Geosynthetics and Reinforced Soil Structures
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Lecture - 15
Design Example of Reinforced Soil Retaining Walls-I

Very good morning students, in the previous lectures, we have discussed about the Design of Reinforced soil Retaining Walls. And in this lecture, let us look at some numerical examples and the actual design of the reinforced soil retaining walls is done through, very complicated, excel spreadsheets or some specialized programs. But just for the purpose of classroom illustration, I will take a very simple example with a very simple geometry. And let us go step by step of how we go about in by hand calculations, and let us take a wall that is of 6 meters height.

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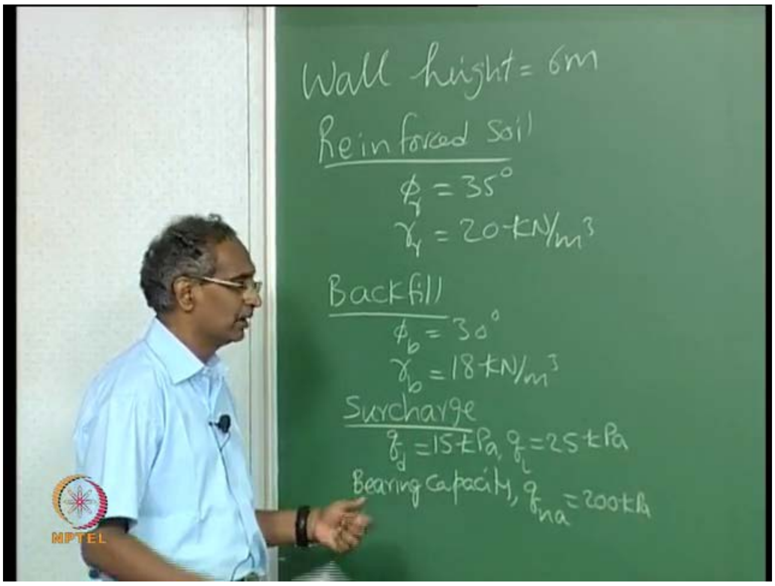

And let us assume, some soil properties like this, the reinforced soil it has got friction angle of 35 degrees and unit weight of 20 kilo Newton's per cube meter, in the back fill has friction angle of 30 degrees and unit weight of 18 kilo Newton's per cube meter. And then the, permanent surcharge are the dead load the surcharge, let it be 15 k P a and the live load surcharge 25 k P a. And then let us assume that, the foundation soil has an allowable bearing pressure q n a of 200 k P a and let us now try to go through some designs.

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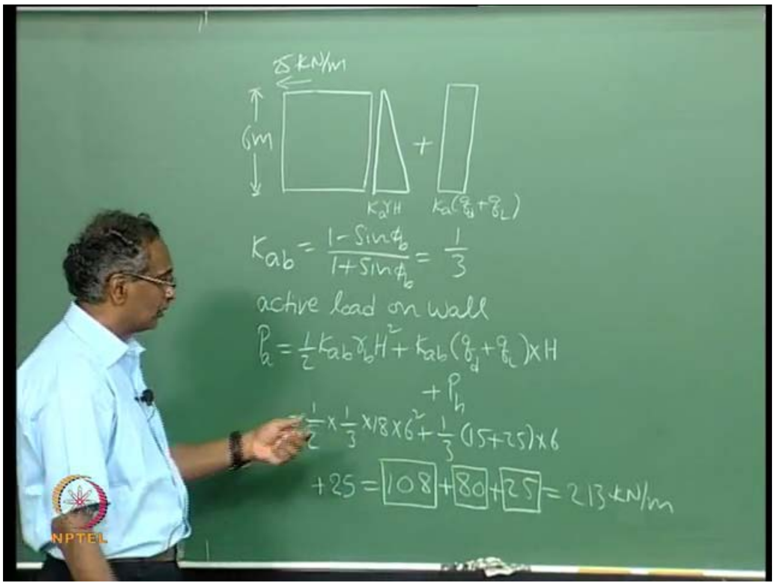

As we have seen in the previous lectures, the fifth of the self weight is the triangular pressure distribution, that is the k a times gamma h and that is a maximum, at the bottom of the wall. And then at the affect of surcharge loading is constant that has a rectangular pressure distribution, and our k a b is 1 minus sin phi b by 1 plus sin phi b and that, comes out as 1 3 rd. So, our active load on wall P a is 1 half and actually, let us also throw in some lateral load that acts at the top of the wall, that could be from the crash barrier. And let us assume that, particular load is 25 kilo Newton's per cubic meter, 25 kilo Newton per meter length, so our the load is a like this.

So, the lateral load that, acts on the wall because of the self weight of the soil is 108 kilo Newton's per cubic meter and because of the dead load and live load surcharge is 80. And because of the traction forces, we have a force of a 25 kilo Newton per meter and the net total of this is 213 kilo Newton's per meter and let us, calculate the over turning moment.

