Geo synthetics Engineering: in Theory and Practices
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Lecture - 32
Geosynthetics for Reinforced Soil Retaining Walls

Dear student warm welcome to NPTEL phase 2 video course on Geosynthetics Engineering in Theory and Practice, this lecture number 32, my name is Professor J. N Mandal, Department of Civil Engineering, Indian Institute of Technology, Bombay, Mumbai, India. Name of the course Geo synthetics Engineering in Theory and Practice this is module 6, lecture 32 Geo synthetics for Reinforced Soil Retaining Wall.

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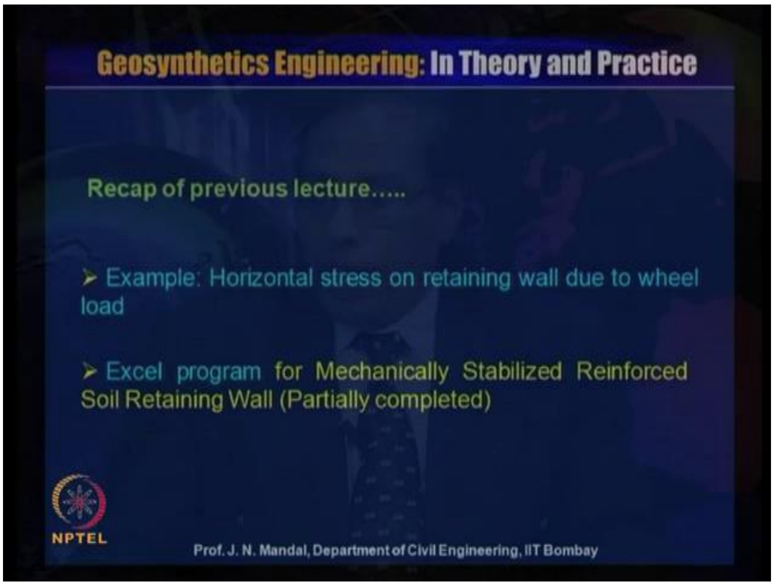

This recap of previous lecture, we give example of horizontal stress on the retaining wall due to the wheel load. And also we showed the relationship between the horizontal stress with the depth, now excel program for mechanically stabilized reinforced soil retaining wall, we partly completed. Now, I will tell you about check for the adherence of the reinforcement.

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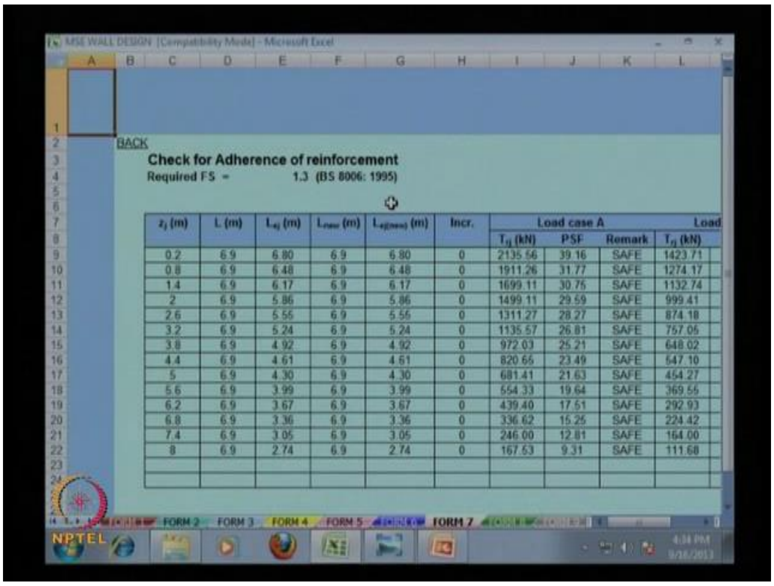

Check for adherence for reinforcement here, required factor of safety is 1.3 as per BS 8006, 1995. And this is the Z j for different depth and this is the L, length of the reinforcement that is 6.9 metre, it is safe all along the depth. And this is the L of g embedment length this 6.80, 6.48 and then continue up to the Z j is 8 metre, 2.74 this embedment length value is more on the top and then gradually it is decreasing it is like a failure surface, you know then what should be the length of the embedment length.

Then you know that L of new will be equal to 6.9 the safe as L we are keeping. And then L is a new which is 6.80, 6.48, 6.17, 5.86, 5.55, 5.24, 4.92, 4.61, 4.30, 3.99, 3.67, 3.36 and 3.05 and 2.74 and Incr is 0, so here for load case A and this B. So, here load case A what is the T r g, so you can calculate T r j 2135.56 and this is the safety factor for load case A, see this is 39.16 and then gradually this factor, partial of safety factor is decreasing and it is about 9.31.

So, it satisfy the criteria as per BS code specification, so it is safe for load case A. For load case B, you can also calculate the T r j, so this is the T r j value and then you can calculate the partial safety factor that is from 36.67 and it is gradually decreasing to 30.83 and which is as per code it is 1.3. So, it satisfy this criteria, so it is also the safe. So, due to pull out that here is reinforcement is satisfying these criteria.

