thing like this. So, that is also possible.

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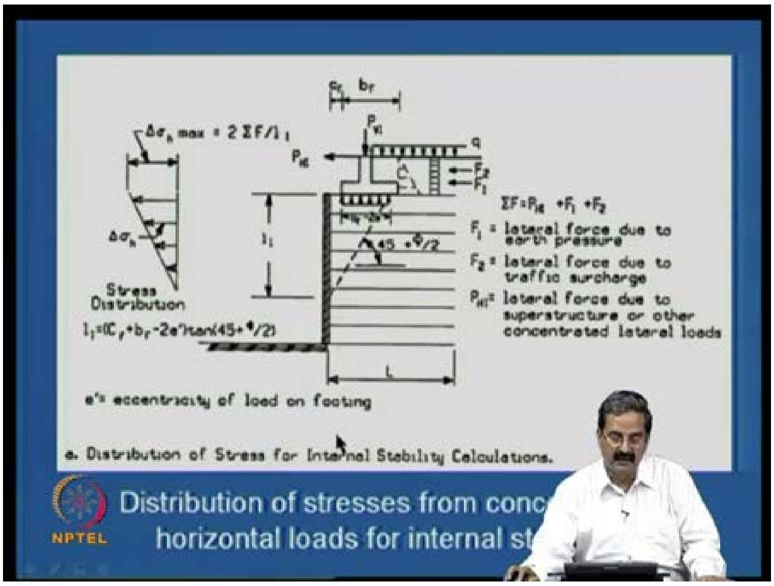

So, and then you also have similar guidelines, you know the thing is that they are all given in some codes and just one should be aware that yes, it is possible to follow these codes, and then give some design solutions you know.

And then, they are all a very important; you cannot ignore them, that is very important thing is that you cannot ignore this factors and you should consider them in design.

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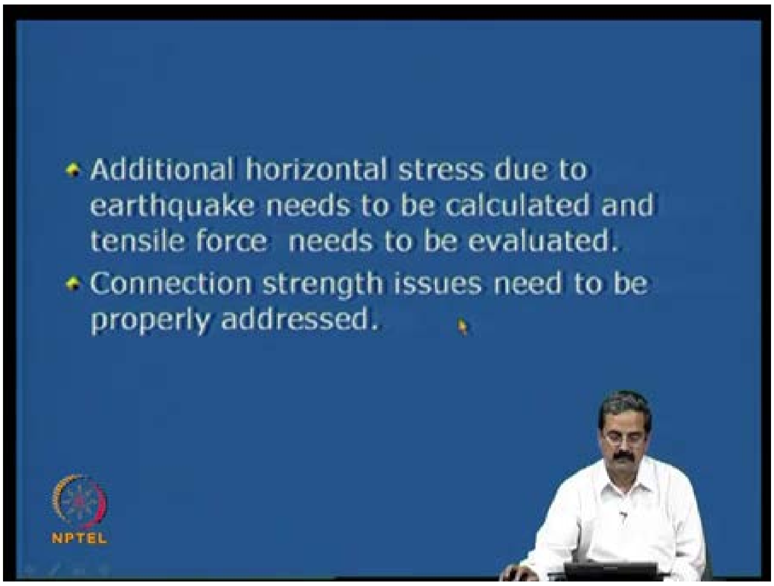

So, what we do is that we calculate the additional horizontal stresses due to earthquake to be calculated, and even any loading, and then tensile force need to be evaluated, that is very important.

So that, you know, whatever as I just said, you know, you can calculate a proper geogrid, I mean, arrive at a proper geogrid specification, what is its tensile strength or you know like, so we have seen that in the design calculations just we discussed.

We saw that the tensile force is one, and then we all saw pullout resistance is one, you can repeat all the calculations, assuming that you can even back calculate certain designs, and see if the things are all right.

Then connection strength; very important point is that when an earthquake comes or even in the simple case, we connect the reinforcement to facing using some connections; if the connections are not good, there is a possibility that it can go very badly; like you know all specifications of backfill, compactions everything is perfect, but if the compaction the connection strength is poor, like you know, I saw a case, you know, it is available, close to Bangalore, where the long time back, you know, the the connection you know, was so weak that it got came out and all the facing panels just they came out; they are all on the ground.

So, that is a very poor situation, reinforced soil you know, the geogrids are all intact, but since the connection was not good, it is not it did not it could not hold the facing weight, just all the facings came out, and people have to rehabilitate that whole RE wall using a soil nailing.