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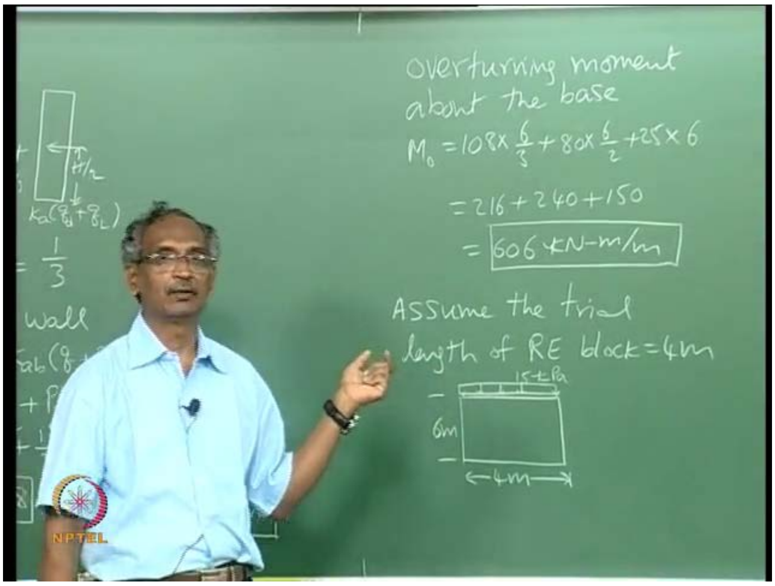

And as we have seen, that the dead load surcharge, the self weight loading acts at a height of 1 3’rd of the wall height; whereas, the uniform surcharge acts at a height of x by 2. So, we can calculate the over turning moment as 108 times 6 by 3 plus 80 times 6 by 2 plus times 6 that is. So, our overturning moment comes out as a 606 kilo Newton per meter length of the wall, in the perpendicular direction and the lateral force is 213 kilo Newton’s per meter.

And now, our length of the reinforced block should be sufficient to counteract, these lateral forces and the overturning moment with sufficient factor of safety and let us see how we can do it. And it is actually it is, a trial and error procedure, and let us start with reinforced block length of 2 3’rds of the wall height, that is let us say 4 meters, let us say that, we take this length as 4 meters. And for all the stability calculations, we include the permanently acting loads let for example, here the dead load surcharge is 15 k P a that we take it as part of our stabilizing forces so our the weight of the reinforced block.

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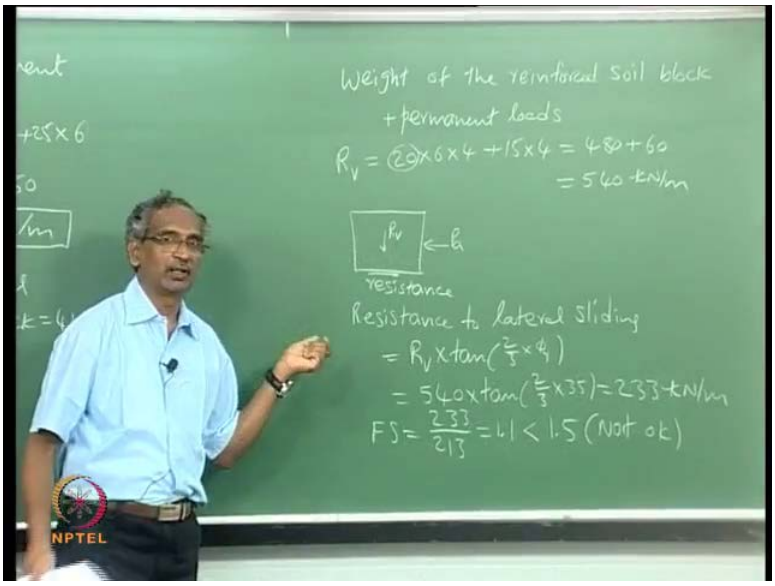

So, the total vertical force, is the sum of the weight of the reinforced soil block and the permanent loads. And the unit weight of reinforced soil, fill is 20 kilo Newton's per meter that is this and the height is 6 meters, and the length of the block is 4 meters and the permanent surcharge is 15 and the length of the block is 4. So, our total vertical load is 540 kilo Newton's per meter. And now, let us estimate the sheer force that is acting. So, this is p a and the resistance, as we had discussed the earlier, is either function of the reinforced soil are the function of the foundation soil, depending on whichever one is more critical. But, in this particular case since, we do not have any data on the foundation soil, as a trail. Let us assume, our the mu that is the friction factor as tan of 2 3'rds of the friction angle of the reinforced fill.

So, let us assume and let us calculate the resistance. So, this resistance force comes out as 233 kilo Newton per meter and our factor of safety, against lateral sliding is the force sorry the resistance divided by force. So, this factor of safety is coming out as 1.1, which is much less than 1.5, so this particular length of the reinforced block is too short and it is not adequate to safely resist the lateral force. So, now, let us increase the length to a higher value and do the calculations.

