Geosynthetics and Reinforced Soil Structures
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Lecture - 17
Design Example of Reinforced Soil Retaining Walls – III

Very good morning students, in the previous lecture we have looked at how to calculate the length of the reinforcement. And then the layout of the reinforcement layers based on the tensile strength of the each reinforcement layer and then the thickness of the compaction, the soil compaction layer and now in this lecture. Let us look at how to verify the safety of these layers against pullout, and rapture type of failures just to briefly highlight.

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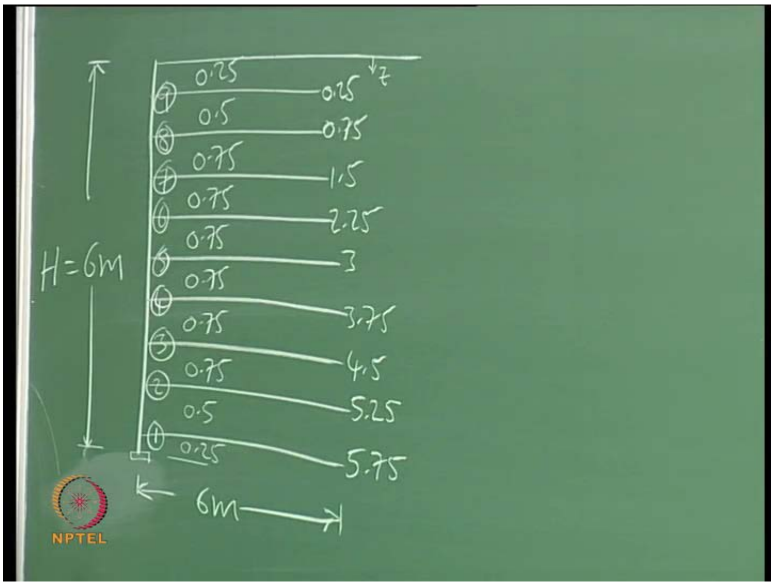

Let us look at our the layout that we had discussed in yesterday’s lecture we had totally nine layers of reinforcement spread over six meters of wall. See when we number the reinforcement layers we always numbered from bottom to top, because that is the way we lay them on the ground the bottom most one is the numbered as number 1, 2, 3 and so on. And our spacing that we have design is like this see the top most reinforcement layer is provided at one compaction layer thickness below the below the top of the soil surface that is mainly to provide an extra lateral restrain to the soil, because to take of surface loads that we apply and then at the bottom. We have started not at the footing level, but at one soil compaction layer above the above the footing and…

So, totally we have 9 reinforcement layers, and the length of this reinforcement is 6 meters, and in terms of the z. We have 0.2, 5 sorry sorry 25 0.7515 to 2.25, 3 3.5, 4.5, 5.25. So, these are the the vertical depths at which different reinforcement layers are provided and now let us calculate the the forces that are transferred into each layer, and then then check for the rapture and pullout capacities.

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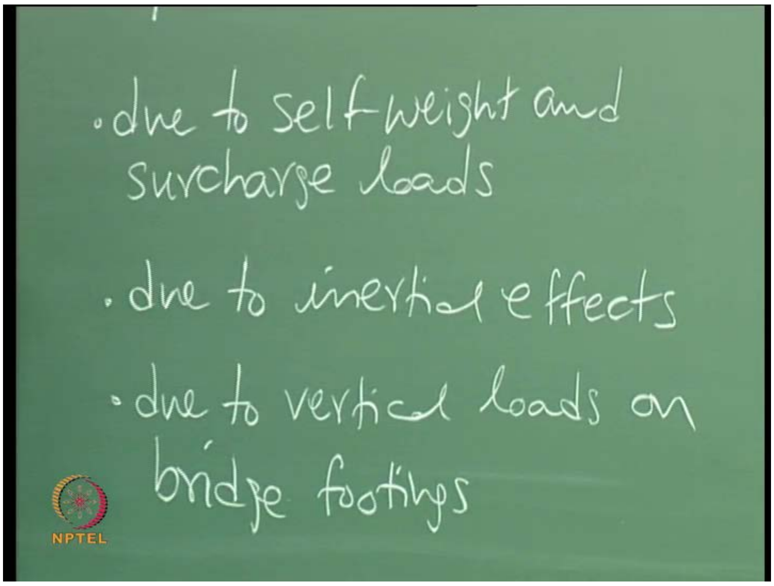

See the tensile forces that are transferred into each reinforcement layer could be because of several effects; the first one is due to the due to the traction force at the top surface due to the horizontal traction that we have. And then due to self weight and surcharge loads and then due to see the reinforcement force could be, because of a combination of these four effects. And just for the purpose of the calculations let us give some dimensions let us assume that we have a footing on top through which our lateral force f h of twenty five was applied. And now we have to check the amount of force that is transferred into each of these reinforcement layers.