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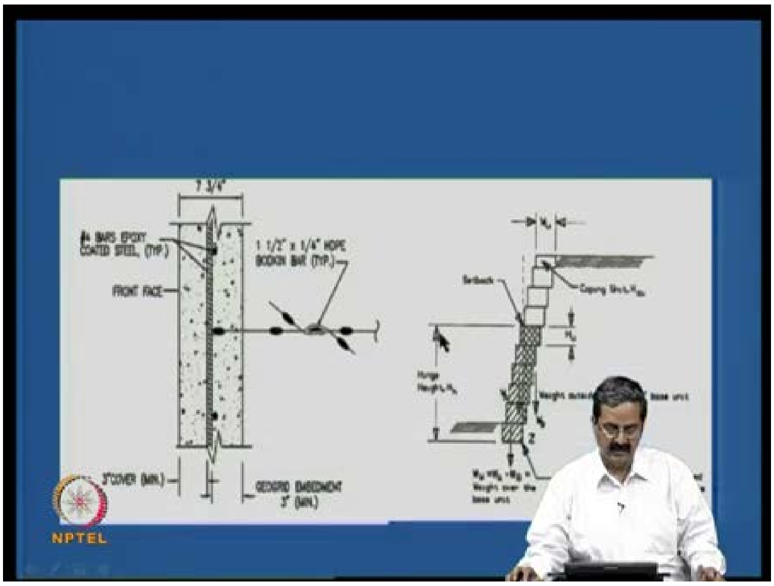

So, I will give you a small example; this is that facing, and you have a, you know some sort of connections here, you know, many of them and their people have different connections, different types of … One should… Actually, codes says that suppose, you are trying to make a connection, 60 percent of the tensile force should be taken for design.

So, your connection should be design, such that it can take care of the even facing also. So say, it comes on the facing, but connection needs to be properly done; that is one thing. So, the other important thing that I would like to highlight is that in the case of precast panels, you have to do this; in fact, I saw one or two failures on these lines where the connection was not good enough, and it yielded.

And the second thing was I was mentioning about segment wall segmental wall construction right; you have a number of blocks like this 1, 2, 3, 4 like this, and when you have this type of materials they are you know, they have to be properly locked actually, they have to be, you know, there is a set back and all that was given. But there is a there is a procedure that one needs to follow. Otherwise, the equilibrium of each block and the forces and the anchorage and all needs to; otherwise, there is a possibility of total collapse that could occur that we saw in failure mechanisms also.

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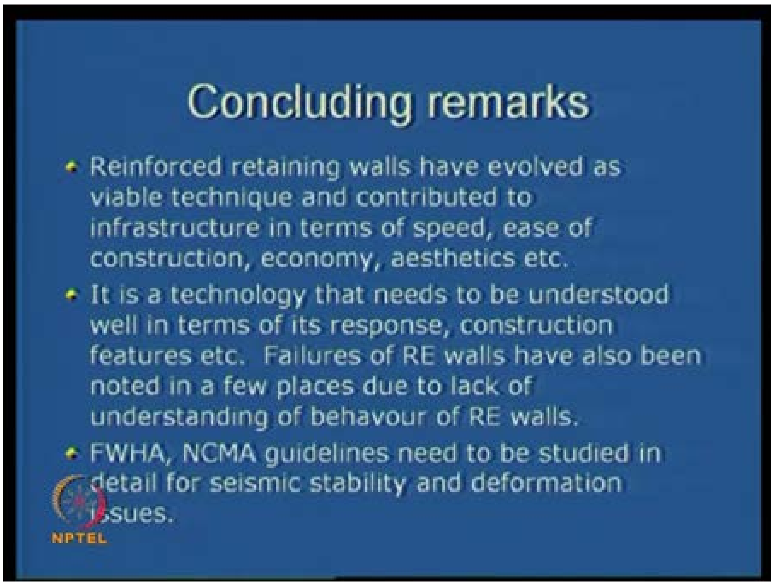

So, what I want to say is that reinforced soil technique is something very viable, and very has been very useful technique in many in many countries, and it contributed to infrastructure and significantly, it increases it increases speed of construction.

It is very useful to construct, you know the speed of construction is very fast; of course, it is economical and aesthetics, it is wonderful actually; compared to many of the treatments for the retaining walls that we have; using this precast panels or you know segmental wall bund construction, you can bring a lot of nice finishes to the retaining structures; very importantly, one should understand that this technology needs to be understood in terms of its response construction features, you know the RE wall is actually a construction technology.

The way it is constructed in the field is very important, and I have seen very many cases where these specifications are all right, but if the it is not done well in the construction the way you join, the way you erect, the way you place, the the time of placement also, like you know, like if you do not allow full drainage to take place, say normally you know, everything is outside only. So, if the lot of drains are there and if there is some still some drainage did not occur, you start constructing, then, you know it becomes problem.

So, there are many issues that one needs to understand and take care. So, because it is a essentially construction. So, as I said failure of RE walls have also been noted in a few places due to lack of understanding of the behavior of RE walls, because people feel that it is a somewhat easier system, but technically yes, it is a very nice and elegant technique, but you know, the implementation needs to be little more careful and of course, guidelines are excellent in this, and one needs to understand them properly.

And as I said Federal Highway guidelines are there, NCMA guidelines are there, they need to be studied in detail for the many of the installations even for seismic stability and deformation, there is lot of scope for research also on these lines, like you know, like as I said 0.75 times a factor of safety.

And so many issues that are deformations and many issues are there, one can investigates in a very, very comprehensive manner and identify new research insights, you know, insights into the behavior in a comfortable manner.

Thank you.