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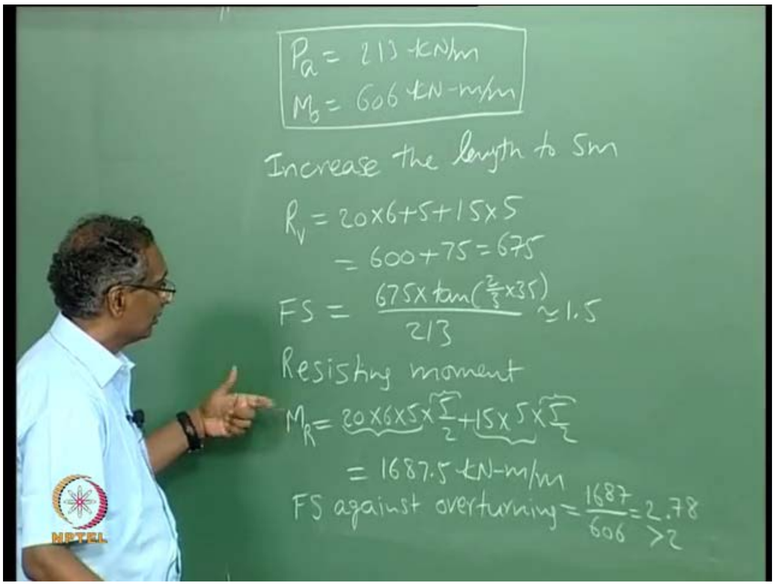

Even when we increase the length of the block because our height of the wall is constant at 6 meters, these sitting forces will not change. Now, let us write them separately and now, increase the length to 5 meters. So, our R v comes to, that comes to 600 plus 75 that is 675 and our factor of safety, against lateral sliding is 675 times, this divided by the upsetting force of 213 it comes to nearly 1.5 and let us, calculate the resisting moment.

So, actually the resisting force is 20 times 6 times 5, 5 is the length of the reinforced block and this 5 by 2 is the lever arm, that is half the length of the reinforced block and 15 times 5 is once again, the resisting force and 5 by 2 is the lever arm. And our resisting moment is 1687 and our, the factor of safety against overturning is 1687 divided by 606 and it comes out as 2.78, which is greater than 2. So, this length of the reinforced block is adequate, as for as our the resistance against lateral sliding is concerned and then the resistance against overturning moment. And now, let us calculate the bearing pressure.

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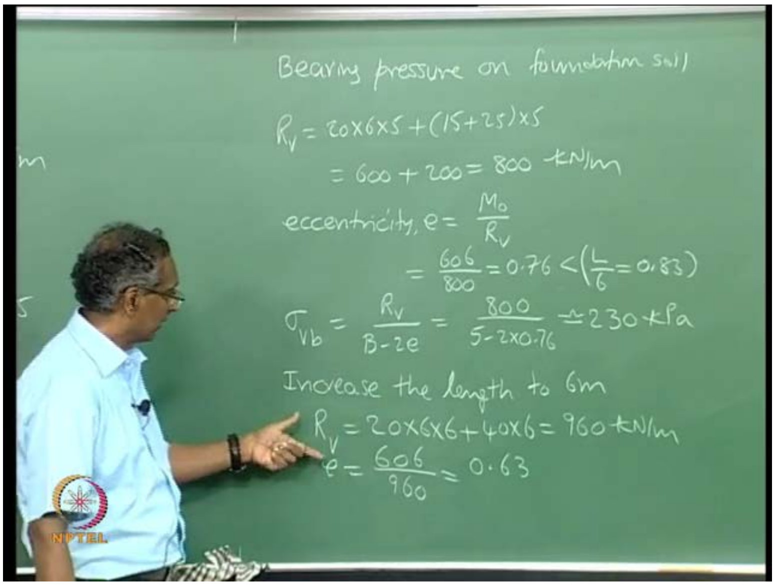

And for calculating the bearing pressure, we include all the loads that are acting, including the live loads and then the permanent loads and so on. So, our R v in this case is 20 times 6 times 5 plus 15 plus 25 times 5 that is a 600 plus 200 800 kilo Newton's per meter and our eccentricity is m naught by R v that is 606 divided by 800 that comes out as 0.76 and this is less than l by 6 that is 0.83.

So, actually our eccentricity should be with in the middle third, in the case of soils and within 1 4'Th of the length, in the case of rock foundation. So, in this case our eccentricity is 0.76 which is less than 0.83, so it is and our sigma v b is R v by B minus 2 e that is 800 by, this comes to a bearing pressure of almost 230 kilo Pascal's, which is more than the allowable bearing pressure of a 200. So, we will have to once again, revise the length. So, that our bearing pressure is, also less than the less than the bearing capacity.

So, now let us say increase the length of the reinforced block to 6 meters. So, our R v comes to, so actually you notice that, our eccentricity now is only 0.63 as compared to 0.76 when our reinforced block length was 5 meters and that is because our overturning moment is remaining constant, though overturning moment of 606 where as, the weight of the reinforced block is increasing when we increase the length. So, this is one way, in which we can increase the stabilizing forces by increasing the length of the reinforcement. So, our eccentricity is now reduced to 0.63.

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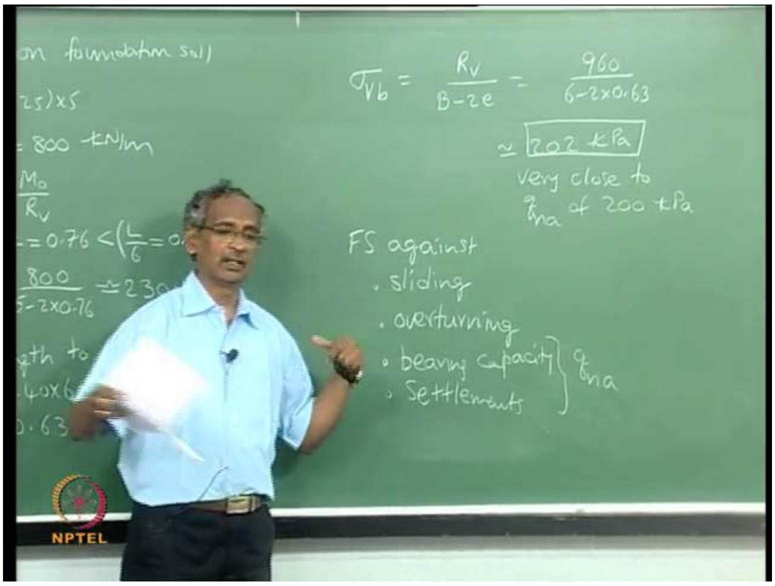