And For that what we have seen is that we have some contributory area, and of into each layer and the top most. As we discussed the the contributory area for each reinforcement layer is half the spacing above and half the spacing below. And when we go to the top most reinforcement layer, because that being the top one it has to take care of all the soil above that that is the top most layer will take of the 0.25 meters of soil above there that and then then half of the spacing that is 0.5 by 2. So, this we can write it as 0.25 plus 0.5

by 2 that is 0.5. And whereas for reinforcement eight the contributory area is 0.5 by 2 plus 0.75 by 2; that is 0.625 where as for the rest of the areas it will be 0.75, and once again because the spacing here is different. So, the reinforcement layer will take the load from half this spacing above that is 0.75 by 2 and half the spacing below that is 0.5 by 2.

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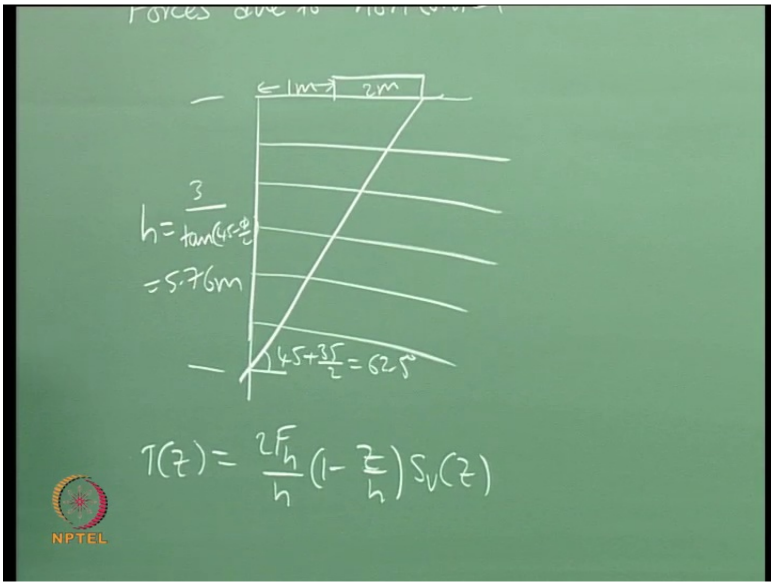

So, this is 0.625 and then the bottom most reinforcement layer, I will take the load from a height of 0.5 meters. And now let us individually calculate the forces that are transferred because of several effects, let us say that the first one forces due to a horizontal traction the forces due to the horizontal traction. We assume that the forces transferred only into some reinforcement layers that are within the Rankine active wedge drawn from behind the footing sat at this particular case, because our friction angle is 35 degrees. We can calculate the height as three divided by tan forty five minus five by two this comes out as 5.76 meters and the the tensile force at any depth z we can write it as two F h by h.

So, this basically in a triangular manner we are varying the force; that is transferred into the layers from maximum at the top minimum at the bottom through this formula. And let us try to apply the in this case our f h is twenty five and our h is 5.6 and z is the the depth of individual layer like. For example, when we consider layer nine our z is o.25 and if we when you consider layer six the z is 2.251, so on.

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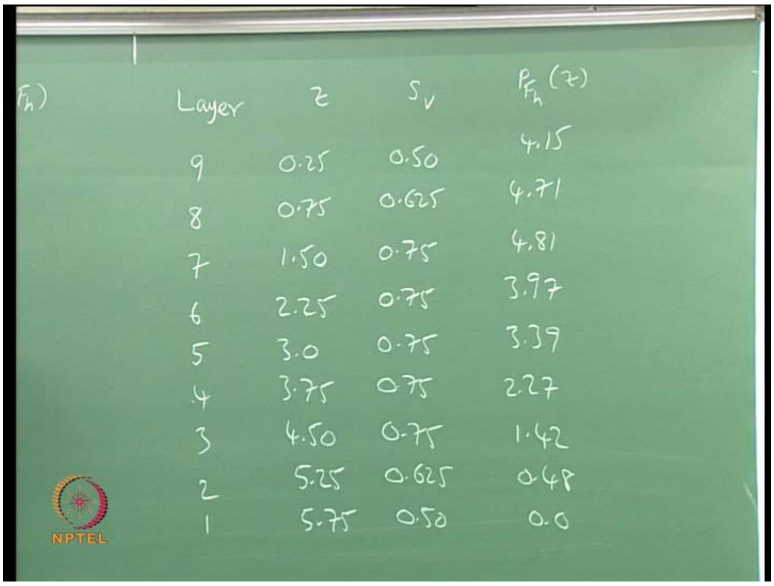

We can substitute different numbers and get the get the forces from basically substituting the different quantities in this formula, and I am getting the forces that we have the different reinforcement layers, they have different forces the peak force is not exactly at the top, but at some depth. Because it is not just simply a triangular variation, but s v is playing an important role because for that particular layer seven the s v is higher 0.75 compared to the other upper layers. So, the force is more at the at the top.