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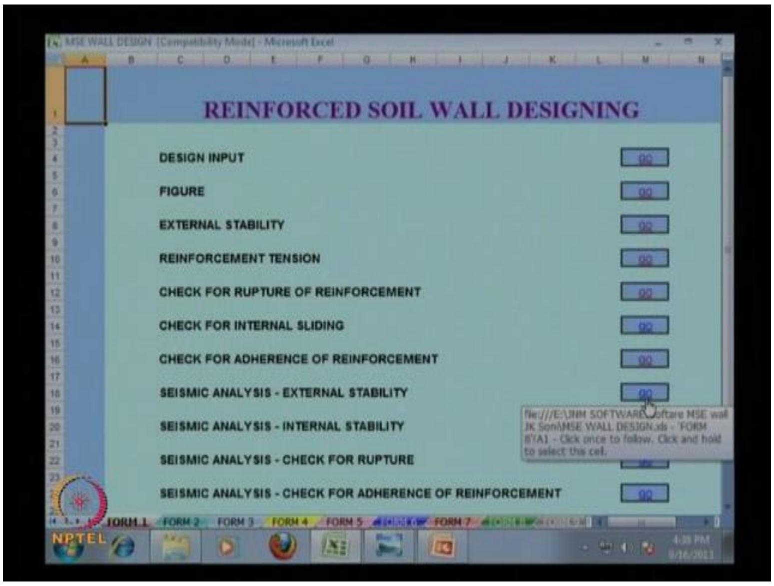

Now, seismic analysis for external stability.

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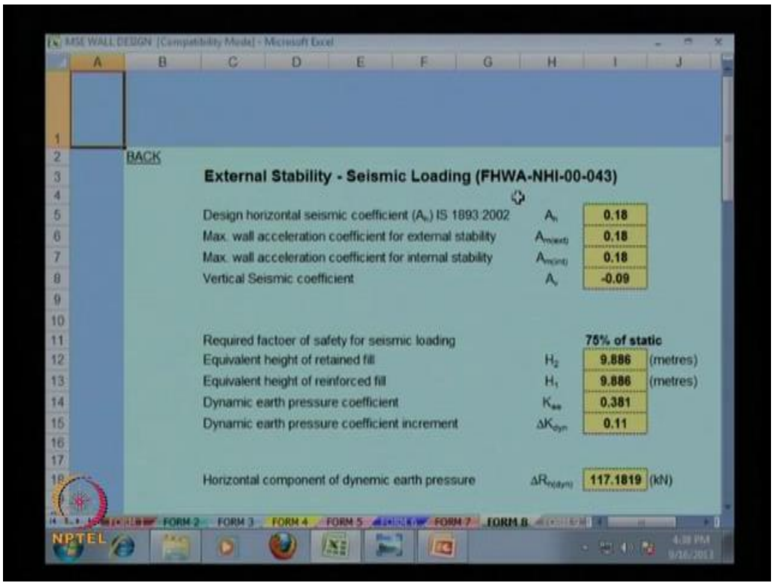

So, for external stability, seismic loading as per FHWA NH1- 00-043. So, it is a design of horizontal seismic coefficient A h as well IS 1893, 2002 we are taking A's value a 0.18. And maximum wall acceleration coefficient for external stability that is A and external is 0.18, maximum wall access and coefficient for internal stability that is A h, A m internal is 0.18 and vertical seismic coefficient A v is minus 0.09.

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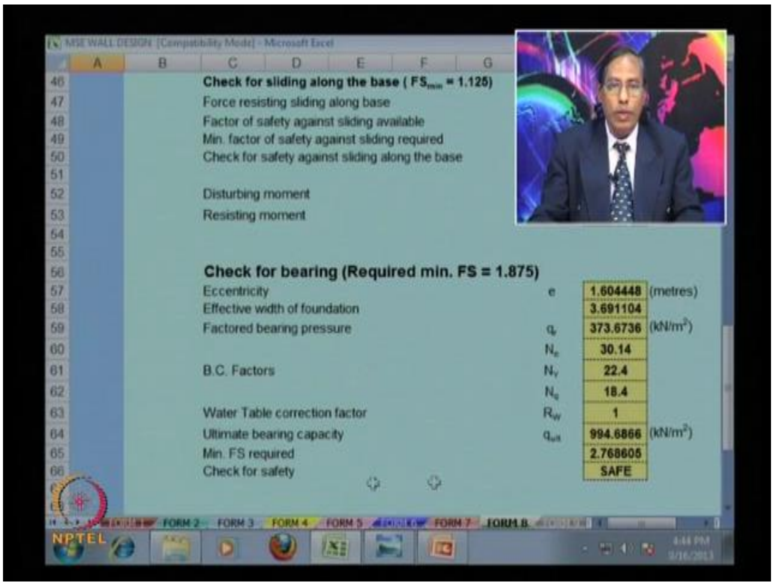

Now, required factor of safety for seismic loading, this is come about 75 percentage of the static value. Equivalent height of the retaining fill H 2 is 9.886 metre and equivalent height of reinforced field H 1 is 9.886 metre, dynamic earth pressure coefficient K a e is 0.381 and dynamic earth pressure coefficient increment, that is delta of K dynamic is equal to 0.11.