And our sigma v b is, so this bearing pressure comes to 202 kilo Pascal's, which is very close to 200 k P a. So, we can just leave it like that, that the 6 meters length of the reinforced block for this particular case and this 6 meters length, will satisfy all the requirements of the factor of safety against sliding. And then the overturning, bearing capacity and then the settlements, the factor of safety against sliding should be greater than 1.5 and the factor of safety of overturning should be greater than 2.

And in this case, we have achieved more than that because our length of the reinforced block is increased just satisfy the bearing pressure. So, our the factor of safety against sliding would have gone up much beyond 1.5 and the overturning factor of safety would have gone to much more than 3 because our eccentricity is become very small. And the factor of safety against the bearing capacity and the settlements is satisfied, by making sure that our bearing pressure, is less than the allowable bearing pressure that is the q n a.

So, this length of the reinforced block of 6 meters satisfies all the requirements from our design considerations. So, this completes the external stability analysis of this particular retaining wall and the next step, is to calculate the reinforcement spacing that, we will see in some other lecture, but let us slightly modify the problem, with a sloped back fill and do the calculations.

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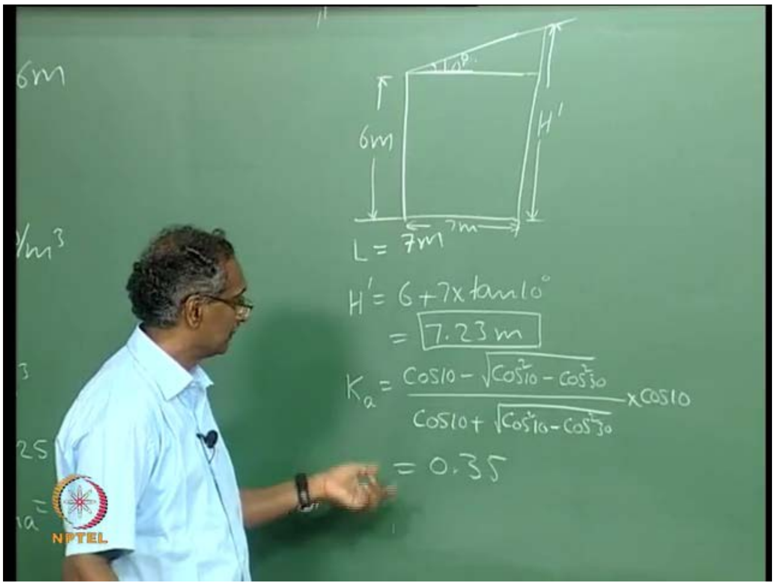

Now, our back fill let us say that it has a slope of 10 degrees sorry it should be 10 degrees. And let us assume, the trial length as a 7 meters because we have earlier seen that we require 6 meters of length, to satisfy all the requirements and this wall, as it has a slope, back fill slope; let us assume slightly higher length of 7 meters and this is our reinforced block has 7 meters length, like this.

And our H prime now, the height of the soil that our reinforced block should support is H prime and our H prime is 6 plus 7 times tan 10 degrees that is and let us use the, a simple rankine's formula for calculating the lateral pressures, say if we apply the Rankine's formula the k a comes out as 0.35, in the earlier case it was only 1 by 3 that is 0.33 this case because of the back fill slope, we have slightly higher lateral pressure constant.

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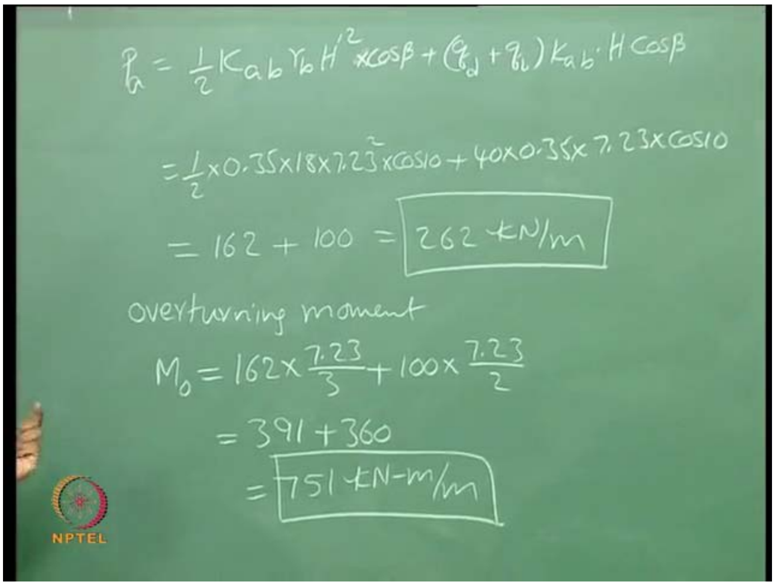

And, now let us calculate the P a as 1 half. So, this lateral force because of the self weight of the soil comes out as approximately 162 and the, lateral force because of the live load and the dead load surcharge comes to nearly 100. So, the total lateral force is 262 and then the overturning moment m naught is 162 times. So, our overturning moment, now is 751 and if you compare this to the earlier one of 606 this is much higher mainly because we have a slope in back fill. So, because of that our k is high and then the effective, height of the soil that we need to support is much higher, the previously it was only 6 meters now, we need to support height of 7 meters, 7.2 meters to be very precise.