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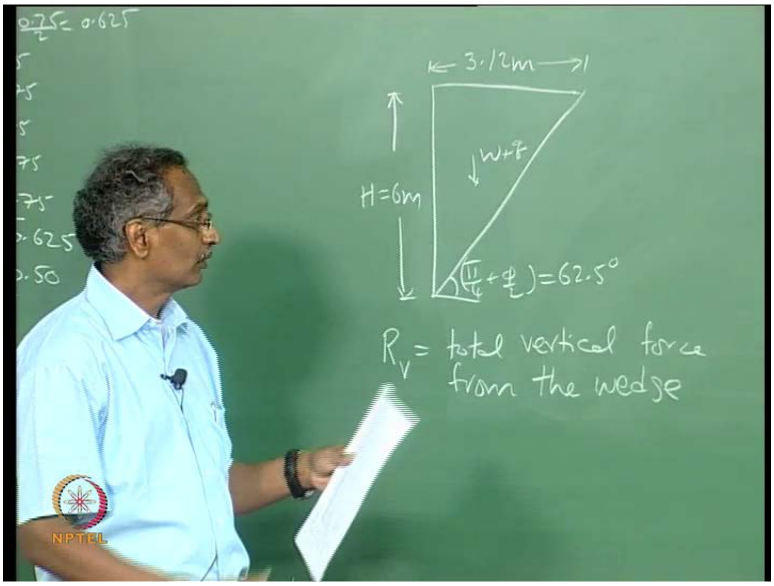

So, if you plot a graph, it is it vary its vary something like this under the bottom bottom of the wedge at 5.75 meters the force is nearly zero its actually 0.04 or something, but now just taken it as zero and now this force has to be added to the other other effects. And let us calculate the force because of other effects. So, there will be some tensile forces that are generated, because of the inertial forces and the inertial forces that we consider are for the entire height of six meters. And we take this rankine wedge and calculate the weight and then at the weight plus the q q effect. So, the and then we multiply with the inertial coefficient that we have estimated earlier to get the inertial forces that are generated and we transfer them into the reinforcement layers.

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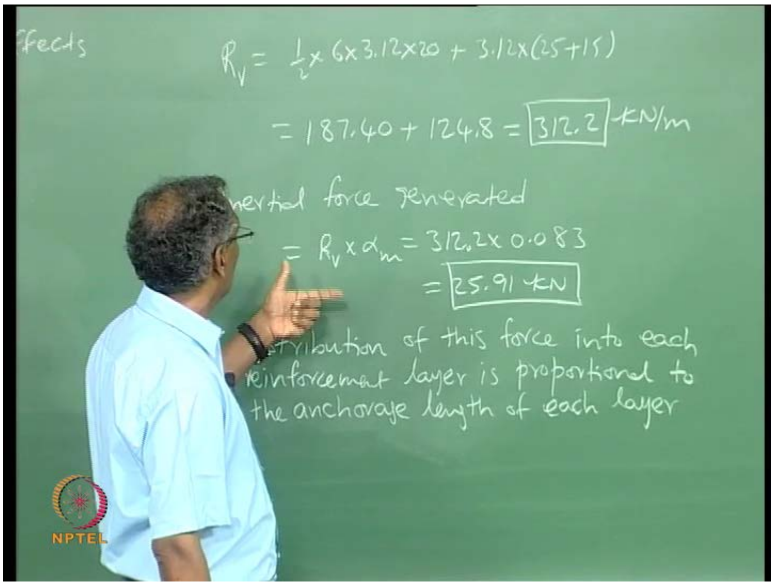

So, our R v is the total vertical force from the wedge and this length is 3.12, it is just from trigonometry, because we know this height six meters, and this angle is pi by four plus pi by two that is a 62.5 because our phi is thirty five degrees for the for the reinforced fill. So, our R v is one half six times 3.12 times 20 plus. So, this total force comes to this vertical force comes to approximately three hundred twelve kilo newtons per meter length of the wall and the inertial force generated generated is R v times alpha m. So, approximately 26 kilo newtons of inertial force generated. And now we have to distribute this into into the reinforcement layers, and that distribution is is depended on the on the anchorage length that each reinforcement layer has, so the distribution.