Now, horizontal component of dynamic earth pressure that is delta R h dynamic is equal to 117.1819 kilo Newton. Calculation of inertia force per meter run, due to the mass of facing block that is F h 1 R f e is 8.076083, due to the mass of the crash barrier I have told about the crash barrier in the beginning. So, this is F h 1 r c b is equal to 2.943, due to the fill and surcharge load that is F h 1 r s q is equal to 191.7521 and total H z inertia force that is delta R h l r is equal to 202.7712.

Now, horizontal force for static loading per metre run, due to the soil pressure 189.2196, due to the dead load surcharge 69.29297 and due to horizontal strip load you consider 0, total horizontal static force that is R h static is 258.5126. So, total resultant force horizontal R h is 519.8747 kilo Newton, total horizontal force per meter run, due to the weight of the field that is 1153.128 kilo Newton, due to the surcharge load 211.14 kilo Newton and due to the vertical strip load which is given 15 kilo Newton and due to inclined of soil pressure it is 0.

So, total resultant vertical force R b is equal to 1379.268 kilo Newton, check for the sliding along the base. And assuming factor of safety minimum 1.125, force resisting the sliding along the base 796.8327, factor of safety against the sliding available 1.530816. So, minimum factor of safety against the sliding required 1.125, so therefore, check for the safety against the sliding along the base, so you find safety along the base is safe.

Now, disturbing moment M D is 2174.714 kilo Newton metre and resisting moment 4720.225. So, check for the bearing capacity required that is minimum 1.875, eccentricity e is 1.604448 meter and effective width of the foundation is 3.691104. Then factor of bearing pressure is 373.6736 kilo Newton per meter square, we know that bearing capacity factor that is N c is equal to 30.14, in gamma 22.4, N q 18.4 and water table correction factor R w is equal to 1 and ultimate bearing capacity that is q ultimate 994.6866 kilo Newton per metre square.

So, minimum factor of safety required is 2.768605, so check for the safety, so you check it is the safe. Check for the eccentricity, eccentricity e is equal to 1.604448 metre, so allowable eccentricity e allowable 2.3 metre, check for the eccentricity also is the safe. So, you check that eccentricity and you find it is the safe.

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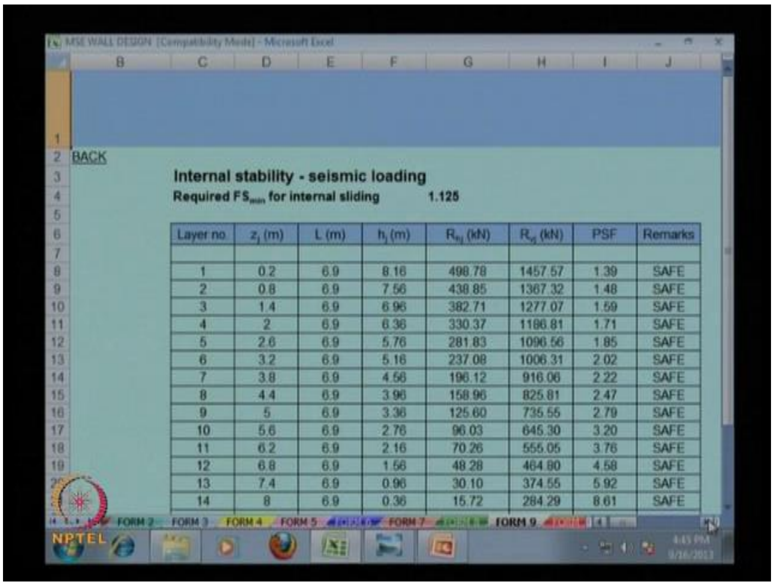

Layer no	z_j (m)	L (m)	h_j (m)	R_{hj} (kN)	R_{sj} (kN)	PSF	Remarks
1	0.2	6.9	8.16	498.78	1457.57	1.39	SAFE
2	0.8	6.9	7.56	438.85	1367.32	1.48	SAFE
3	1.4	6.9	6.96	382.71	1277.07	1.59	SAFE
4	2	6.9	6.36	330.37	1186.81	1.71	SAFE
5	2.6	6.9	5.76	281.83	1096.56	1.85	SAFE
6	3.2	6.9	5.16	237.08	1006.31	2.02	SAFE
7	3.8	6.9	4.56	196.12	916.06	2.22	SAFE
8	4.4	6.9	3.96	158.96	825.81	2.47	SAFE
9	5	6.9	3.36	125.60	735.55	2.79	SAFE
10	5.6	6.9	2.76	96.03	645.30	3.20	SAFE
11	6.2	6.9	2.16	70.26	555.05	3.76	SAFE
12	6.8	6.9	1.56	48.28	464.80	4.58	SAFE
13	7.4	6.9	0.96	30.10	374.55	5.92	SAFE
14	8	6.9	0.36	15.72	284.29	8.61	SAFE

Now, we will discuss seismic analysis for internal stability. So, internal stability for seismic loading required factor of safety minimum for internal sliding is 1.125. So, this is layer 1, 2, 3, 4 up to 14 layer and Z i is 0.2 metre to 8 metre. So, this is the length of the reinforcement 6.9, it is constant throughout the depth and h j 8.16 to 0.36 R h j is kilo Newton 498.78 and then it is gradually decreasing to 15.72 kilo Newton and R v j is kilo Newton 1457.57 to it is to 284.29.

