Geosynthetics Engineering: In Theory and Practices
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Lecture - 31
Geosynthetics for Reinforced Soil Retaining Walls

Dear student warm welcome to NPTEL phase 2 video course on Geosynthetics Engineering in Theory and Practice. My name is Professor J. N. Mandal, department of civil engineering, Indian Institute of Technology, Bombay, Mumbai, India. The name of the course Geosynthetics Engineering in Theory and Practice, this is module 6, lecture number 31, Geosynthetics for Reinforced Soil Retaining Wall. Now, I will show recap of the previous lecture.

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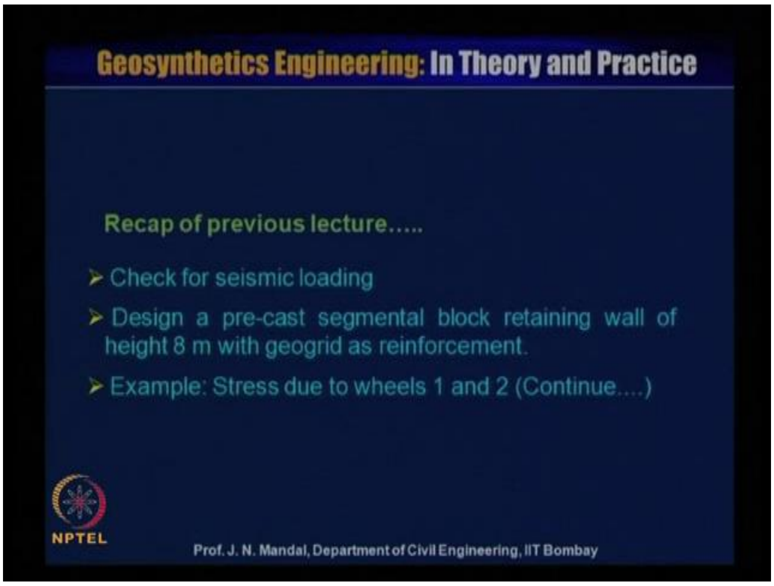

Check for the seismic loading, design in pre cast segmental block retaining wall of height 8 meter with the geogrid as reinforcement, and one example stress due to wheel 1 and 2 and now we will continue with the other wheel.

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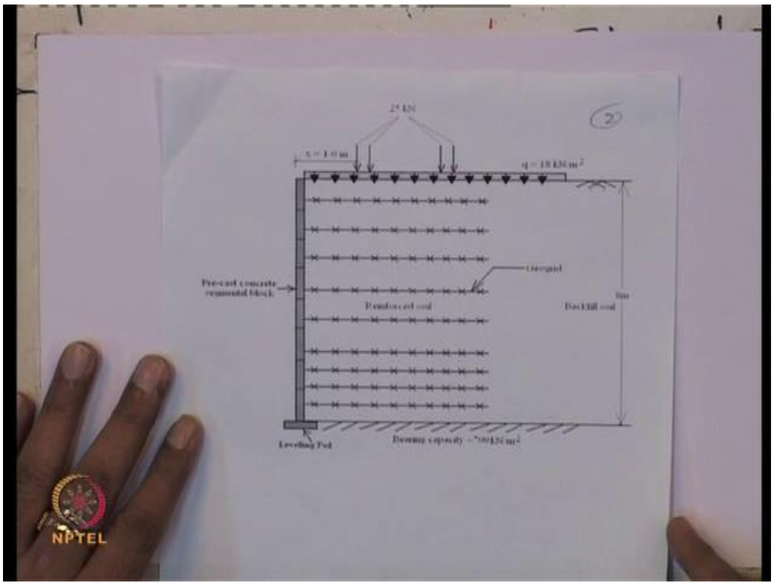

Now, we have shown you this earlier that, this is the wall, this is pre cast concrete block, this is the leveling pad and here is a number of the rare of the geogrid reinforcement, we have already designed. And this is the wheel load and each wheel load is about 25 kiloNewton and there are 8 wheel and this wheel is located almost 1 meter from the facing element of the wall. So, which is designated at X so X is equal to 1 meter so you have also earlier shown that, what will be the stress due to wheel 1 and 2.

Now, I will focus that, what should be the stress due to wheel 3 and 4, here we know that, total z in meter, this is 8 meter depth and we are considering 0 1 2 3 4 5 6 7 8. And from this, we have to calculate what is n value, n value is equal to z by H, we know what will be the height of the wall is about 8 meter.

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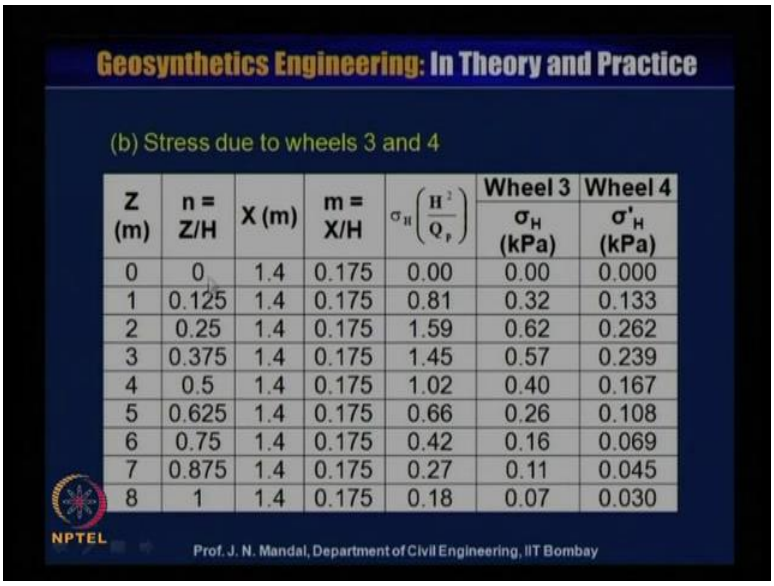

Z (m)	n = Z/H	X (m)	m = X/H	$\sigma_H \left(\frac{H^2}{Q_p}\right)$	Wheel 3 σ_H (kPa)	Wheel 4 σ'_H (kPa)
0	0	1.4	0.175	0.00	0.00	0.000
1	0.125	1.4	0.175	0.81	0.32	0.133
2	0.25	1.4	0.175	1.59	0.62	0.262
3	0.375	1.4	0.175	1.45	0.57	0.239
4	0.5	1.4	0.175	1.02	0.40	0.167
5	0.625	1.4	0.175	0.66	0.26	0.108
6	0.75	1.4	0.175	0.42	0.16	0.069
7	0.875	1.4	0.175	0.27	0.11	0.045
8	1	1.4	0.175	0.18	0.07	0.030

So, considering that, z is equal to 1 so n value will be 1 by, H is 8 meter so 1 by 8 is equal to 0.125. Similarly, when z value is equal to 2 so 2 divided by 8 is 0.25 then when z value is equal to 3, 3 divided by 8 is equal to 0 3 7 5. When Z value is equal to 4, 4 divided by 8 is 0.5, when 5 then 5 by 8 is equal to 0.625. Similarly, 6 by 8 is equal to 0.75, 7 by 8 is equal to 0.875 and 8 by 8 is equal to 1. So, we know, what would be the n value and now, what is X, X as I mentioned that, from the facing element.

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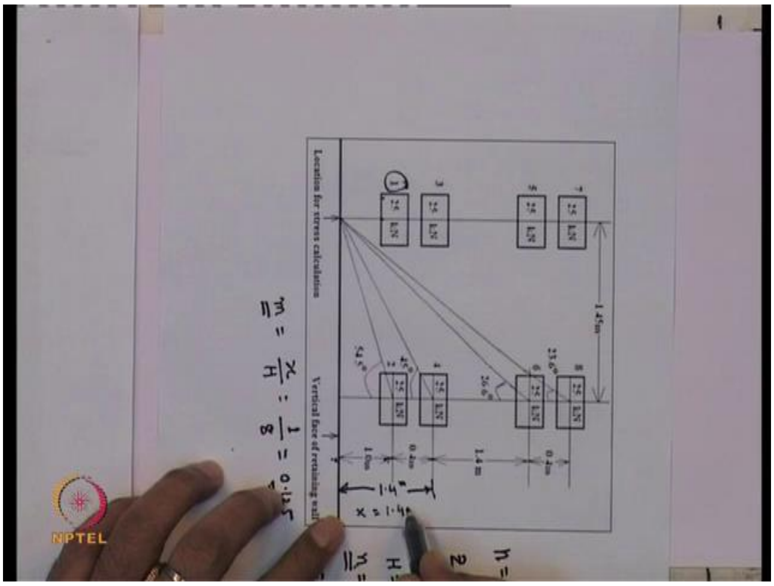

So, you can see here that, this is the wall let us say, if this is the wall and this wheel that is, number 1 and wheel number 2, wheel number 3, wheel number 4, 5, 6, 7 and 8. So, we have shown that, what will be the stress here for the wheel load 1 and 2, you have already calculated. Now here, we want to show, what will be the stress due to wheel 3 and the 4 so you can see that, this 3 and 4, which is located from the vertical face of the retaining wall, from here to here is about 1 meter and here to here is 0.4 meter.

So, this wheel load 3 and 4 is located at a distance of 1.4 meter that means, this is X is equal to 1.4 meter (Refer Slide Time: 05:54). So, here that is why, this X it is meter is shown 1.4 meter. Either 3 or 4, both the wheel is located from the vertical face of the retaining wall is 1.4 meter that is why, X is equal to one point 4 meter.

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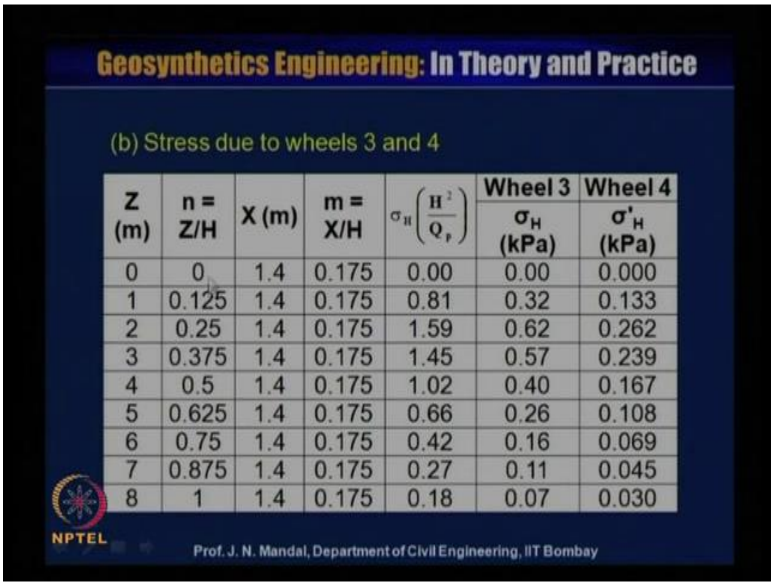

Z (m)	n = Z/H	X (m)	m = X/H	$\sigma_H\left(\frac{H^2}{Q_p}\right)$	Wheel 3 σ_H (kPa)	Wheel 4 σ'_H (kPa)
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7	0.875	1.4	0.175	0.27	0.11	0.045
8	1	1.4	0.175	0.18	0.07	0.030

Now, you have to calculate that m, m is equal to X by H so X is 1.4, 1.4 divided by H, 0.175 so X is constant so this m value also 0.175, is constant are upto depth of 8 meter. Now, we have to calculate the sigma H, H square by Q p. Now, what is sigma H, H square by Q p.