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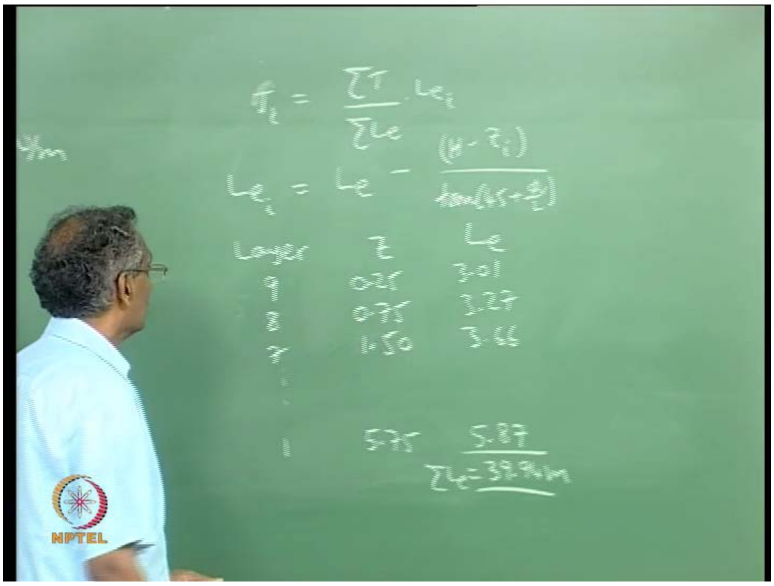

So, what we do is the this the T i is the tensile force, that is transferred into i'th layer is the sum total of the the total inertial force, that is 25.91 divided by the sum total of all the anchorage links sigma of l e times l e of the particular layer. And as we have seen earlier the l e is the length of the reinforcement that is embedded into the passive zone of the soil that is beyond the rapture plane. And as you may recall the rapture plane depends on the type of analysis that we have that is the tieback wedge method of analysis of the coherent gravity method of analysis in the tieback wedge method. We assume a simple rankine active to rapture surface that is applicable for flexible type of reinforcements and the other type of failure is the the coherent gravity type of analysis that has a bilinear edge that has slightly different shape of the rapture plane. And now our l e of i is i am just simply l e minus, because this angle is pi by four plus phi by two, this length is this horizontal length is just simply this height h minus z divided by tan pi by four plus phi by two and. So, we can calculate the l e for different layers.

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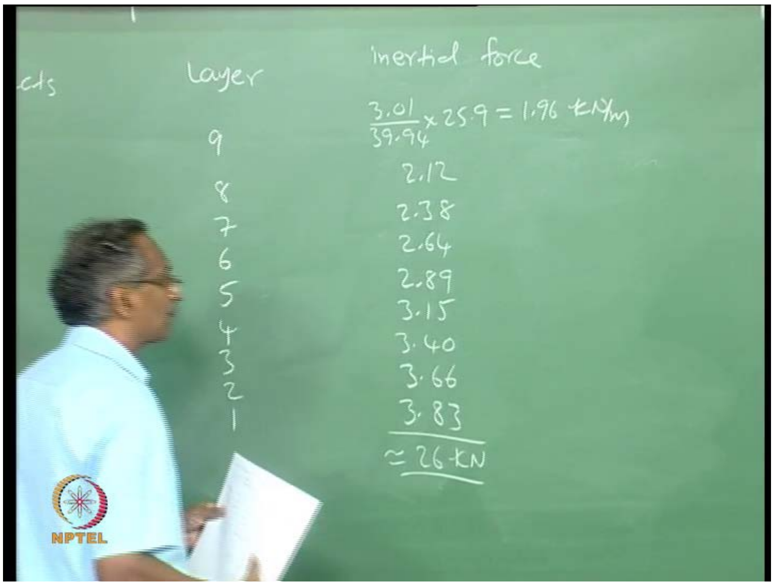

So, for example, if… So, we can calculate the anchorage length in each of these reinforcement layers, and the sum total comes out as nearly forty meters. And now this inertial force of twenty six kilo newtons is distributed into its layer in terms of the anchorage length. And obviously, the the top most reinforcement layer has the the least anchorage length because the our rapture plane is expanding as it goes up. So, our our anchorage length reduces and as we come down the anchorage length is more.

So, the maximum anchorage length that we have is 5.87 for reinforcement layer one and minimum is three meters and the top most reinforcement layer. And now let us distribute the reinforcement force into each of these layers see the top most reinforcement layer has an anchorage length of three meters and the sum total of all the anchorage lengths is 39.9 multiplied by 25.9 is inertial force. So, then the force in the top most layer is 1.96. And similarly if we calculate in layer two we have 2.12 and layer 7 2.38 and layer 62.64.