Then, you check that what will be the partial safety factor it is 1.39 and 1.48, 1.79 and this you calculated the partial safety factor, you know what will be the t d design divided by what is the t j that what is required. So, you can calculate this factor of safety. So, you can see that with the satisfying the criteria as per the BS code specification. So, that is why it is the safe, so all these factor of safety is the safe now the seismic analysis check for the rupture.

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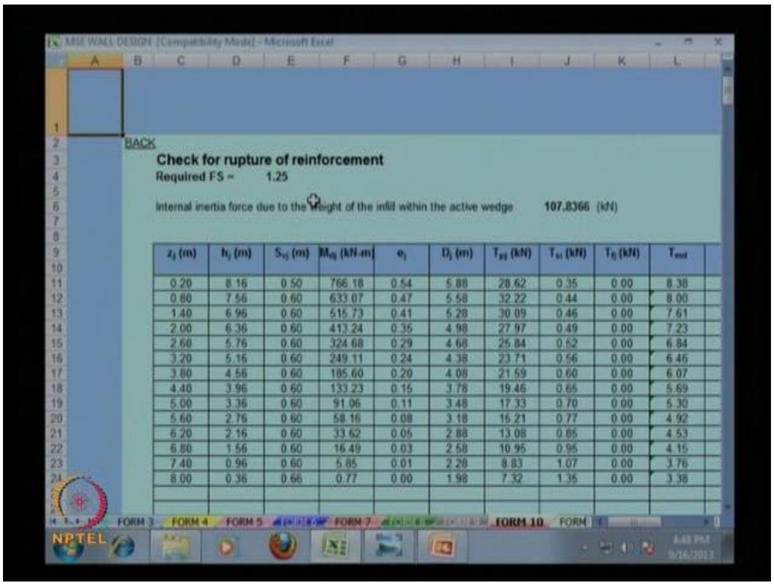
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Check for rupture of reinforcement

Required FS = 1.25

Internal inertia force due to the weight of the infill within the active wedge 107.8366 (kN)

z_i (m)	h_j (m)	S_{vj} (m)	M_{dj} (kN-m)	e_j	D_j (m)	T_{pj} (kN)	T_{si} (kN)	T_{fj} (kN)	T_{md}
0.20	8.16	0.50	766.18	0.54	5.88	28.62	0.35	0.00	8.38
0.80	7.56	0.60	633.07	0.47	5.58	32.22	0.44	0.00	8.00
1.40	6.96	0.60	515.73	0.41	5.28	30.09	0.46	0.00	7.61
2.00	6.36	0.60	413.24	0.35	4.98	27.97	0.49	0.00	7.23
2.60	5.76	0.60	324.68	0.29	4.68	25.84	0.52	0.00	6.84
3.20	5.16	0.60	249.11	0.24	4.38	23.71	0.56	0.00	6.46
3.80	4.56	0.60	185.60	0.20	4.08	21.59	0.60	0.00	6.07
4.40	3.96	0.60	133.23	0.15	3.78	19.46	0.65	0.00	5.69
5.00	3.36	0.60	91.06	0.11	3.48	17.33	0.70	0.00	5.30
5.60	2.76	0.60	58.16	0.08	3.18	16.21	0.77	0.00	4.92
6.20	2.16	0.60	33.62	0.05	2.88	13.08	0.85	0.00	4.53
6.80	1.56	0.60	16.49	0.03	2.58	10.95	0.95	0.00	4.15
7.40	0.96	0.60	5.85	0.01	2.28	8.83	1.07	0.00	3.76
8.00	0.36	0.66	0.77	0.00	1.98	7.32	1.35	0.00	3.38

So, you have checked for the rupture of the reinforcement and it is required factor of safety 1.25, this internal inertia force due to the weight of the infill within the active wedge is 107.8366 kilo Newton. So, this is the z i up to 8 meter, this is h j 8.16 the safe 3.6, this is S v j that is the spacing 0.50 and then 0.6 is constant and this is 0.66. Then what will be the M d j this 766.18 and then gradually decreasing to depth of 0.77, then eccentricity 0.54 then it is almost it is 0 here. And this is the D j I explained all the earlier this is 6.88 to 1.96 and this is T p j that is 28.62 to is decreasing up to 7.32.