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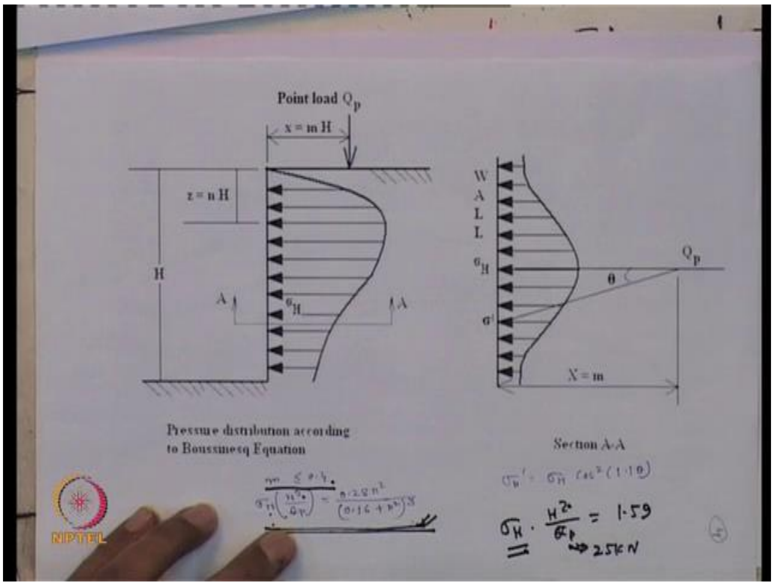

Now, we know that earlier, from this Boussinesq pressure distribution that, if the m value is less than equal to 0.4 sigma H, H square by Q p is equal to 0.28 n square divided by 0.16 plus n square whole to the power cube. If m value less than equal to 0.5, if it is that m value greater than equal to 0.5 then equation is different, which I have explain also earlier.

Now, in this table because m value, you can see m value is 0.175 so it is less than equal to 0.4. Therefore, this sigma H by H square Q p is equal to 0.28 n square by 0.16 plus n square whole to the power cube. So, we will use this equation to calculate that, what is sigma H by H square Q p because n value is known to you, this n value is known to you so you can calculate sigma H, H square by Q p.

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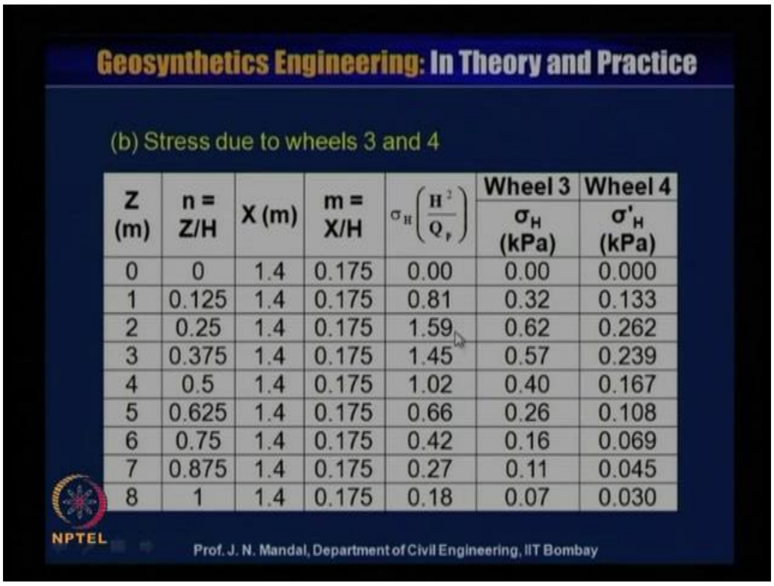

Z (m)	n = Z/H	X (m)	m = X/H	$\sigma_H \left(\frac{H^2}{Q_p}\right)$	Wheel 3 σ_H (kPa)	Wheel 4 σ'_H (kPa)
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1	0.125	1.4	0.175	0.81	0.32	0.133
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7	0.875	1.4	0.175	0.27	0.11	0.045
8	1	1.4	0.175	0.18	0.07	0.030

So, in this table that is how, it putting this value of n so you calculated that sigma H, H square by Q p value. So, you wrap putting n value in that equation, you can have 0.81, 1.59, 1.45, 1.02, 0.66, 0.42, 0.27 and 0.18. Now, what should be the sigma H for the wheel 3 so let us say that, for a depth of 2 meter and what should be the sigma H value. Now, see from this equation, sigma H, H square by Q p, you know what will be the value. You know this value is equal to at a depth of 2 meter is 1.59 that means, you know sigma H, H square by Q p is equal to 1.59.

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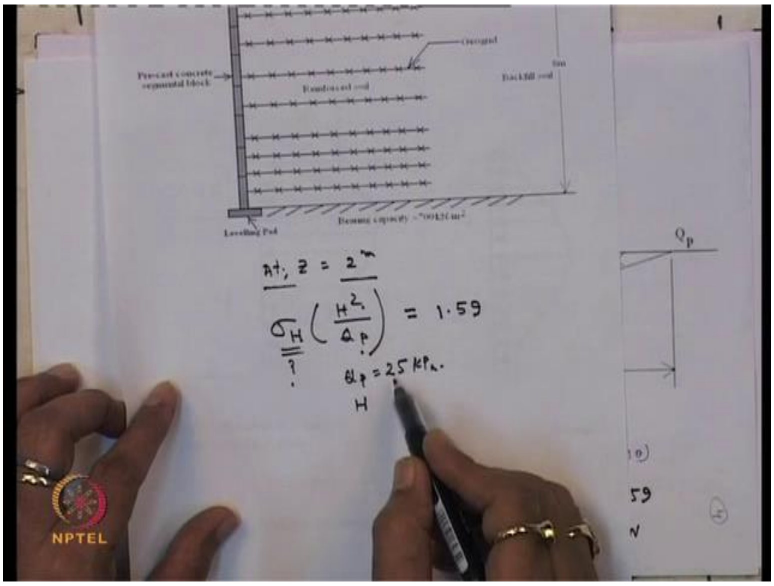

Now, I am showing you here that, we know that sigma of H, H square by Q of p is equal to, you calculate at a depth at z is equal to 2 meter, you calculate this value is 1.59. So, when at a depth of 2 meter, sigma H by H square Q is 1.59, you substitute value n and you find it is, 1.59. Now, you have to calculate sigma of H, this is unknown, H is 8 and Q p is point load that is, 25 that means, this will have a 25, this point we are, this is 25 so Q p is 25.

So, 25 is known to you so you can substitute this value of Q p, Q p is equal to 25 that is, k p a and H you know that, what will be the height. So, you can calculate that, what will be the sigma H so you can obtain the sigma H value at a depth of 2 meter is equal to 0.62. So, similarly, you can calculate sigma H at the different depth so 1 meter, 2 meter, 4 meter, 5 meter, 6, 7 and the 8 meter so you can calculate sigma H. Now, we are considering wheel 4, so here you can see that wheel 4.

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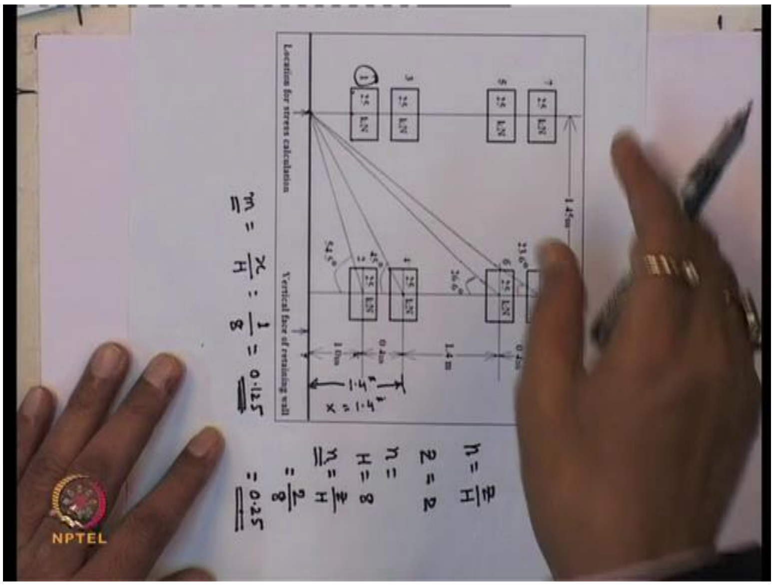

We are calculating location for the stress calculation at this point and this is the wheel 4 so this wheel is the 4, which is making at an angle of 45 degree. Let us say, this is theta is equal to 45 degree and you want to measure the, what will be the stress or which we call the sigma H dash. So, sigma H dash for the wheel load 4, what it will be.

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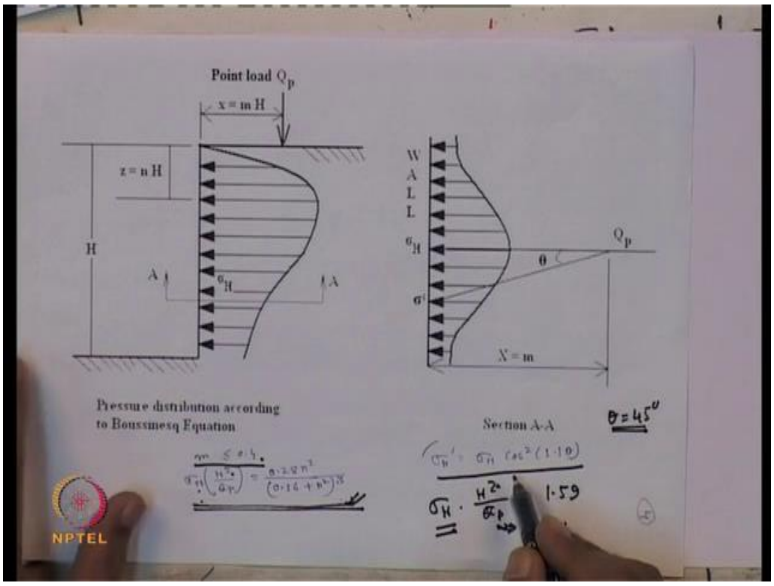

So, when you want to calculate the sigma of H dash, you can see here for at an angle theta, here theta is equal to 45 degree and this is the equation that is, sigma of H dash for the wheel load 4 will be equal to sigma H cos square 1.1 theta. And you know what is sigma H, you know what is theta value, 45 degree so then you can calculate what is sigma of H dash.