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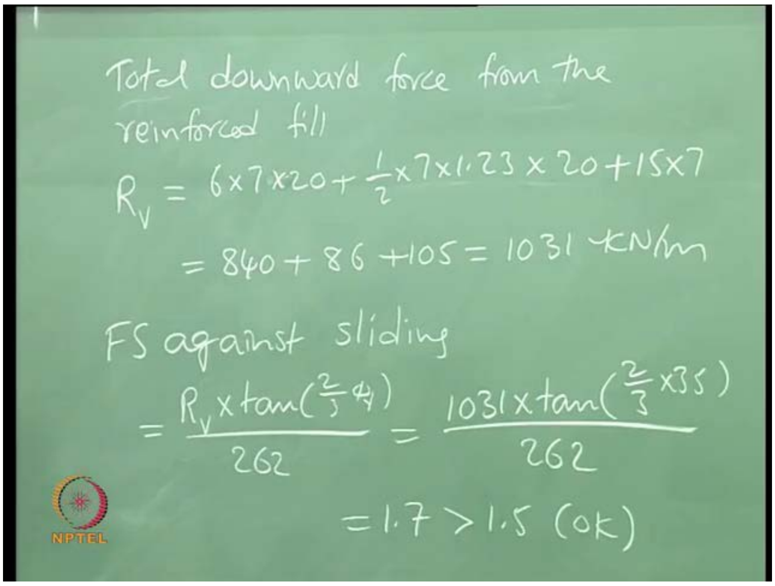

So, now let us do the stability calculations, see the total downward force is because of this rectangular portion, plus the weight of the soil within the triangle and then the permanent surcharge, that is acting on top of the slope and this, force is the total downward force, say it is 6 times 7 times 70 plus and this comes out as 840 plus 86 plus 105 that is, this the total downward force is 1031 kilo Newton per meter, the factor of safety against the sliding. So, our factor of safety against sliding comes out as 1.7 which is more than 1.5. So, this length of the block, is sufficient as per as the factor of safety against the lateral sliding is a concern and now, similarly let us calculate the, factor of safety against overturning.

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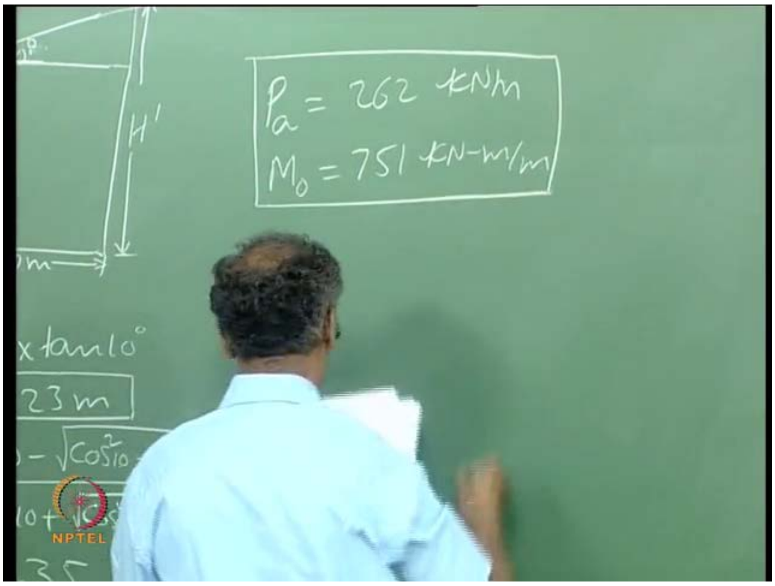

So, we have already calculated our P a as 262 and our overturning moment as 751.

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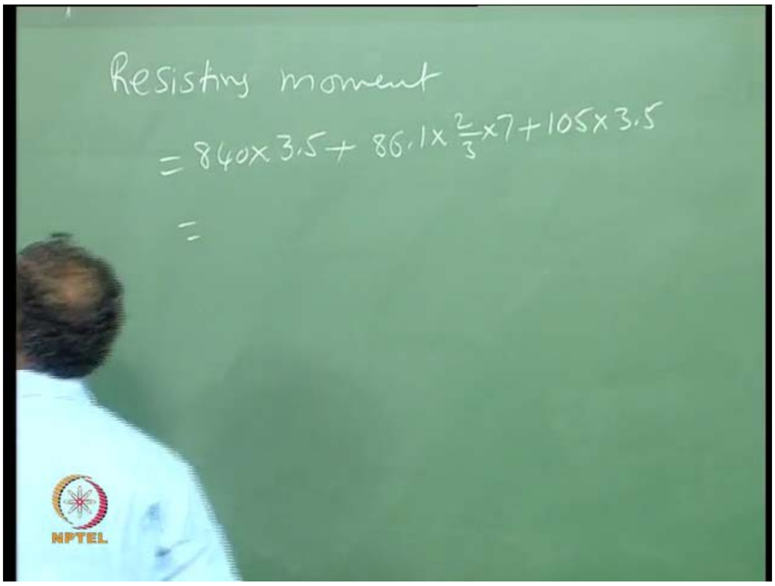