And then this is the T s i this kilo Newton 0.36, 0.44 and then it is up to 1.35 at deep there and this is the T f j which is the 0 and this is the what is that T required that is 8.36 and this going down to 3, this is 3, this is 3.38. And then T s j also it is the 0, T j is 37.35

and then it is decreasing up to 12.05, T of d j 70.99 and then it is decreasing up to 28.40 and this is what you safety factor, partial safety factor this is 1.90, 1.75 you see 1.61, 14 and 2.65. So, you can see that it satisfy this, criteria as per the BS code specification. So, it is safe.

So, we find that due to the rupture of the reinforcement that our required factor is 1.25 and it is satisfying this factor of safety. So, due to the rupture of the reinforcement this design is safe. Now, you will go seismic analysis check for adherence of the reinforcement.

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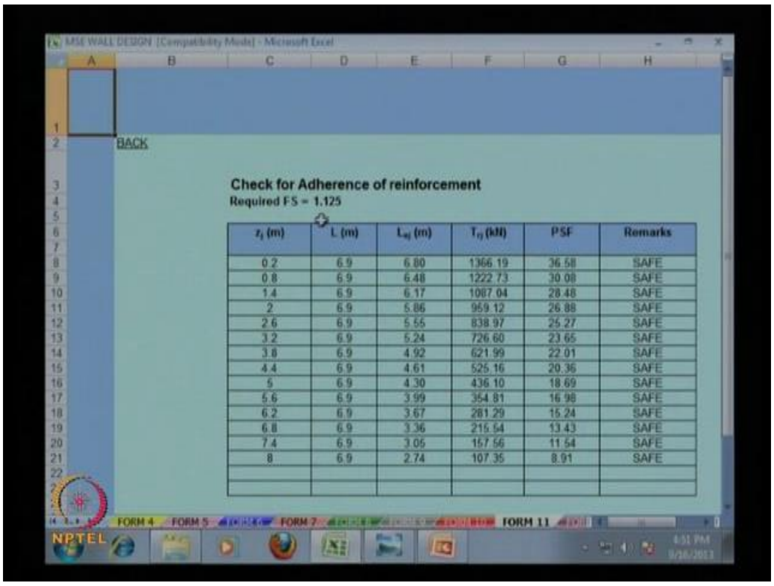

Now, check for the adherence or reinforcement required factor of safety 1.125 this is z j this 0.228, this you know length is 6.9 constant and this is L e j 6.80, 2.74. Then again T r j kilo Newton is 1366.19 and decreasing to 107.36 and then this is the partial safety factor 36.58 and it is decreasing to 8.91. So, your requirement is 1.125, so it is the safe. So, safe for the adherence of reinforcement is also safe.

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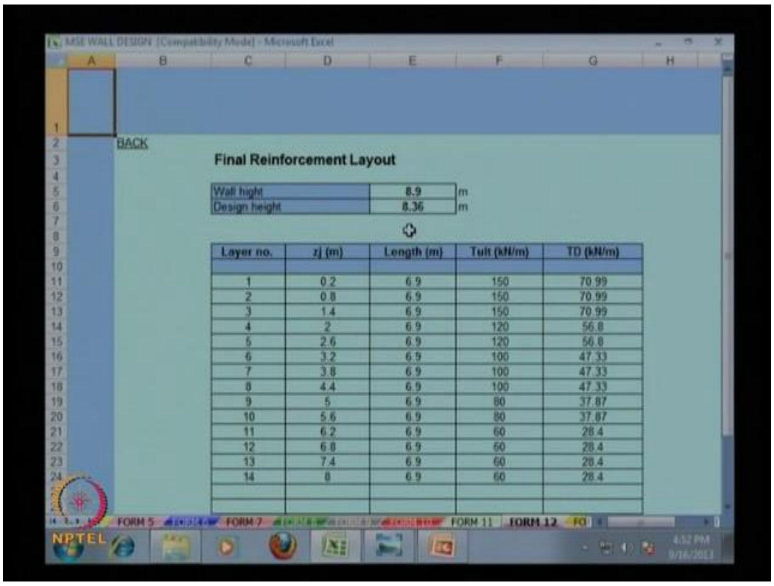

Now, here I will show the final reinforcement layout, wall height is 8.9 metre, design height is 8.36 meter and this is the layer, this is 1 to 14 layer and this is z j is 0.2, 0.6 like this, this is point I can say the 0.6 metre spacing or vertical spacing between the 2 reinforcement, almost 0.66 in this zone. Then length of the reinforcement is constant throughout that is 6.9 meter and T ultimate is kilo Newton 150 then 120 then 100 then 80 and then 60.

And TD is kilo Newton per metre is 70.99, then again 56.8, 47.33, 37.87 and 28.4. So, you can see that what should be the layout of this that final reinforcement layout what should be the spacing and what should be the length of the reinforcement. Now, you check for the connection strength, this is very important sometimes due to the connection the reinforcement soil structure fail.