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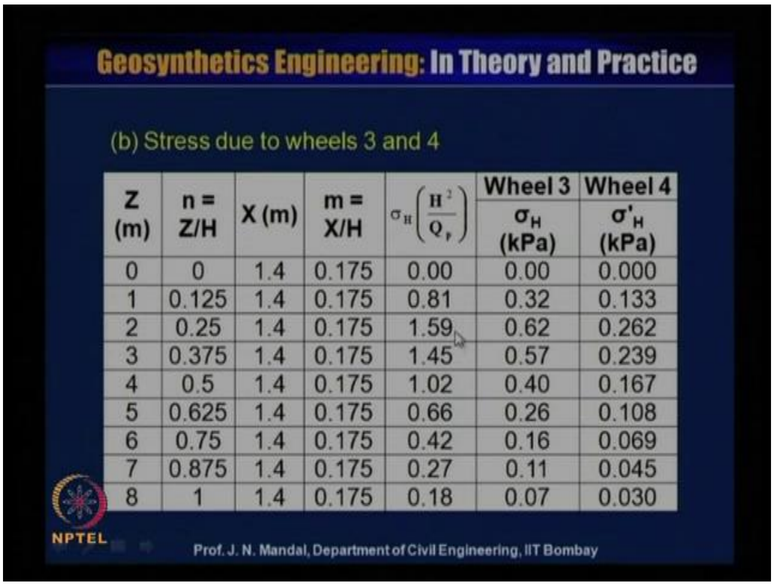

Z (m)	n = Z/H	X (m)	m = X/H	$\sigma_H\left(\frac{H^2}{Q_p}\right)$	Wheel 3 σ_H (kPa)	Wheel 4 σ'_H (kPa)
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1	0.125	1.4	0.175	0.81	0.32	0.133
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For an example, that you know at a depth of 2 meter, this sigma H value is 0.62, it is known. So, sigma H is 0.62 so then sigma of H dash will be 0.62 into cos square 1.1 into theta, theta is 45 degree. So, you can calculate that, sigma H dash at any point so let us say that, I am showing this again this equation.

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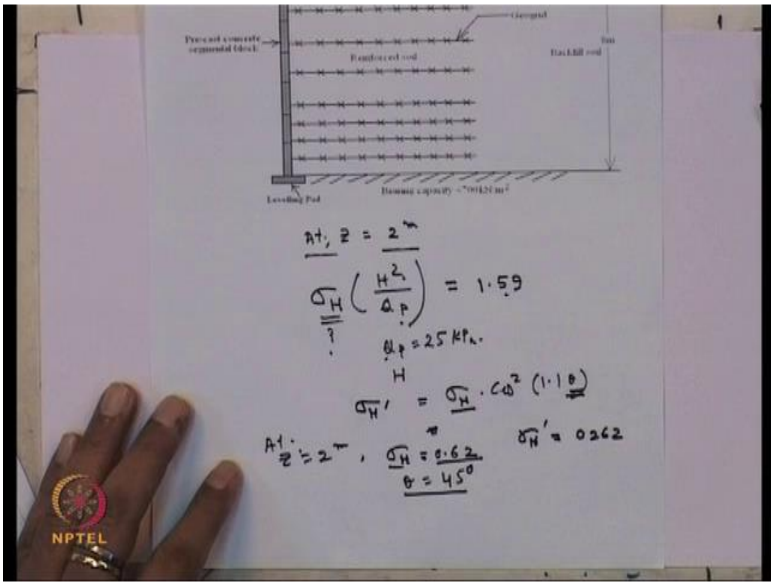

Also here, you want to calculate sigma H dash is equal to sigma H into cos square 1.1 theta. Now, you know at depth let us say, z is equal to 2 meter. So, sigma of H value is known, sigma of H value is equal to 0.62 and theta you know, this is making at an angle 45 degree. So, you substitute the value of sigma H and theta here so then you can calculate sigma of H dash and that will give at a depth of 2 meter about 262.

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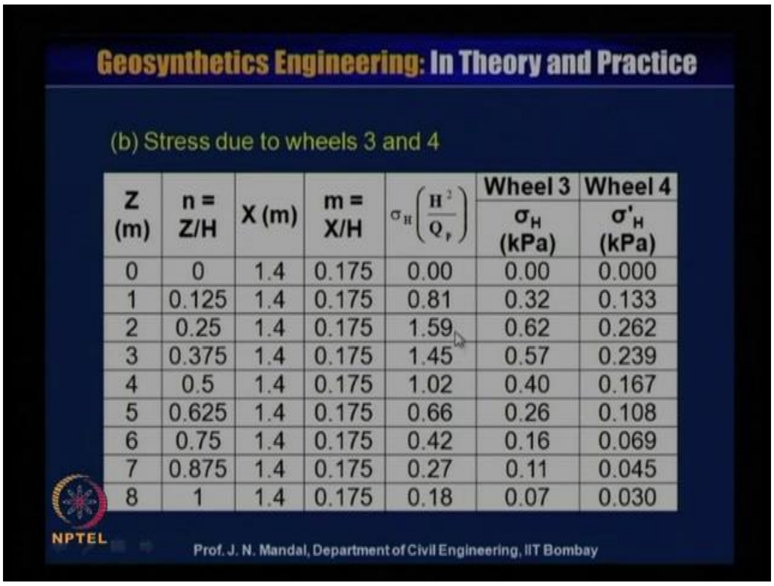

Z (m)	n = Z/H	X (m)	m = X/H	$\sigma_H \left(\frac{H^2}{Q_p}\right)$	Wheel 3 σ_H (kPa)	Wheel 4 σ'_H (kPa)
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So, you can calculate that sigma H dash at a depth of 2 meter, 0.262 similarly, you can calculate for the depth 3 meter, 4 meter, 5 meter, 6 meter, 7 meter and 8 meter like this. So, this you can calculate, what will be the stress for the wheel 3 and the 4 now, we will consider for the stress due to wheel 5 and 6, so you look here that 5 and 6.

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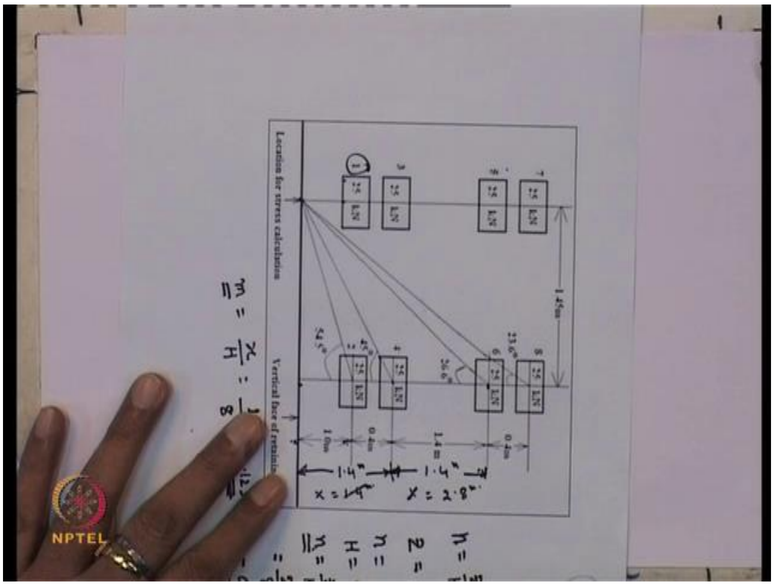

So, this is the 5 here and this is the 6 so 5 and this is 6 so we have to calculate, what will be the stress for the wheel 5 and as well as wheel 6. So, location of the stress calculation at this point so for the wheel 5 so what is the distance X. So that means, what is the location of this wheel, this wheel from the vertical face of the retaining wall. So, we know this is 0.4, this is 1.4 meter and then this is also 1.4 meter so this is also 1.4 meter so total will be, X will be now 2.8 meter. So, this wheel load, wheel 5 and 6 are located from 2.8 meter from the vertical face of the retaining wall, so this is X.

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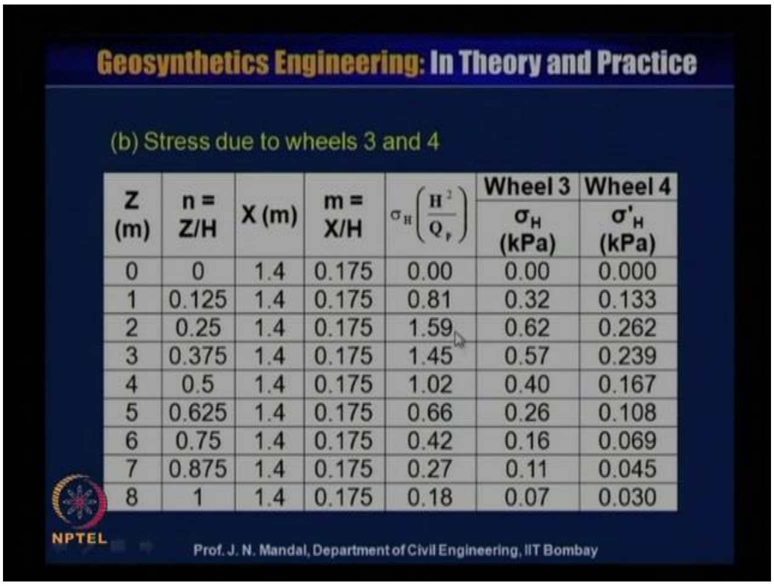

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4	0.5	1.4	0.175	1.02	0.40	0.167
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6	0.75	1.4	0.175	0.42	0.16	0.069
7	0.875	1.4	0.175	0.27	0.11	0.045
8	1	1.4	0.175	0.18	0.07	0.030

So, this x is here, you can see 2.8 all along the depths and because this is Z, 1 to 8 so n will be the same and now, X only will change 2.8. Now, you have to calculate, what is m, m is equal to X by H, you know what is X and H because X is constant 2.8, H is also constant 8 meter. So, X by H is equal to 0.35 is constant all along this depth, here again you can observe that this m value is less than equal to 0.4. Therefore, you can use this again equation sigma H, H square by Q p.

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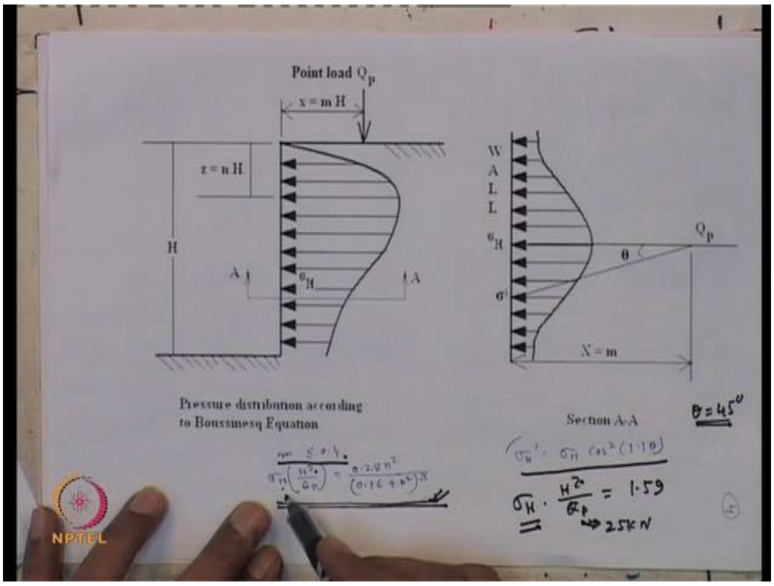

So, you can adopt this equation, because this m value is less than equal to 0.4 so we can adopt sigma H, H square by Q p is equal to in terms of n 0.28, n square 0.16 plus n square whole to the power cube. Now, you know what is the n value, and so you can calculate sigma H, H square by Q p.