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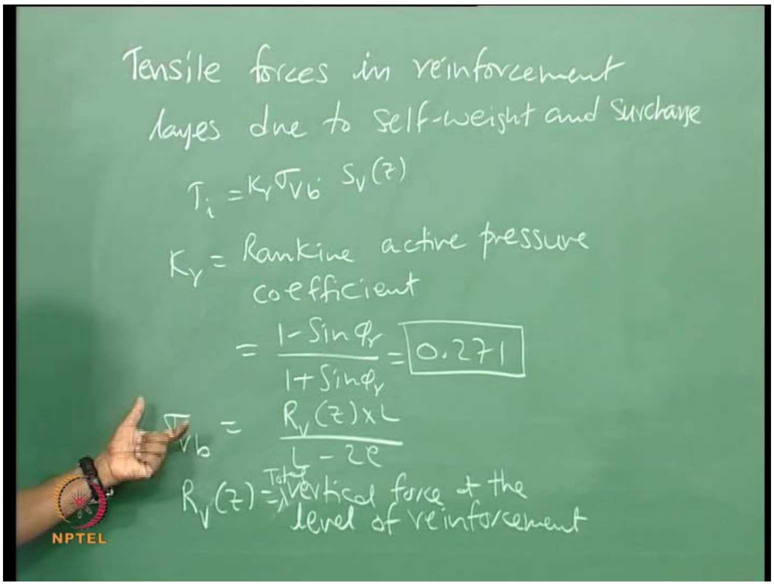

So, as you see the inertial force is maximum in the in the bottom force reinforcement layer, because that has the maximum anchorage length and the sum total comes to nearly 26 kilo newtons, which is equal to the to the inertial force. Now the other force that we have is because of the sulfate, and then the the surcharge load is acting on the and the soil how we calculate the tensile force is using this equation the k r multiplied by sigma V b that is the mail half pressure at the level of the reinforcement layers. And then as we have judge is the contributory area corresponding to these reinforcement layers then our K r is just simply the rankine active pressure coefficient that is that is just simply 0.271 So, now let us apply this and and then calculate the the forces that we have and the sigma V b is r Vof z times l by l minus 2 e. So, the sigma v b is r Vof z where the the r V is the total vertical force at the level of reinforcement is actually we say total vertical force, and one is the length of the reinforcement divided by l minus 2 e.

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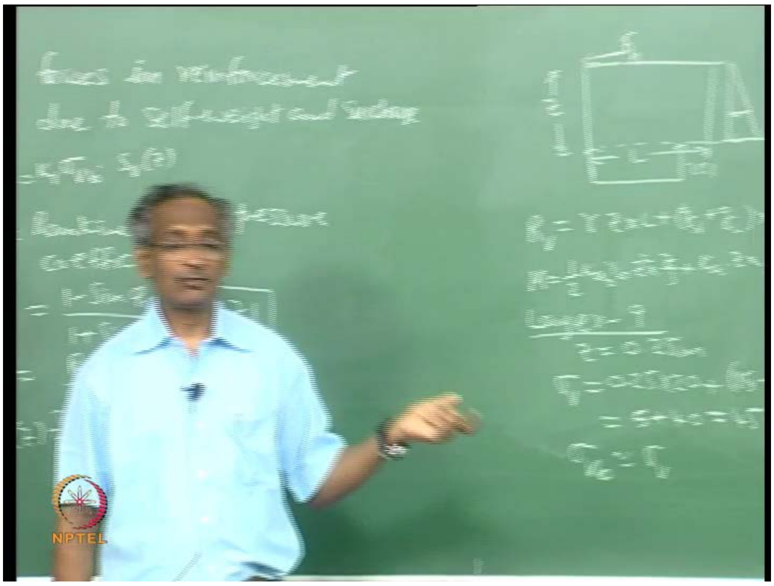

And for this how we do the calculations, let us say that we consider this particular reinforcement layer at any depth. We have some overturning moment that is coming from the backfill and because of that our vertical pressure is not uniform it varies along the length and mayer half distribution is the most ah appropriate one, because we use granular soils. And the mayer half's data shown is that the there is a loss of contact over a length of two e between the fitting and the soil and so our... So, we assume that our pressure is distributed only over this length.

So, our r v is gamma z times l plus q d plus q l times l and our overturning moment because of the, and the backfill pressures they are like this k a b our overturning moments are like this. And then of course, we have the lateral force f h. So, that is f h times z. And we can apply this for different layers, and I just illustrate for for let us say two two layers. So, the layer let us first consider layer nine where our z is 0.25 meters and our sigma v is our sigma v is 45 kilo pascals and sigma v b will be approximately equal to sigma v, because we do not have much of height of soil above the layer nine is only 0.25.