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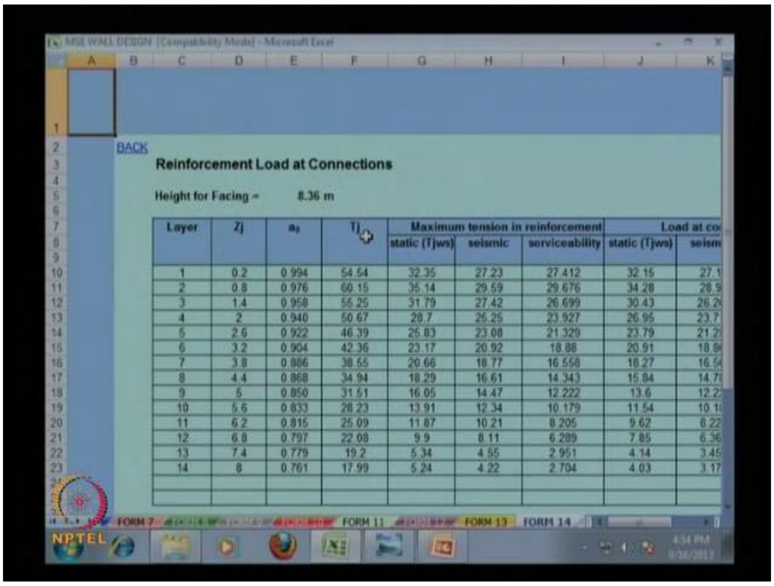

So, reinforcement load at the connection height of the facing is 8.36 metre, this is the 1 to 14 layer this is z j is 0.2 to this is 8 and this is a 0 is 0.994 to 0.761, T j is 64.64 to 17.99. So, this is the maximum tension in the reinforcement that is in static that is T j w s that is 32.36 is decreasing up to 5.24, but when it is a seismic case, it is lesser than the static case that is 27.23 to 4.22. Then serviceability what is required 27.41 to 2.704 that is the serviceability.

Now, know that connection this is talk about maximum tension in the reinforcement either in the static and seismic and what is serviceability? Now, load at the connection the static T w s 32.16 to 4.03 and in the seismic it is 27.1 to 3.17 and serviceability requirement 27.25 to 2.08. So, we check this, what should be the reinforcement, load connection and we find it is the on the safer side.

And now, almost we complete the design, but the here also this is check for the internal sliding, the required factor of safety 1.3 as per BS 8006, 1995 the reinforcement layout detailed here this is 1 to 14 and z value 0.2 to 8, this L is 6.9 is constant, h j is 8.16 to 0.36 and R h kilo Newton 444.15 to decreasing up to 8.22 and R v is kilo Newton 225603 to 641.43 for the load case A and this is the partial of safety factor, this is 3.02 and increasing up to 46.42. So, your requirement is 1.3, so it satisfy the criteria, so it is on the safer side.

Now, this is for load case B and this R h j is 4.15 to 8.22 and R v j is kilo Newton 1352.22 to 275.82 and then you calculate what will be the PSF Partial of Safety Factor 1.81 to 19.92, so this also safe, because it satisfy the criteria as per the BS code specification.

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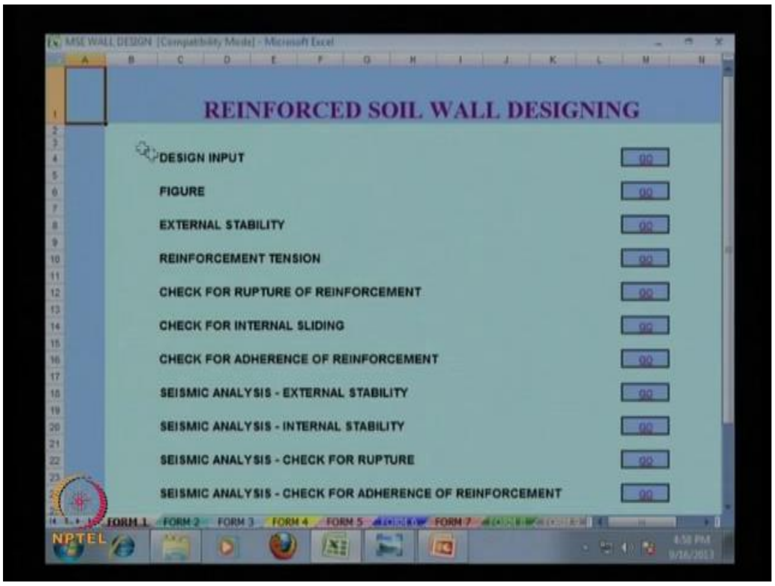

So, we almost complete this design for the reinforced soil this retaining wall. So, there are numerous computer program is available from the manufacturer for their specific product. And also this is a kind of generic program that are commercially available and it can be observed that geo grid manufacturer have developed, the different types of the design, chart, algorithm and also the graph. For the specific product it is very good and we should consider this as a guideline.