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(b) Stress due to wheels 3 and 4

Z (m)	n = Z/H	X (m)	m = X/H	$\sigma_H\left(\frac{H^2}{Q_p}\right)$	Wheel 3 σ_H (kPa)	Wheel 4 σ'_H (kPa)
0	0	1.4	0.175	0.00	0.00	0.000
1	0.125	1.4	0.175	0.81	0.32	0.133
2	0.25	1.4	0.175	1.59	0.62	0.262
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So, here you calculate and find that sigma H, Hh square by Q p, for at depth 2 also, it is the same, because m value is always less than 0.4. So then you have to calculate again what will be the stress on wheel 5.

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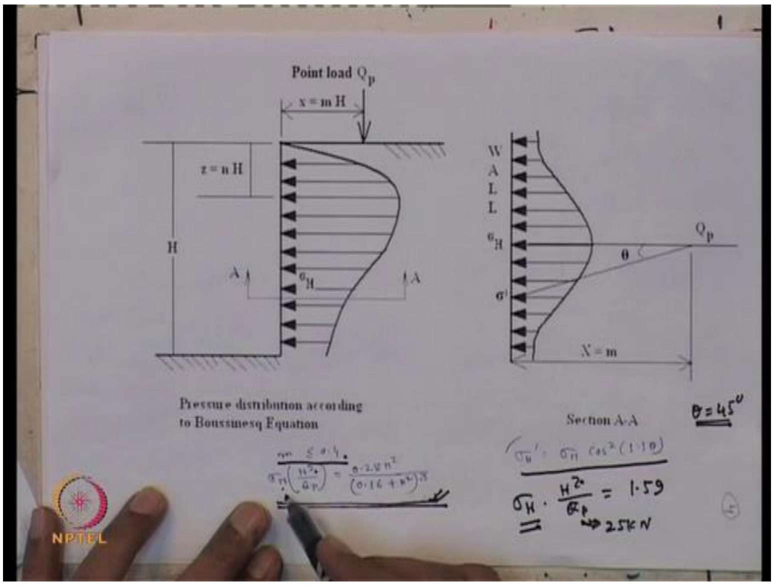

So, stress on the wheel 5, again you know sigma H, H square by Q p is equal to, this n value is known. Let us say at depth 2, this value is equal to 1.59 so if this value is equal 1.59, I am writing here again.

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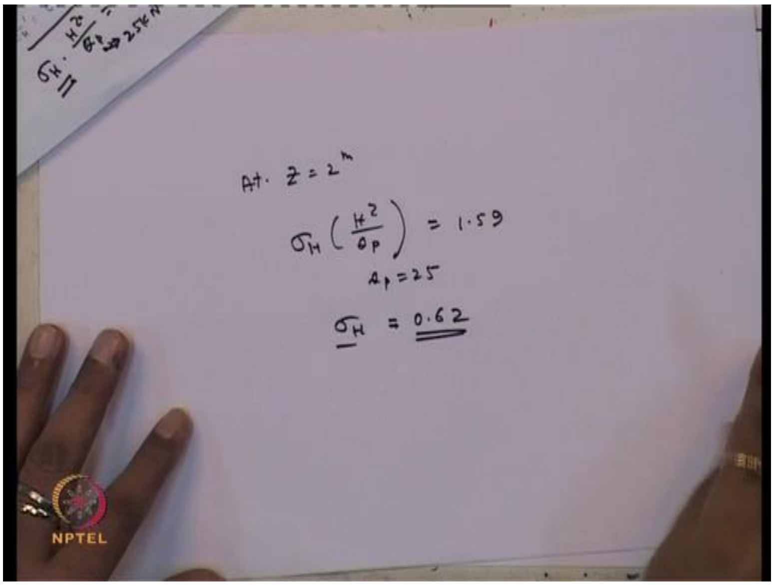

If you know sigma of H, H square by Q of p and at depth that is, z is equal to 2 meter and this value is equal to 1.59. Now, H is known 8 meter height, Q p also that wheel Q p is also 25 so Q p also is known 25 so H is known, 8. So, you can calculate, what the sigma H for wheel 5 so for wheel 5 at a depth of 2 meter, the sigma H will be equal to 0.62. So, you know, what is sigma H is equal to 0.62 now, you have to calculate that, what will be the stress for wheel 6.

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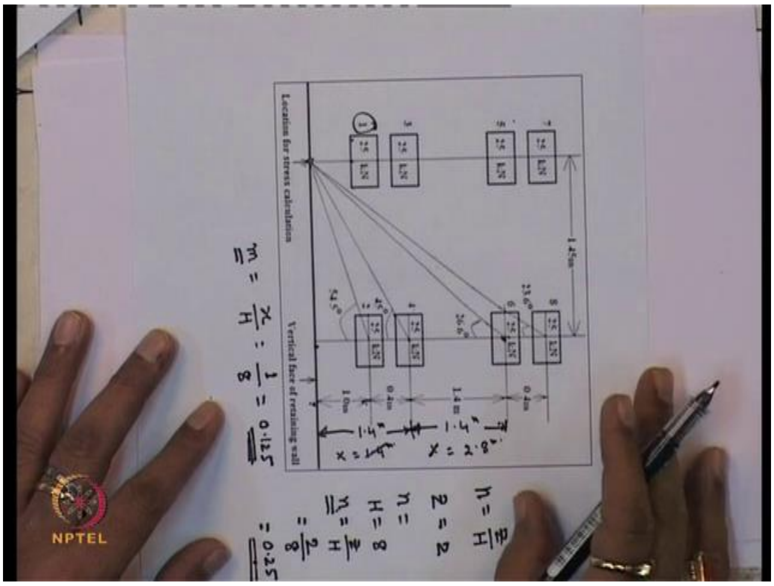

You can see here, wheel 6 is located here, which is making, we have to find out that, what will be the stress of the wheel or wheel 6 and which is making at an angle let us say, theta is equal to 26.6 degree. So, this angle is 26.6 degree so we know that, theta angle is equal to 26.6 degree.

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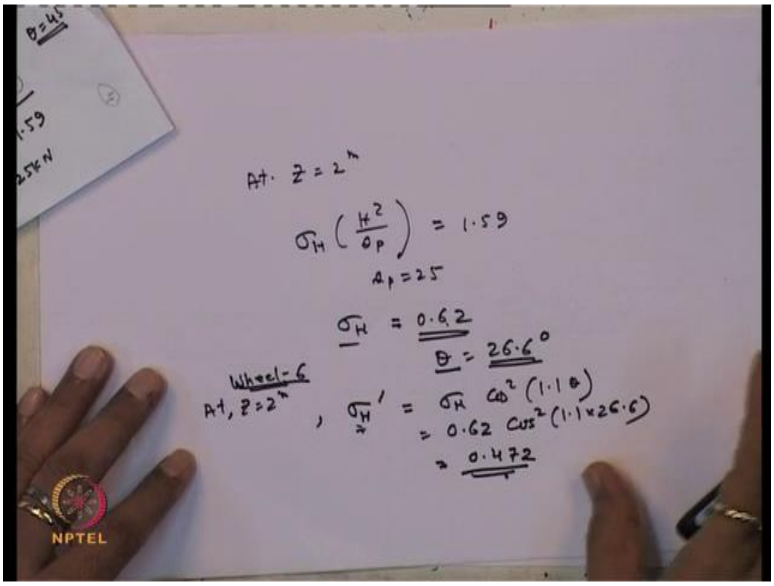

So, we know that equation to calculate the stress that is, sigma of H dash for the wheel 6 and let us say, at a depth of 2 meter so sigma H dash will be equal to sigma H in cos square 1.1 into theta. Now, theta value is known, 26.2 and sigma H value is known so this is sigma H, 0.62 into cos square 1.1 into theta 26.6. So, sigma H at a depth of 2 meter, you can calculate and this will give 0.472 so this you calculate what will be the stress for the wheel load 2 there then this is 0.4672 kiloPascal sigma H dash. So, we calculated for the stress for the wheel load 5 and 6.

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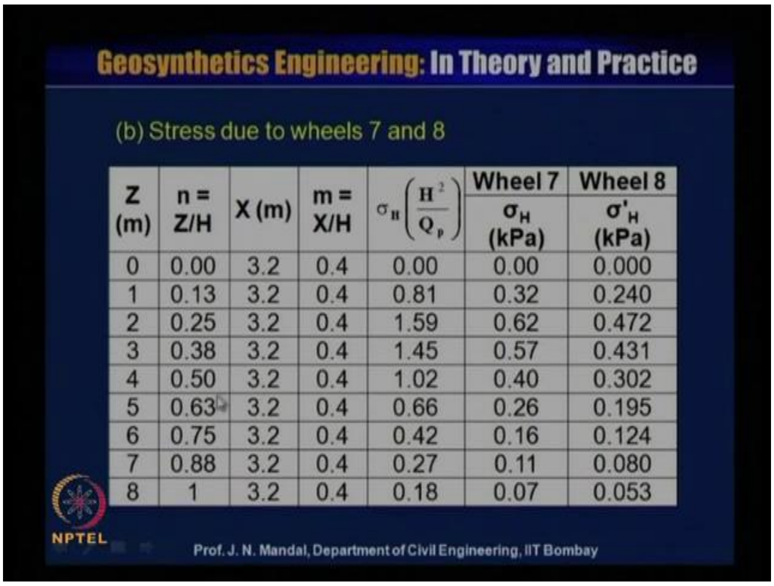

Z (m)	n = Z/H	X (m)	m = X/H	$\sigma_H \left(\frac{H^2}{Q_p}\right)$	Wheel 7 σ_H (kPa)	Wheel 8 σ'_H (kPa)
0	0.00	3.2	0.4	0.00	0.00	0.000
1	0.13	3.2	0.4	0.81	0.32	0.240
2	0.25	3.2	0.4	1.59	0.62	0.472
3	0.38	3.2	0.4	1.45	0.57	0.431
4	0.50	3.2	0.4	1.02	0.40	0.302
5	0.63	3.2	0.4	0.66	0.26	0.195
6	0.75	3.2	0.4	0.42	0.16	0.124
7	0.88	3.2	0.4	0.27	0.11	0.080
8	1	3.2	0.4	0.18	0.07	0.053

Now, we have to calculate stress due to wheel 7 and 8 now, you can see, this is almost constant and what is the location of X.