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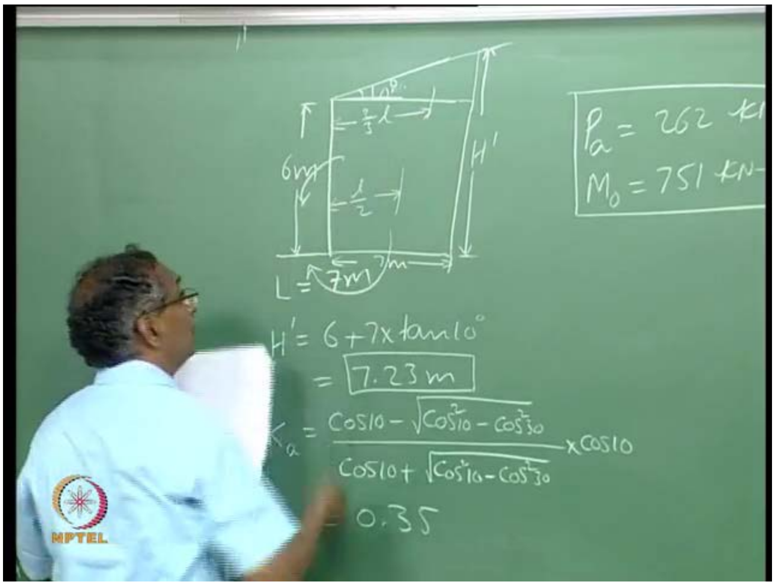

See here, our overturning moment is acting in this direction, the resisting moment is acting in this direction and the lever arm for the rectangular portion is this and the laver arm for this triangular portion is 2 by 3 l.

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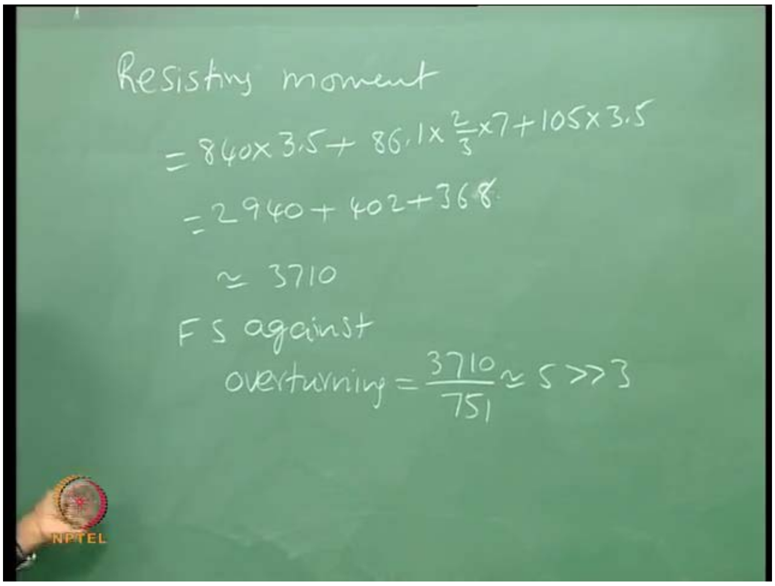

So, because of that we have taken 2 3’rds of the 7 and so the total resisting moment comes out as 2940 plus 402 plus 367, the factor of safety this is, this factor of safety against a overturning comes out as much more than, 3 it comes out as 5 which is much higher than 3. So, this length of reinforcement is adequate and now, let us calculate the bearing pressure.

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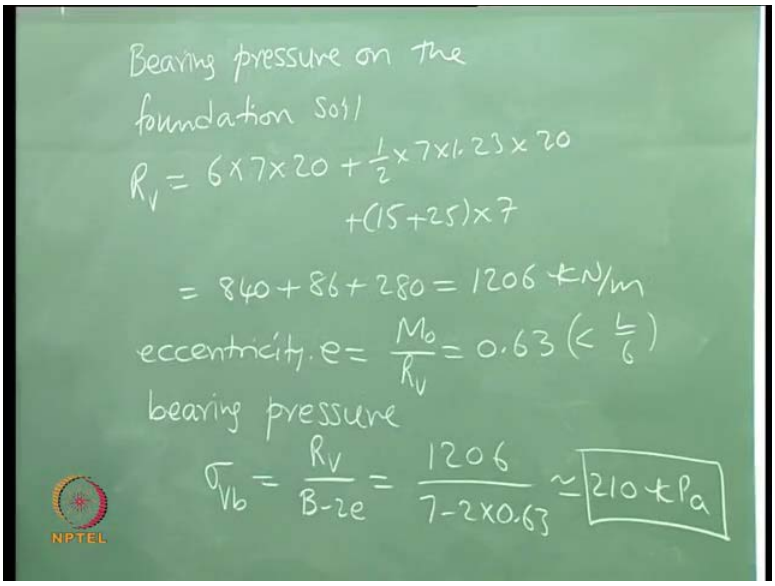

And for this we need to include the affect of the dead load also, so let us calculate the total force once again. So, by including the affect of the dead load and the live load ,our total downward force increases to 1206 and our eccentricity is M naught by R v which comes out as 0.63 which is less than l by 6. So, this is and our bearing pressure.