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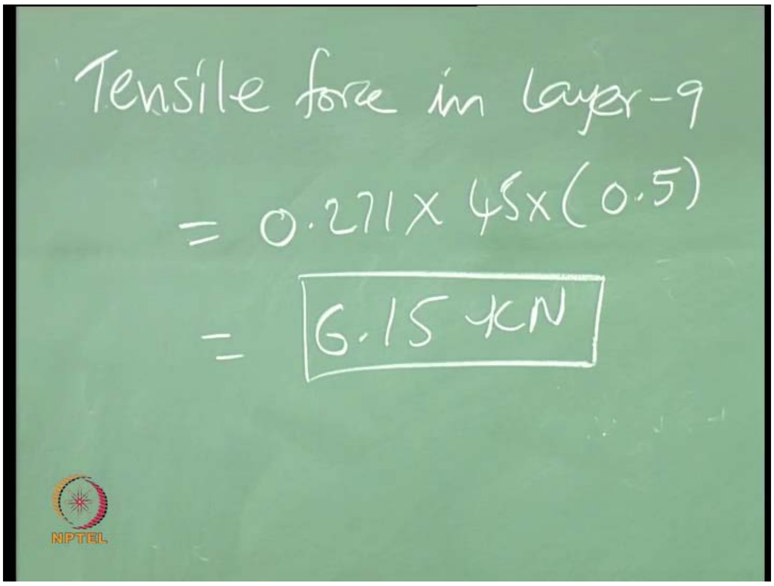

So, we can assume that sigma v b is approximately equal to sigma v. So, our the tensile force in layer nine is k r is 0.271 times sigma v b is 45 times the contributory area, we have seen that it is 0.5. So, the sum total comes to comes to 6.15 kilo newtons. And similarly let us calculate the the tensile force in in one of the bottom layers well for illustration purpose.

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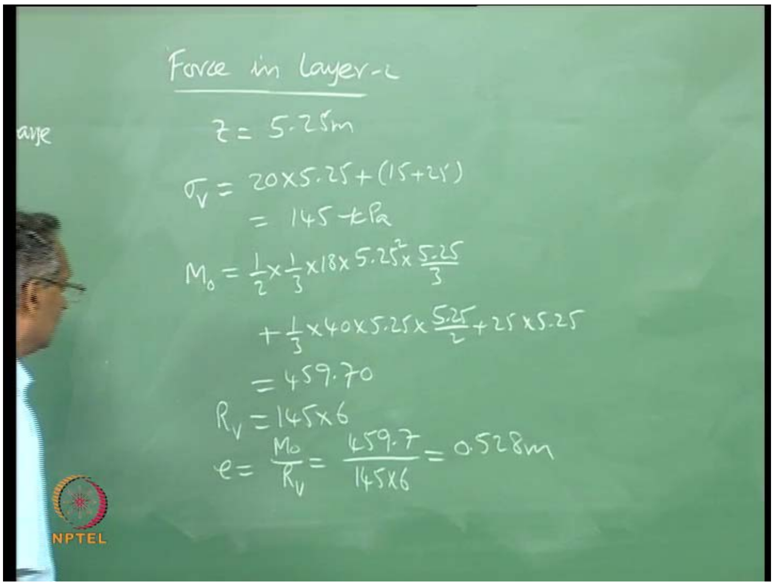

Let us consider the force in layer two, for layer two z is 5.25 meters, and our sigma v is 20 times 5.25 plus 15 plus 25. So, that comes to one 45 k p a and our m naught, because of the backfill soil over a height of 0.25 meters is the total overturning moment comes out as 45 9.7. And our r v is 145 r times 6, and our e is m naught by R v, that is our extrinsity at this depth is 0.528 meters.

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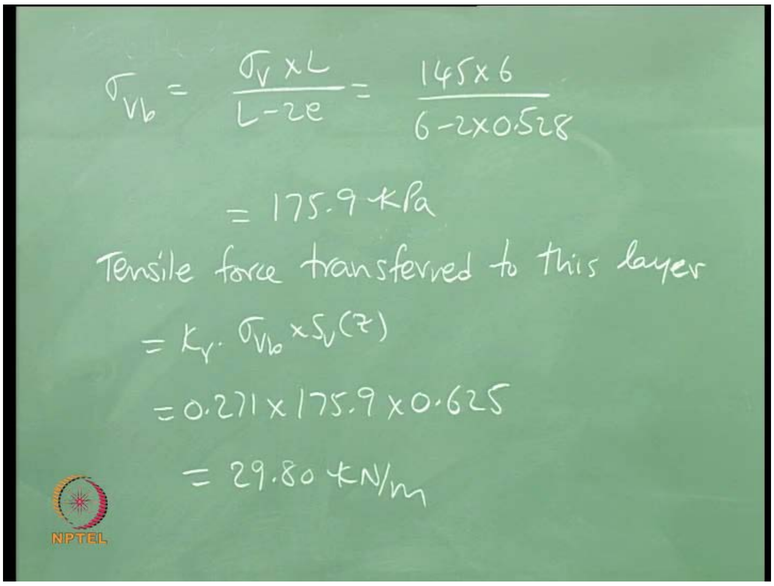

So, our sigma V b. So, our vertical pressure at this depth of 5.25 meters is 175.49 as compared to the sigma v of 145, because of the overturning effect this Mayer half pressure is more than the normal static pressure. So, our the tensile force transferred to this layer is K r times sigma V b times s V of z that is 0.271 times sigma v b is 175.9 times the s V is 0.625. So, the force that is transferred into layer number two is 29.8, and similarly if we do all these calculations we can just list out the forces in different layers.