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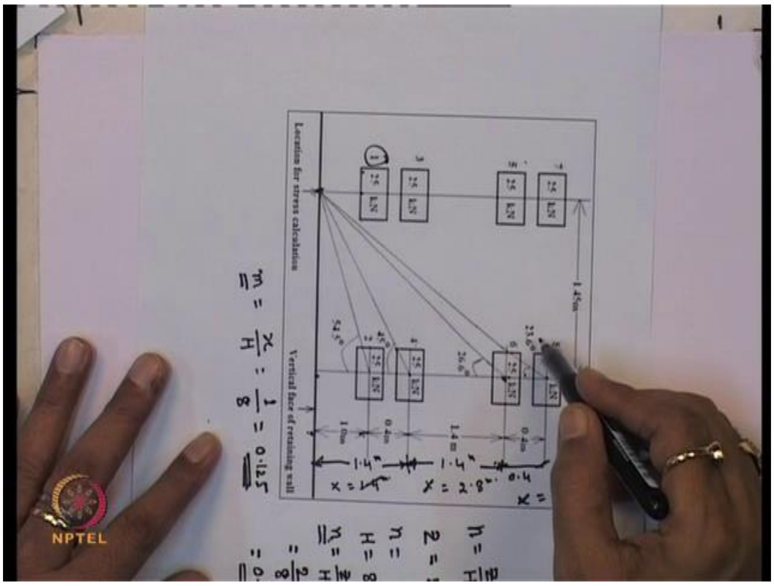

So, location of X, this is for wheel load this is 7 and this is 8 so this located from here to here, 2.8 and this 0.4, this is 0.4 that means, X will be equal to 2.8 plus 0.4 that means, X will be equal to 3.2 meter. So, for the wheel load 7 and 8, X is located from the vertical place of the retaining wall is about 3.2 meter and this 3.2 meter that is why, the X value is 3.2 meter all along the depth. But, again you calculate m is equal to X by H, X is known, here also you find that, m value is almost less than equal to 0.4.

Suppose, this m value is equal to greater than 0.4 then we could adopt the another equation, which I have previously explained. But, in this problem here, that m value is almost 0.4 so that means, we are using the same equation and to calculate, what is sigma H by H square by Q p. You can see for the depth 2, again this value is the same 1.59 and for the wheel load 7, so you calculate the stress, this is 0.62. And similarly, because here, wheel load 8 and which is making at an angle 23.6 degree, so you know what is the theta angle, 23.6 degree.

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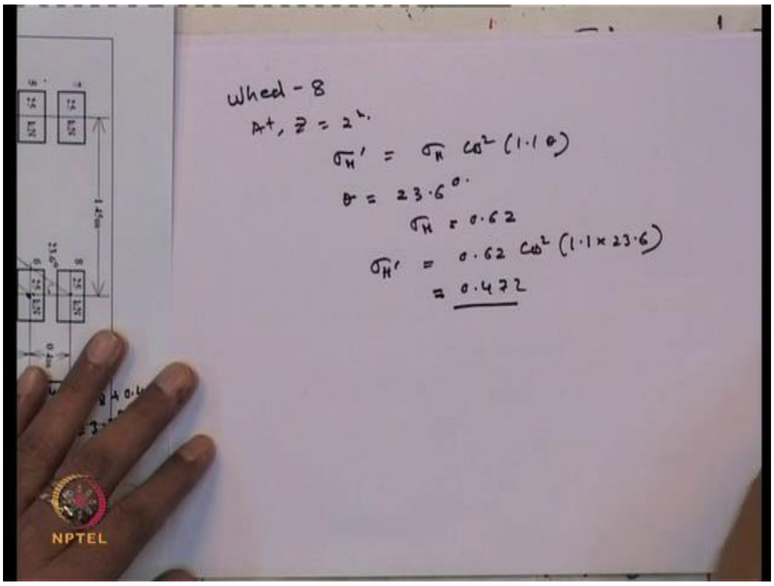

So, let us say, I am just showing you for the wheel load 8 only, wheel 8 at depth z is equal to 2 meter and you know, what will be the sigma H dash. This is equal to sigma of H into cos square 1.1 theta and theta is given 23.6 degree and sigma H at a depth of 2 meter is 0.62. So, you can calculate sigma of H dash is 0.62 into cos square 1.1 and theta is 23.6. So, you can have at a depth of 2 for the wheel load 8 will be equal to 0.472 so this you can obtain 0.472.

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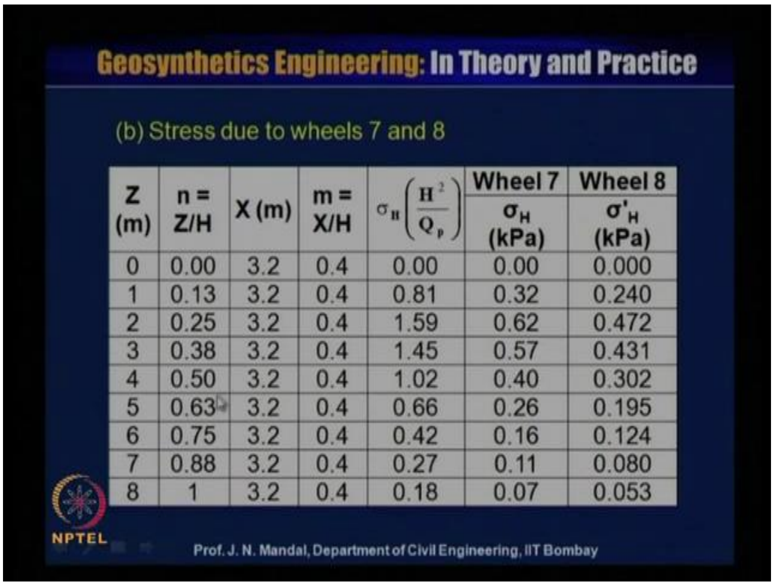

So, you can calculate for any other depth, what will be the stress so here we calculate what will be the stress for the wheel 7, as you have learn for wheel 8. So, we completed the stress for the wheel load 1, 2, 3, 4, 5, 6, 7 and 8.

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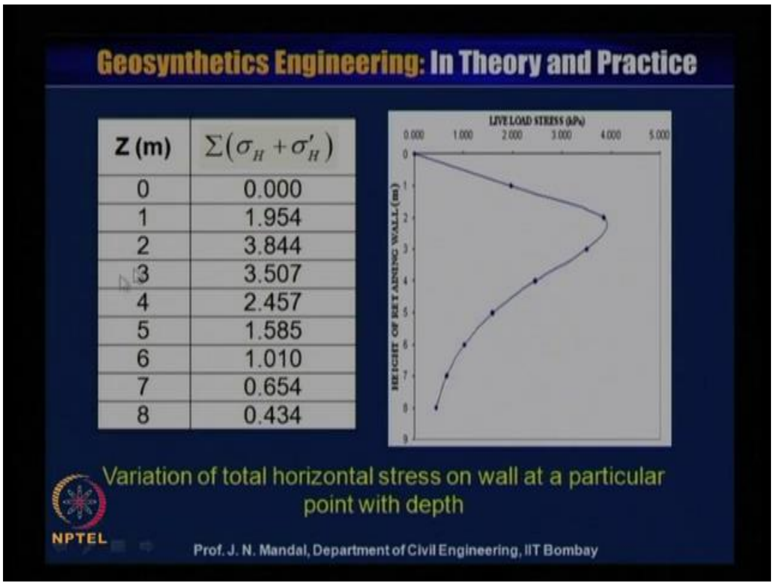

So here, you can see that, variation of the stresses here and this is the depth, at any depth you calculate what will be the total stress. So, you know what is sigma H, you know what is sigma H of dash so you know that, what is the wheel from this table, wheel 7 and any depth, wheel 7 and wheel 8. So, you can calculate, what is sigma H and sigma H dash similarly for wheel 5 and 6, at depth 2 let us say, what is sigma H and sigma H dash.

Similarly, for wheel 3, you can calculate what is sigma H and sigma H dash and we have also earlier calculated for the wheel 1 and 2 and at a depth 3.62 and 0.262. So, this is almost 4 times of 0.62 and 4 times of 2.62 at a depth 2 and if you calculate, you can obtain at a depth 2 about 3.844 that is, summation of sigma H and sigma H dash at depth of 2 meter. So, what will be the horizontal stresses, that is acting on the wall. So, for various depths 3 meter, you can sum up the sigma H plus sigma H dash, which will give 3.507.

Similarly for 4, when z is equal to 4, this summation will be 2.457, 5 1.585, 6 1.010, 7 0.654 and at depth 8, this will give 0.434. So, you can see that, with respect to the depth, this horizontal stresses it is initially, it is increasing and it reached to some maximum value and then we can see that, this value is decreasing. So now, on the right hand side then we can draw a plot a relationship between that, what should be the stress and what should be the depth.

So, this is the depth and this is the, what will be the lateral stress so you can substitute for the different values of the z and corresponding the stress. So, you can have 1 meter let us say, 1.954 then for 2 meter, which will give almost the maximum value 3.844 and then for 3 meter, you are having 3.507, 4 meter you can having 2.457, 5 meter you can have 1.585 and 6 meter, you can have 1.01, 7 meter 0.654 and 0.434. You can see, it is increasing and it reach to the maximum value and then it is decreasing that means, it can be observed that, after this depth 2 meter then lateral horizontal stress will be the maximum.

So, this maximum lateral horizontal forces pressure are to be considered into the design of the wheel load so this has to be added with the reinforce soil retaining wall and to calculate. Suppose, if you do not consider then there is a possibility for the bulging so we talk about that, what should be the pressure due to the wheel load and at what depth you can reach to the maximum value and then how it is decreasing. So, you can have some idea about the lateral pressure due to the wheel load now, we will discuss some design critiques.

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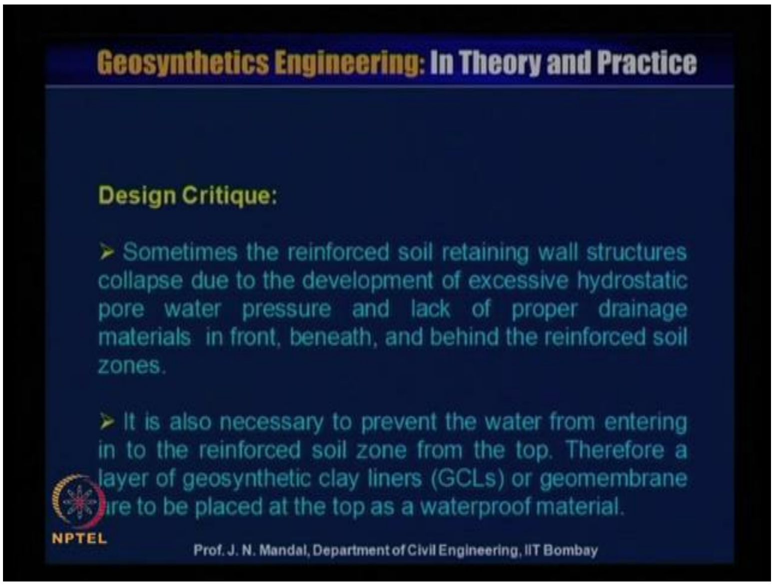

Sometimes the reinforced soil retaining wall structure collapse due to development of excessive hydrostatic pore water pressure and lack of proper drainage material in front, beneath and behind the reinforced soil zone. So, it is necessary to prevent the water from entering into the reinforced soil zone from the top. Therefore, a layer of geosynthetics clay liner or geomembrane are to be placed at the top, as a waterproof material. Apart from that, to prevent the excess pore water pressure, you need proper kind of the drainage system.

You should provide sufficient that, permeability of the material and at the same time, you require adequate transmissivity, which can fulfill the criteria for the proper kind of the drainage. You can provide even then with the geocomposite material, geonet or geotextile material at the back of the retaining wall for proper drainage.