So, our bearing pressure after all this calculations comes out as 210, which is higher than the allowable bearing pressure of 200. So, we will have to increase the length of the reinforcement section and when we increase the length, we increase in some convenient numbers like, we cannot increase by just say 5 centimeters or 10 centimeters because it becomes very difficult, to cut the reinforcement, especially to odd lengths, especially when you have a say the geo grids, which have specific puncture openings it may not be possible to cut at odd places through the through the apertures.

And normally, we increase the length of the reinforcement block, in increments of 250 mm and this particular case a length of reinforced block of 7.5 meters satisfies, the bearing pressure requirement also I am not showing that calculation, but you can follow the similar calculations by substituting 7.5 in place of a length of 7 meters. So, we will see that, the bearing pressure comes out as less than 200. So, length of 7.5 meter satisfies all our requirements, the factor of safety requirements.

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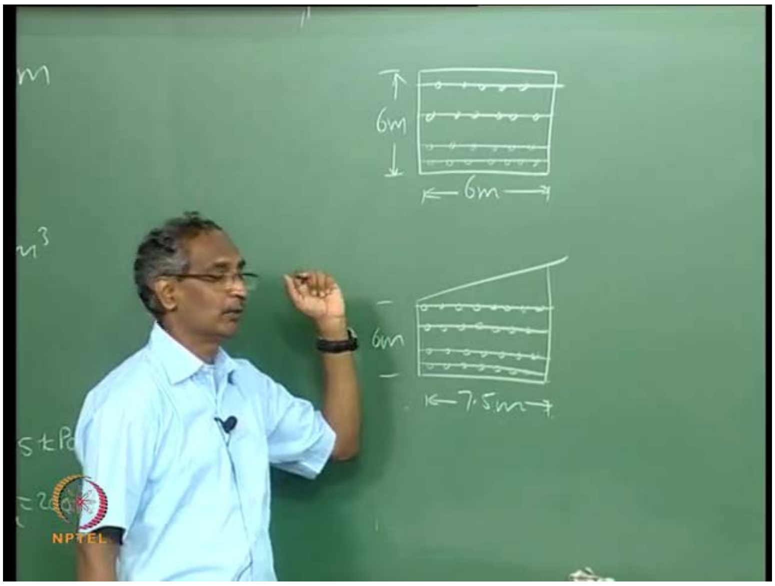

So, we have seen that the, if you have a horizontal fill, we require a reinforced block length of 6 meters and if you have a sloped fill, we require a block length of 7.5 meters, which is more than that we have for a horizontal back fill.

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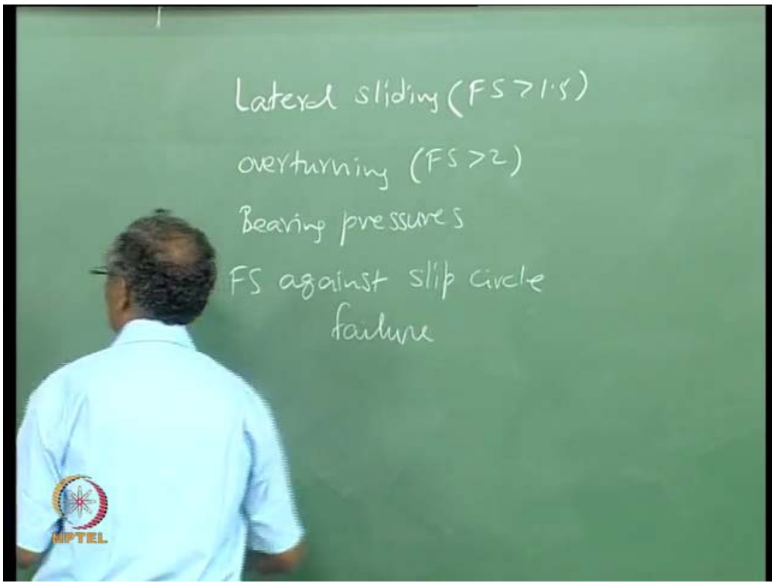

And in this particular example, we have set for safety against the lateral sliding greater than 1.5 overturning factor of safety greater than 2 and then the bearing pressure. So, the remaining calculation is, the overall factor of safety the or a the factor of safety against the slip circle failure.