But, you have to remember that design should not be based on the product, but design should be site specific. So, you should know what will be the site and based on that you should design because every times that there will be the change of the design because for various factor that initially when, the seismic force also are not taken into consideration, also sometimes the connecting strength also not been taken into consideration. So, always you should update this program and you should adopt the design, which should be the latest design program. So, design should be based on the site specific.

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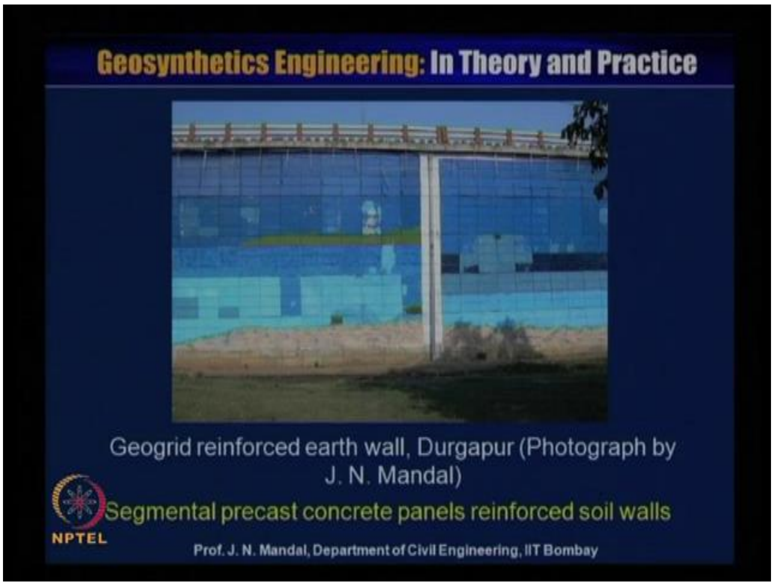

So, here some geo grid reinforced earth wall and this is wall is panel has been used and this the first time in India about 50 meter height geo grid reinforced soil wall. And here, this local fly as has been used, this is the one first the geo grid reinforced soil retaining wall, where the huge amount of the fliers has been used.

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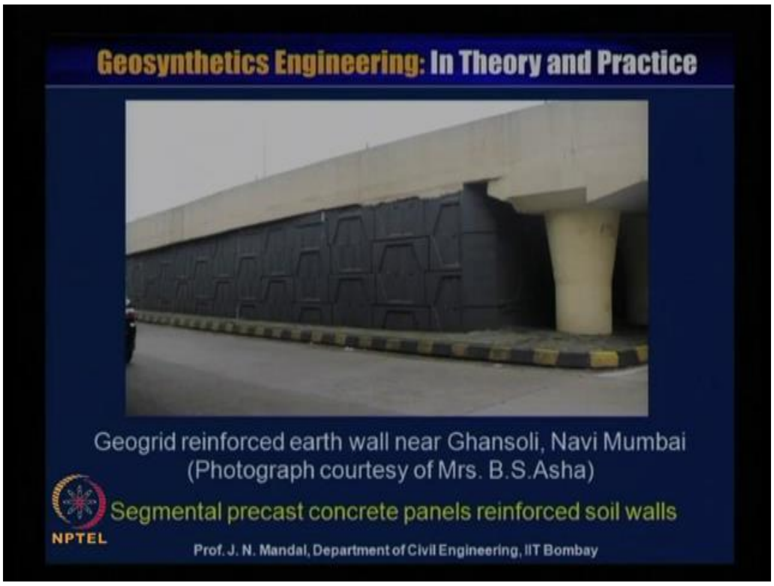

This is another segmental precast concrete panel reinforced soil wall, this geo grid reinforced soil wall in ghansoli in navi Mumbai, courtesy to doctor asha.

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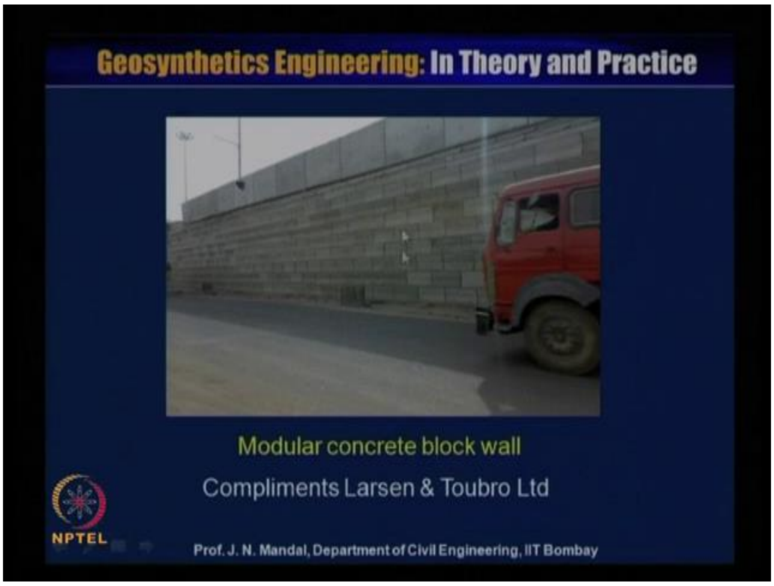

This is modular block, concrete block. We can see that facing element is the different type and this is complement to the Larsen and toubro limited, this is also geo grid material has been used.