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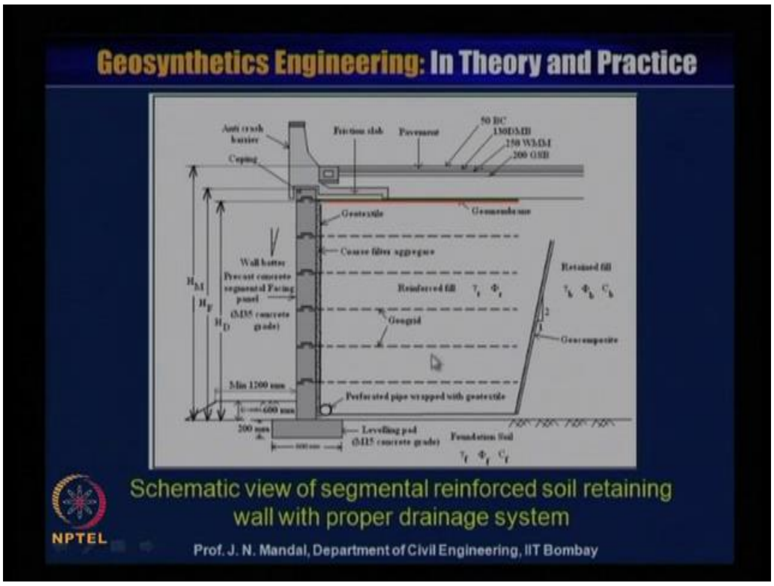

Now, here is one schematic view or segmental reinforced soil retaining wall with proper drainage system. So, this is the wall, this is the number of the layer of the reinforcement that is, geogrid material and at back, here providing with the proper kind of geocomposite drainage. And this is the reinforced fill back whose, unit weight is gamma b and angle of internal friction piping and cohesion is C b. This is the foundation soil with designated unit weight of foundation is gamma f, angle of internal friction of the soil is phi f and this cohesion value is C of f.

And this is the reinforced fill, whose angle of friction for reinforced zone is gamma r, angle of internal friction of reinforced soil zone is phi r, unit weight of soil in the reinforced zone is gamma r. And you are providing with the drainage material at the back of the retaining wall, you can provide geotextile, geocomposite or the aggregate and also at the top, you are providing with the geomembrane material. So, water cannot percolate from road to this so you are providing with the some design of the pavement here.

While you are 200 GSB or 150 WMM or 130 DBM or 50 BCC or you can provide with the geotextile material to reduce the thickness of the pavement and this is the frictional slab and this is the anticrash barrier to prevent any accident. So, you should provide with a anti crash barrier and this also you require for the design and this is the coping, here is the coping. And when you construct the wall, always you have to provide with a wall barrier that is, pre cast concrete segmental, this is spacing panel and you can with m 35 of concrete grade.

And also back, you should provide with the minimum of 1200 millimeter and you can make a slope and this is from this leveling part is should be about 600 millimeter. And this also, I have discussed earlier, this is about 600 millimeter, this is 200 millimeter that is, a leveling plug and toward M 15, that concrete grade you can use it. So, here is the H d, this is the in length and this is H f from here to W for the coping here and this is H f here, considering from the road. This height is about H of m and this near to the coping from this height is about H of f exile, so that excel program for mechanically stabilized reinforced soil one.

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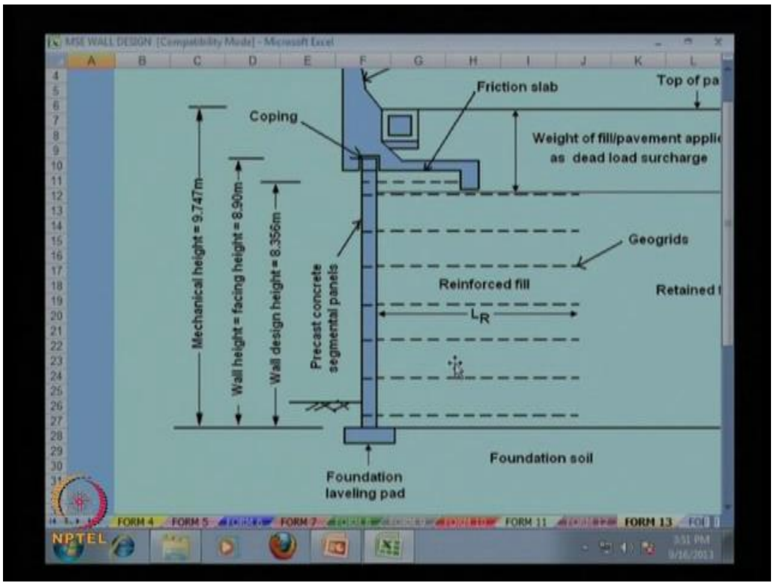

So, this is the figure, which I have also little bit shown you so this is the wall design height from here to here is about 8.356 meter. And this is the wall height that mean, facing length is about 8.90 meter and this is mechanical height that is, 9.747 meter so I talked about all this parameter here.

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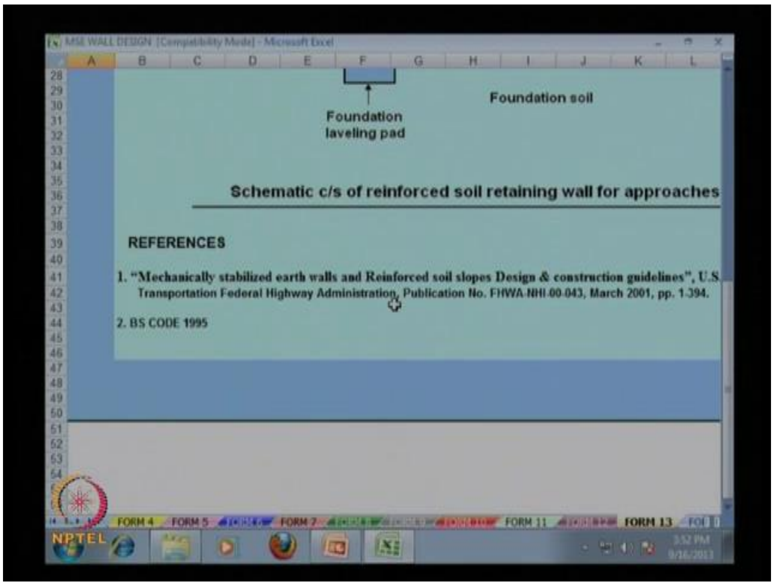

And then we used that mechanically stabilized earth wall reinforced soil slope for reinforced soil, this is US transport FHWA. And apart from that, we have also used that BS code here that is, 1995 that is reinforced soil, while that we have shown. So, we will follow this, these are the code, this code we will follow it then I will show you that, what should be the design input for this.

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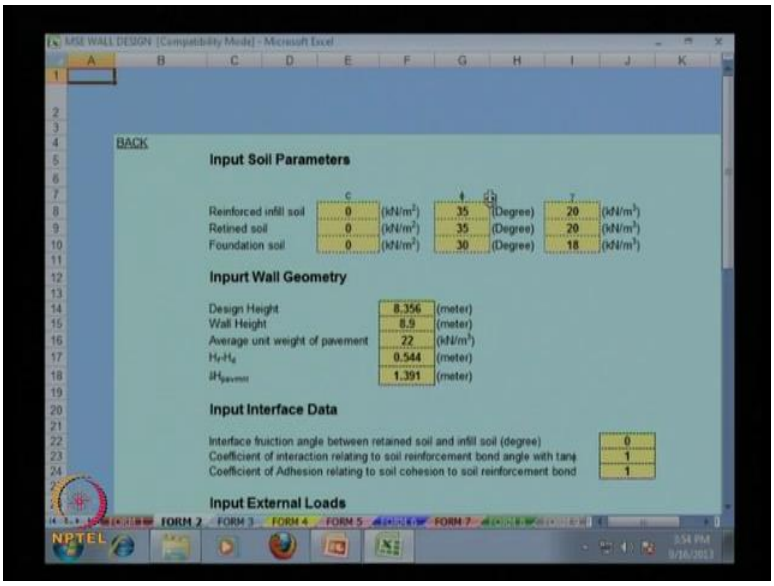

So, this is the input soil parameter and this is the reinforced infill soil that is, C and the retain soil and foundation soil. This C value you considering is 0 and for the phi value is for reinforced infill soil is 35 degree and retain soil 35 degree and foundation soil 30 degree. I have already explained that, what is the reinforced soil fill and what is the retain soil and also foundation soil. And gamma, unit weight of the reinforced fill is 20 kiloNewton per meter cube and the retain soil is 20 kiloNewton per meter cube and the unit weight of foundation soil gamma is 18 kiloNewton per meter cube.

Then, what will be the input wall geometry so input wall geometry, this design height I have shown that, that is 8.356 meter and wall height is 8.9 meter. And average unit weight of the pavement is 22 kiloNewton per meter cube and H f minus H d will be equal to 0.544 meter and this H of pavement is 1.391 meter.

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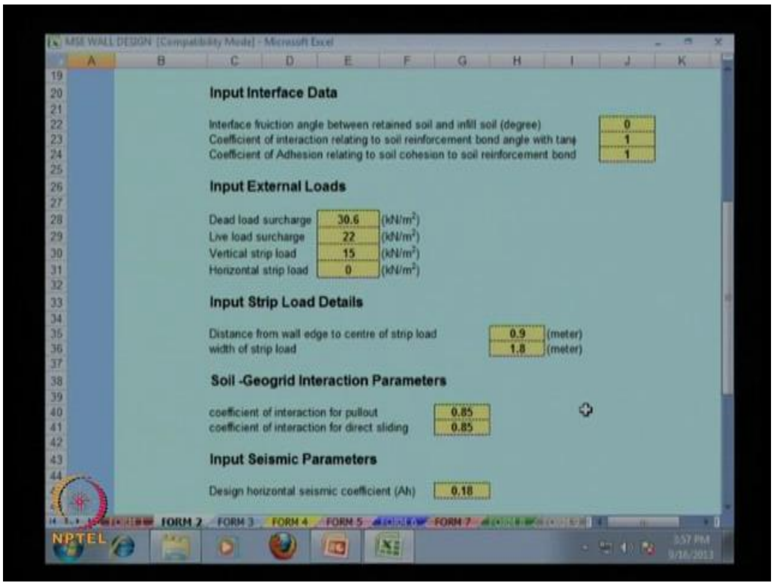

Now, input interface data so interface friction angle between the retain soil and infill soil is 0, coefficient of interaction relating to the soil reinforcement bond angle with tan phi is equal to 1, coefficient of adhesion retained to the soil cohesion to soil reinforcement bond is 1. Now, also you have to put input external load so design load surcharge is 30.6 kiloNewton per meter square, live load surcharge is 22 kiloNewton per meter square, vertical strip load is 15 kiloNewton per meter square and horizontal strip load is 0. Now, input strip load that is, here given in detail, distance from the wall edge to center of the strip load is 0.9 meter and width of the strip load is 1.8 meter.