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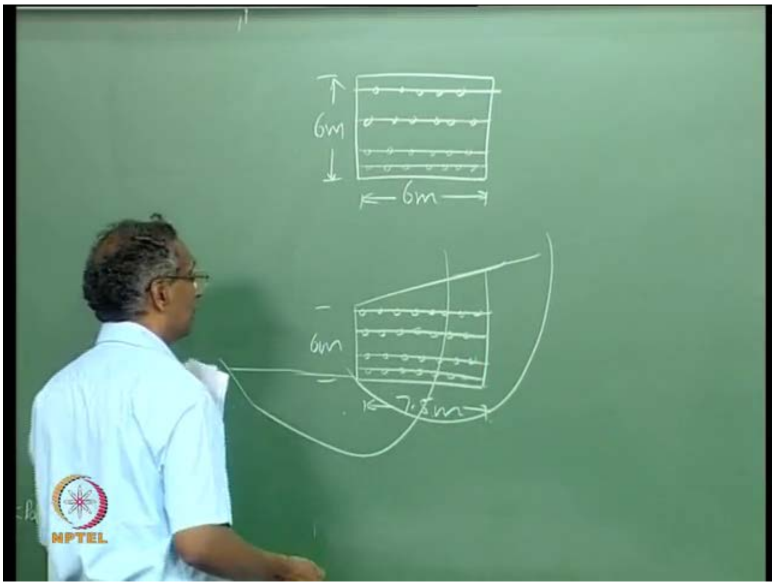

So, that is we consider number of slip circles, passing through the foundation soil, either through the toe or anywhere in general.

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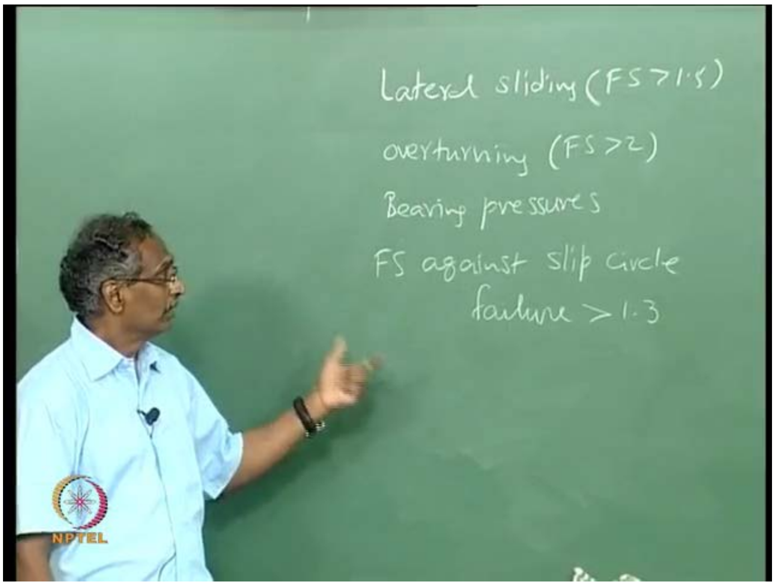

And make sure that, the factor of safety that we get through the slip circle analysis should be at least greater than 1.3 for moderate factor of safety, and if it is very important structure, the factor of safety that, we need to get through the slip circle analysis, should be at least greater than 1.5.

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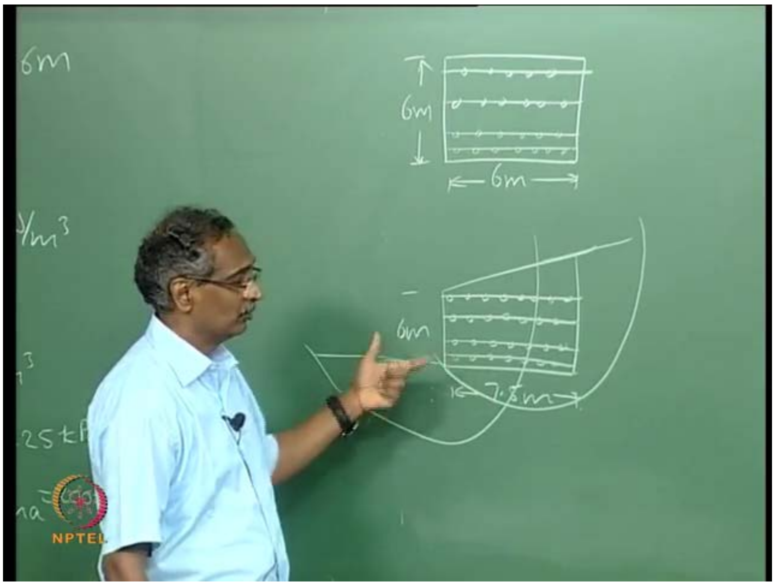

The actual in this particular example that we have considered, the reinforce the block length has come out as very high, usually the length of the block that, we require is about 2 3’rds to 3 4’th of the of the wall height, but in this case because our foundation soil is relatively, it has relatively less bearing capacity that is 200 k P a our block length is 6 meters in the first case, that is the length almost equal to the height of the wall.

And in the second case, the length is 7.5 meters once again, it is almost equal to the height of the affective worm, height of the wall the backend of reinforced block and the calculations are, reasonably simple, but then is actually what we do is, we write a small excel spreadsheet because all this calculations are repetitive in nature and so we need to repeatedly revise the calculations, especially for a sloped fill like this, whenever you revise the length of the block, the height of the soil also changes and because of that our upsetting forces they increase.

So, the next step in the design calculations is how do we decide, the vertical spacing of the different reinforcement layers and then what a reinforcement do we provide, what should be the strength and then what should be the type, whether it should be polymeric geo synthetic or should it be a steel steps or it should a steel mesh type thing, then what should be they facing, there the things all those factors we let us consider, in some other lecture because of lack of time in this particular lecture.

Thank you.