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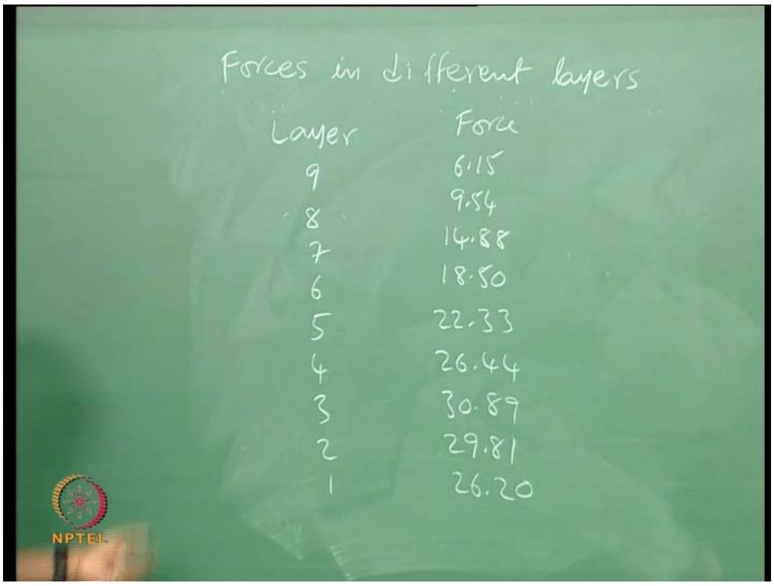

So, we see that as we go down the reinforcement forces are increasing mainly, because our vertical stresses are increasing. So, now if we sum up all these forces all the three forces will get the total tensile forces that are developed in each of these layers.

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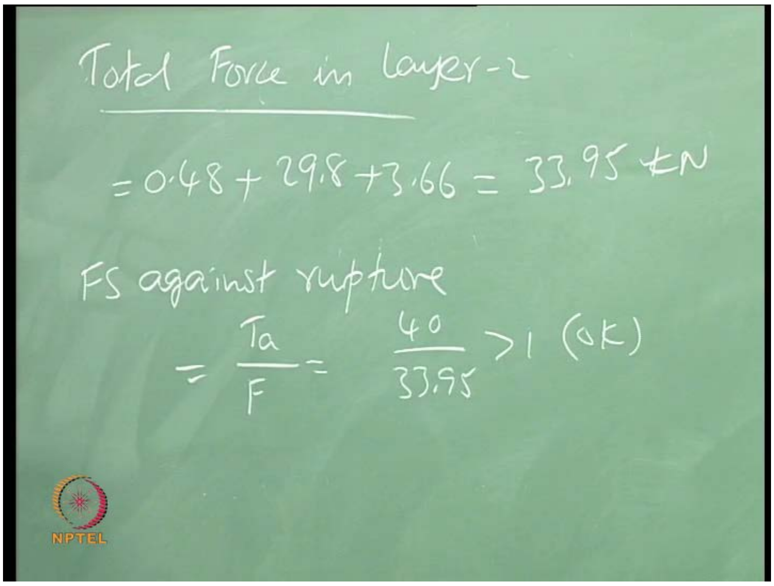

We will just consider a two typical layers for these calculations, let us consider the total force in layer number two the total force is 0.48, because of the horizontal attraction that we have at the surface. And 29.8, because of the sulfate and the surcharge of it and because of this the inertial affect it is 3.66. So, our total tensile force including all the affects in layer number two is nearly 34 kilo newtons. So, our fact of safety against rapture is our ten the t a divided by by f that is 40 divided by. So, we do not look for any fact of safety against rapture, because in the t a that is already facted to account for several factors like the degradation and due to the environmental factors degradation due to the construction affects then the time effects and so on. So, if we get ha anything more than one that is that sufficient as for fact of safety against rapture. And now let us look at the fact of safety against pullout, and our l e for layer number two is 5.61 and as we have considered earlier only the permanent loads are considered for calculating the fact of safety against pullout we do not consider the live loads.