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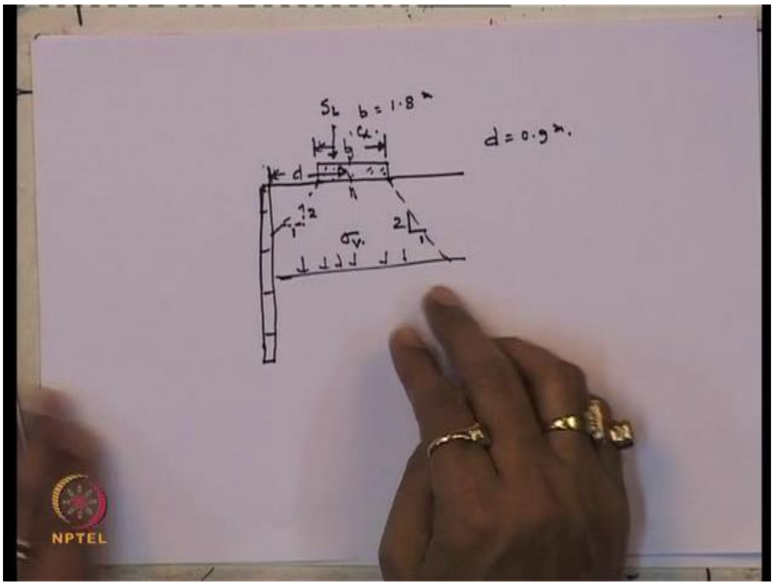

I am showing you that so it is like this and this is b and this b is 1.8 meter and this is the wall let us consider, this is the wall and this is dispersed with the slope horizontal to vertical is 1 is to 2 and similarly, this is also 2 vertical 1 horizontal. So, any strip 1 is the vertical stresses acting, this is sigma of V and this the center line and where, the strip load S L is acting. And from this center line to here, this distance is equal to that is d and this d is equal to 0.9 meter.

So, where it has shown distance from the wall edge to the center of the wall edge to the center of the strip putting is equal to 0.9 meter and width of the strip load, this is width of the strip load that is, b is equal to 1.8 meter. So, this is how, the disperse of vertical strip load through the reinforced soil, this is a kind of back weight method analysis.

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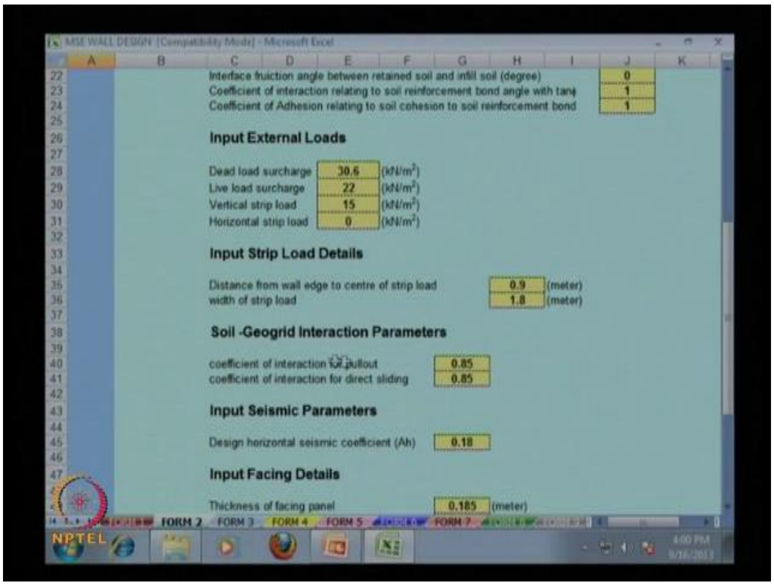

Now, apart from that, you have to add that, what will be the input soil geogrid interaction parameter. So, coefficient of interaction for pullout is 0.85, coefficient of interaction for direct sliding is equal to 0.85. Now, input seismic parameter so design horizontal seismic coefficient that is, A h is equal to 0.18 and input facing details that means, thickness of the facing panel that is, 0.185 meter. And unit weight of the facing panel is 25 kiloNewton per meter cube and depth of the ground water table below the ground level is about 10 meter. So, these are the parameter you have to take as a input soil parameter.

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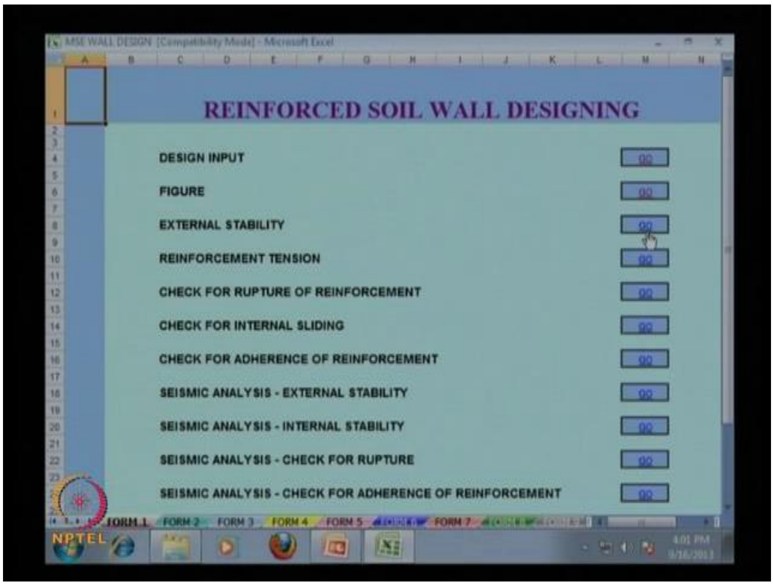

Now, we will calculate the external stability of the water.

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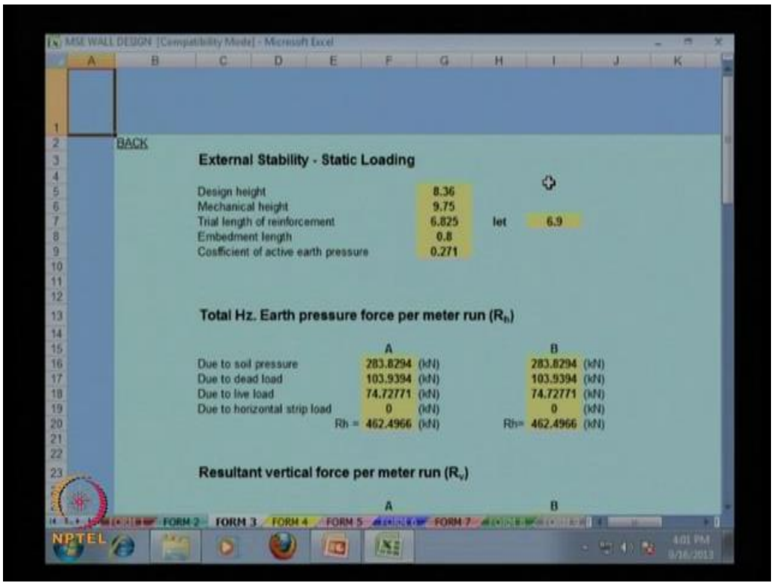

For external stability, first is the static loading, you know design height is equal to 8.36, mechanical height is equal to 9.75 and trial length of the reinforcement 6.825 or you consider at about 6.96 and embedment length is 0.8 and coefficient of active earth pressure is equal to 0.271. Now, what is total horizontal earth pressure force per meter run R h, you have to calculate what would be the total horizontal earth pressure force then due to soil pressure this is, 283.8294 kiloNewton.

So, you can calculate this, this pressure that is, you know what is K of A value that means, K of A value is known, you know the gamma value and you know the, what will be the height. So, you can calculate half K gamma H square and there are combined load, this is A and combined load this is B. So, combined load A, when it is the maximum value when all load are taken into consideration, into the design. This design has been made as per the British Standard Institute 1995 and this also combined load for the B where, it is due to the over turning load.

So, due to soil pressure, you have calculated for A this value, for B also this value, due to the dead load so this is having the dead load that means, you know what is K A and you know what will be the q D value and also you know the H value, also you have to consider that, some factor of safety. This factor of safety for the A and the B, for the various soil pressure, dead load or the live load so this is given in the BS code specification.

So, for this, this factor of safety is equal to 1.5 and for due to also soil pressure, this factor of safety 1.5. So, when you will do for the soil pressure A so what is half K gamma H square into 1.5 you have to multiply. Similarly, for soil B 1.5, sometimes this give also the depend factor safety value for the combined load A as well as combined load B. Similarly, for the dead load, you can have 103.9394 and for B, 103.9394 and due to the live load, this is 74.727, that is live load is K into q into A.

And also, you have to multiply that factor of safety for A, 1.5 similarly, for B also, 1.5 and due to the horizontal strip load, this is 0. So, you can calculate, what will be the total horizontal earth pressure force per meter run so you can R h is total for A, 462.4966 and for B, total horizontal earth pressure force per meter run R h is equal to 462.4966. Now, next, we will discuss resultant vertical force per meter run an R v.

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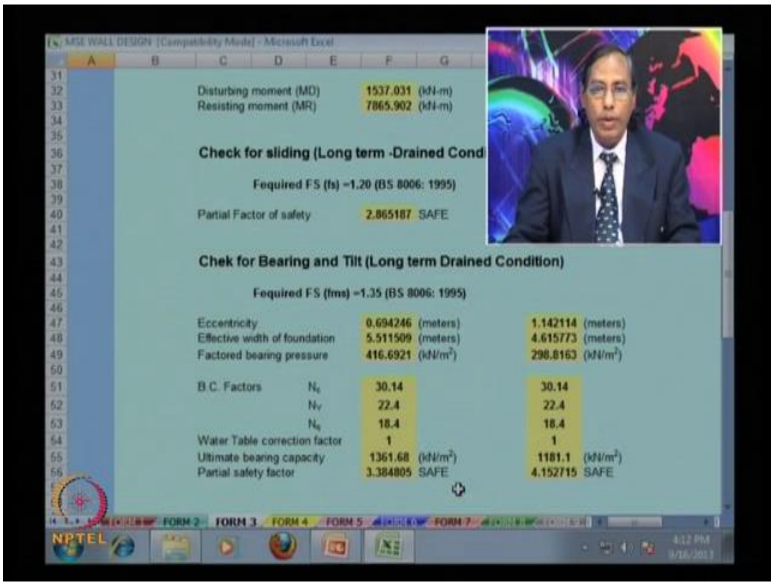

That also for combined load A and combined load B now, due to the weight of the fill for A so you can calculate that, what will be the weight of the fill. You know that, a reinforced soil wall, which has a height capital H, L is equal to length of the reinforcement and gamma is equal to unit weight of the reinforced soil. So, weight will be equal to gamma into H into L so you know, what is the gamma for the reinforced soil zone, you know what will be the height of the wall is given, you know what will be the length of the reinforcement.

So, you can calculate that, what will be the weight of the fill and at the same time, as far combined load A, what will be the factor of safety so factor of safety is 1.5. So, you have to multiply that gamma into H into L into factor of safety 1.5 so you can obtain 1729.692. Similarly, for the combined load B, you can calculate, you can have 1153.128 so there may be variation of the factor of safety as per BS code specification. So, due to the surcharged load, you can also calculate that, what will be the combined load A.