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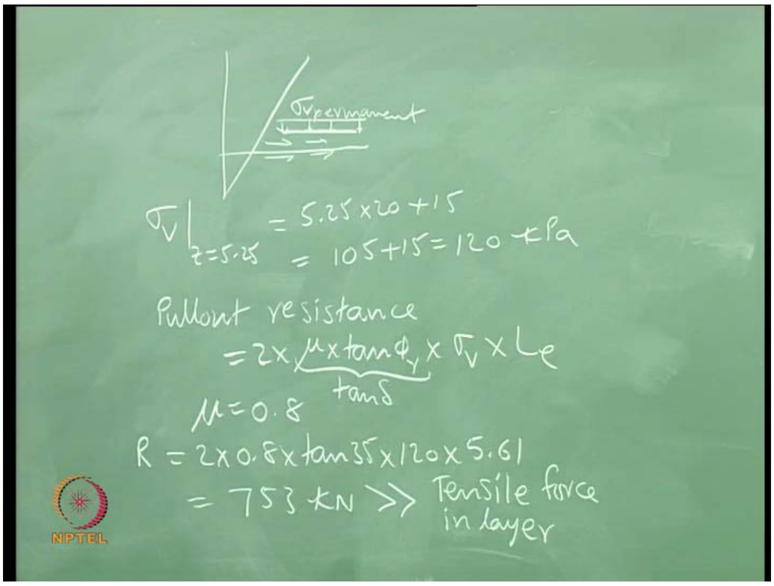

So, I will just write it here and we also do not consider the mayer half pressure because the pullout resistance is happening at the backend of the of the backend of the retaining wall where the overturning effects are negligible are not, so significant. So, we use only sigma V and not sigma V b. So, the sigma V at z of 5.25 meters is is 5.25 times 20 plus 15; that is one 120 k p a and our the pullout resistance is two times mu times. So, the pullout resistance is calculated as two times mu times tan phi r times sigma v times l e, in the some codes instead of this mu times tan phi we also write it as tan delta, but both are equal length and the i prefer this method of mu times tan phi r. Because its bit more easy to understand because the tan phi r is friction fill that we have for the reinforced fill. And then the mu could be like an efficiency factor and if it is one; that means, that there is a very good bind between the reinforcement and the and the soil. And if it is very less; that means, that it is a very smooth interface and the value of mu it also changes with the normal pressure at very low normal pressures the mu can be much more than one, it could be of the order of 1.2 to 1.3, because of the effect of dilation. Because of the the dilation as you know increases the the normal pressures locally where this soil is trying to expand against the pressure, and because of that the mu could be high at very shallow depths and at very large depths where the dilation is not.

So, significant our mu could be low and the average mu; that is observed for most types of and geogrids geotextiles is about 0.8 or 0.7 for very smooth materials like polymeric strips, and for steel strips also it is about 0.65 to 0.7. And let us assume that our mu is 0.8 just for the illustration purpose. So, our pullout resistance are is a two times 0.8 times tan 35 times the sigma v that is one 20 times l e l e is 5.61; that comes out as seven hundred. So, this pullout resistance we get. So, as seven hundred fifty three which is much much greater than the tensile force that is transferred into this layer. So, we have a very fact of safety against pullout. And now let us consider the top most reinforcement layer because that has the least anchorage length.

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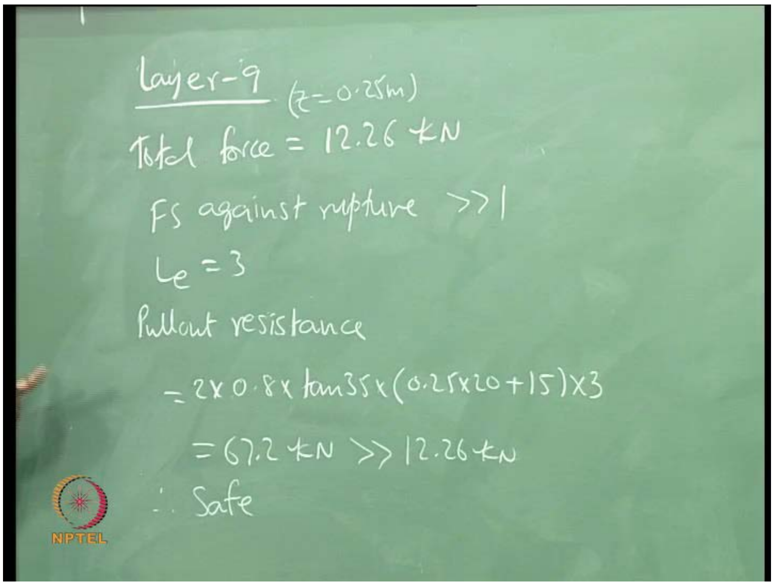

Let us consider layer number nine total force is 12.26, and the fact of safety against rapture much much greater than one, because our allowable tensile strength is is 40 kilo newtons the our l e is three. So, the pullout resistance. So, the z is 0.25 meters. So, our pullout resistance is two times 0.8 times tan 35 times the sigma v; that is 0.25 times 20 plus plus 15 times 3. This comes to 67.2 kilo newtons which is much much more than 12.26 kilo newtons. Therefore, safe and similarly we can calculate the fact of safety against pullout and rapture of all reinforcement layers, it is a it is a bit tedious procedure, but then if you do it systematically. We can easily do the calculations and the best is we develop a small excel spread sheet program, so that we can do all these calculations in a in a very simple manner that we will see in the next lecture.

Thank you.