That is, is equal to you know that, what will be the L, you know what will be the dead load q D, you know what will be the surcharged load plus q L into that factor of safety 1.5. So, this will give 22.5, sometimes this will give 1 then this will give B, it will give 15 and due to the inclined soil pressure, this is 0 and this is 0. So, resultant vertical pressure, you can have R v is equal to 2296.602 and for R v 1379.268 kiloNewton. Now, you calculate the disturbing moment MD so you know that so we calculated resultant R v pressure and we calculated the R of v.

So, disturbing moment M D is equal to 1537.031 for A and for B, 1537.031 and resulting moment M R is 7865.902 this is on kiloNewton meter and 4720.225 kiloNewton per meter for B. Now, check for the sliding that is, long term drainage condition so you require factor of safety is 1.20 as per BS 8006 1995, so partial factor of safety is equal to 2.865187. If it is then it is safe and for case of B, it is 1.720743 means, it is safe. Check for the bearing and tilt, this is a long term drainage condition so you require F require factor of safety is 1.35 as per BS 8006 1995.

Now, as per mere distribution, you can calculate the eccentricity and that is, 0.69246 meter for A, and 1.42114 meter for B. So, effective width of the foundation, this is 5.511509 and for B, 4.615773 you know the, what is the effective width, L minus 2 of e. A factored bearing capacity pressure in case A, it is 416.6921 this is kiloNewton per meter square and for B, 298.8163 kiloNewton per meter square. Now, you know that, what is bearing capacity factor, N c value 30.14 or N gamma 22.4, N q 18.4 and water table correction factor is equal to 1 for A.

And similarly for B, this is eccentricity 1.142, N c factor will be 30.14, N gamma is 22.4 and N of q is 18.4 and the water table correction factor is 1. So, you can calculate, what will be the ultimate bearing capacity that is, 1361.68 kiloNewton per meter square for A and 1181.1 kiloNewton per meter square for B. So, you can check that, what will be the partial factor of safety that is, for A 3.384805 so it is safe and for B, it is 4.152715 so it is the safe. So, you know what will be the factor of safety for A and B so if satisfied this criteria, bearing capacity for criteria, it satisfy the moment criteria. So, it is the safe design.

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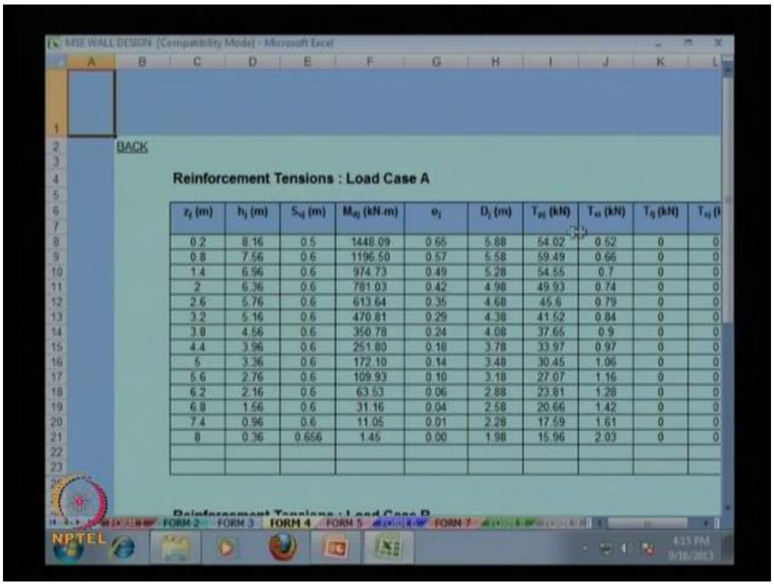

z_j (m)	h_j (m)	S_{vj} (m)	M_{dj} (kN.m)	e_j	D_j (m)	T_{pj} (kN)	T_{sj} (kN)	T_{fj} (kN)	T_{rj} (
0.2	8.16	0.5	1448.09	0.65	5.88	54.02	0.52	0	0
0.8	7.56	0.6	1196.50	0.57	5.58	59.49	0.66	0	0
1.4	6.96	0.6	974.73	0.49	5.28	54.55	0.7	0	0
2	6.36	0.6	781.03	0.42	4.98	49.93	0.74	0	0
2.6	5.76	0.6	613.64	0.35	4.68	45.6	0.79	0	0
3.2	5.16	0.6	470.81	0.29	4.38	41.52	0.84	0	0
3.8	4.56	0.6	350.78	0.24	4.08	37.65	0.9	0	0
4.4	3.96	0.6	251.80	0.18	3.78	33.97	0.97	0	0
5	3.36	0.6	172.10	0.14	3.48	30.45	1.06	0	0
5.6	2.76	0.6	109.93	0.10	3.18	27.07	1.16	0	0
6.2	2.16	0.6	63.53	0.06	2.88	23.81	1.28	0	0
6.8	1.56	0.6	31.16	0.04	2.58	20.66	1.42	0	0
7.4	0.96	0.6	11.05	0.01	2.28	17.59	1.61	0	0
8	0.36	0.656	1.45	0.00	1.98	15.96	2.03	0	0

So, here you are showing reinforcement tension for load case A, here is the z i is the depth from the top of the soil that is, 0.2 then 0.8 and 0.6, 1.4 like this, it goes upto 8 meter. Now, this is h of j, that is equal to you know, the h minus this z j so h minus z j, it will give 8.16. So, this is the S v j that is, spacing between the two reinforcement so here it is 0.5 and then we are keeping constant, the spacing about 0.6 and at z 8 is 0.656. So, almost we are keeping the spacing constant, almost 0.6 meter.

Here, M d j, what is the driving moment, you can calculate for various depth so you will obtain this different value and driving moment value is, you can see gradually it is the decreasing. Then it is the e of j that is, the eccentricity of resultant vertical load at the j th level in the wall. So, you can calculate, what is the eccentricity for bearing depth and D of i in meter that is, a function of S j b and d, I have already explained, what is h j is and the b also strip of the putting and d the…

So, you can calculate D j at various depth and here is the T p j that is, tensile force per meter run, this is a tensile force per meter run. Then T s j that is, the tensile force due to the vertical load, so this what you can calculate. And next is T f j that is, T f j is the shear force develop due to the horizontal shear, so shear force due to horizontal shear is 0 here.

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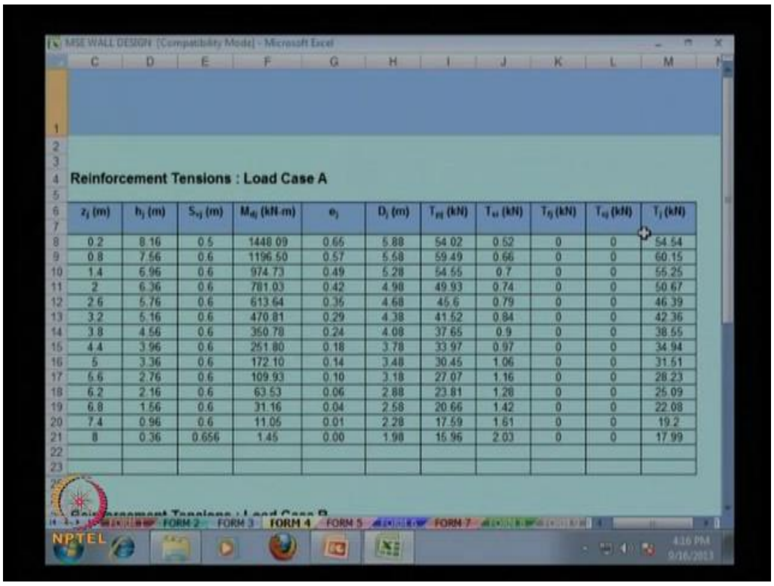
Reinforcement Tensions : Load Case A

z_i (m)	h_j (m)	S_{vj} (m)	M_{dj} (kN-m)	e_j	D_j (m)	T_{pj} (kN)	T_{sj} (kN)	T_{fj} (kN)	T_{cj} (kN)	T_j (kN)
0.2	8.16	0.5	1448.09	0.65	5.88	54.02	0.52	0	0	54.54
0.8	7.56	0.6	1196.50	0.57	5.58	59.49	0.66	0	0	60.15
1.4	6.96	0.6	974.73	0.49	5.28	54.55	0.7	0	0	55.25
2	6.36	0.6	781.03	0.42	4.98	49.93	0.74	0	0	50.67
2.6	5.76	0.6	613.64	0.35	4.68	45.6	0.79	0	0	46.39
3.2	5.16	0.6	470.81	0.29	4.38	41.52	0.84	0	0	42.36
3.8	4.56	0.6	350.78	0.24	4.08	37.65	0.9	0	0	38.55
4.4	3.96	0.6	251.80	0.18	3.78	33.97	0.97	0	0	34.94
5	3.36	0.6	172.10	0.14	3.48	30.45	1.06	0	0	31.51
5.6	2.76	0.6	109.93	0.10	3.18	27.07	1.16	0	0	28.23
6.2	2.16	0.6	63.53	0.06	2.88	23.81	1.28	0	0	25.09
6.8	1.56	0.6	31.16	0.04	2.58	20.66	1.42	0	0	22.08
7.4	0.96	0.6	11.05	0.01	2.28	17.59	1.61	0	0	19.2
8	0.36	0.656	1.45	0.00	1.98	15.96	2.03	0	0	17.99

And then is the T c j and that is the tension due to cohesion, and which we consider as a 0 so you can calculate, what is T j that mean, tensile force that is, total tensile force so you can calculate the total tensile force. So, for the load case A so total tensile force has different depth, you can calculate so this is 64.54, 60.15 and then 55.25, 50.67, 46.39, 42.36, 38.55, 34.94, 31.51, 28.23, 26.09, 22.08 and 19.2 and 17.99. You can see that, how the forces are decreasing, reinforcement tension force is decreasing so this table shown the reinforcement tension for load case A.

Similarly, you can check that, what will be the rupture of the reinforcement so required factor safety for the rupture of reinforcement is 1.1, this as per BS 8006 1995. The same this is z i, this is z i is the same and this is the spacing is the same and you can calculate here, you have been shown for case A and the case B, this is T j and T j. So, you can calculate T j for this, for different depth similarly, for case B, it has been calculated and shown here.

Then, what should be the reinforcement property then ultimately you can have the tensile strength, ultimate tensile strength of geogrid material 150 then 120, 100, 80 and the 60. So, you can distribute the strength and then you can find out the reinforcement property and you can see, you can calculate what will be the factors, this is 2113 and what will be the design tensile strength. So, you can calculate that, what will be the factor of safety, you know this is the design strength value.

And then for case A and B, this is for PSF that is, provided factor of safety for case A so this will be you have calculated, what will be the T of D for the design is known and T j what is the requirement. So, provided factor of safety for case A will be equal to the T d design divided by T j require. So, if you divide this then you can have 1.30. So, like this for case A, you can calculate what should be the provided factor of safety. Similarly, for the case B, you know what will be the T d design, you know what will be T j require and then you can find out what will be the provided factor of safety for case B.

So, this way, you can calculate and you can see, as for the code specification it is 1.1 so it is satisfying all the criteria, either in the case of A or in the case of B. So, this is the part that, which I showed you that, what will be the check for the rupture of the reinforcement, what will be the required factor of safety. So, it is the safe so for any length or any height so you can design with this excel program. With this, I finish this today's lecture, any question.

Thank you for listening.