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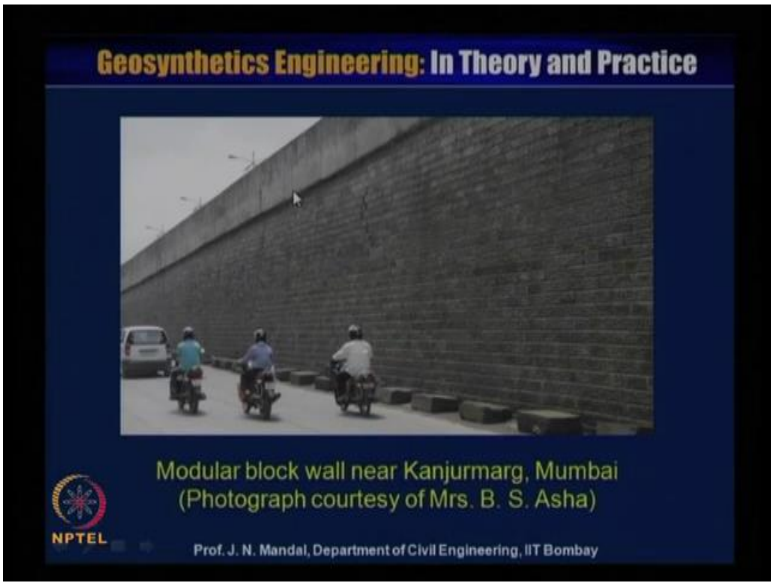

Here, modular block wall in kanjurmarg and this photograph courtesy to doctor asha.

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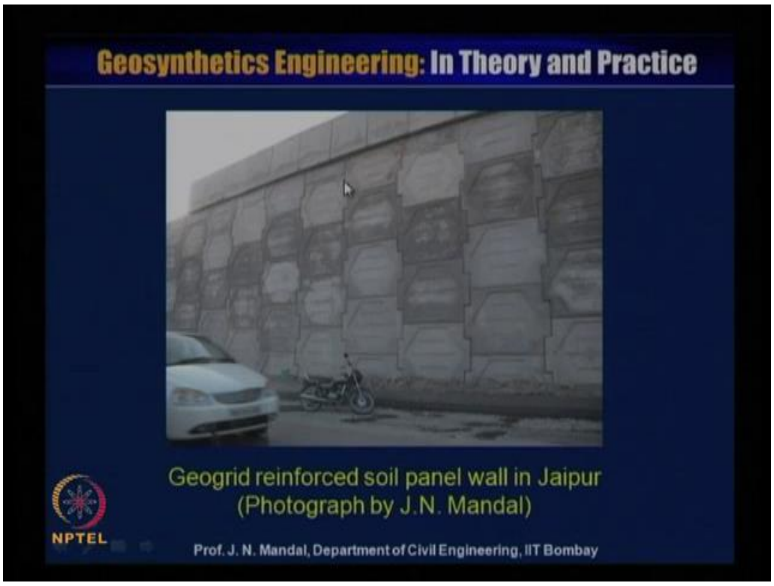

Here, geo grid reinforced soil panel wall in the jaipur it has been used, you can see different types of the panel.

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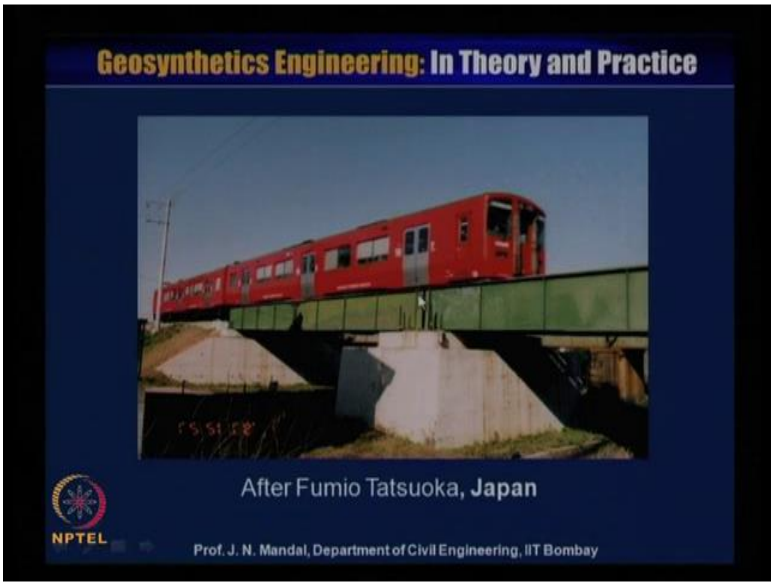

Here, that you can see that how the railway train can pass through the geo grid reinforced soil wall. This is after professor fumio tatsuoka Japan and so you can have some the idea about this.

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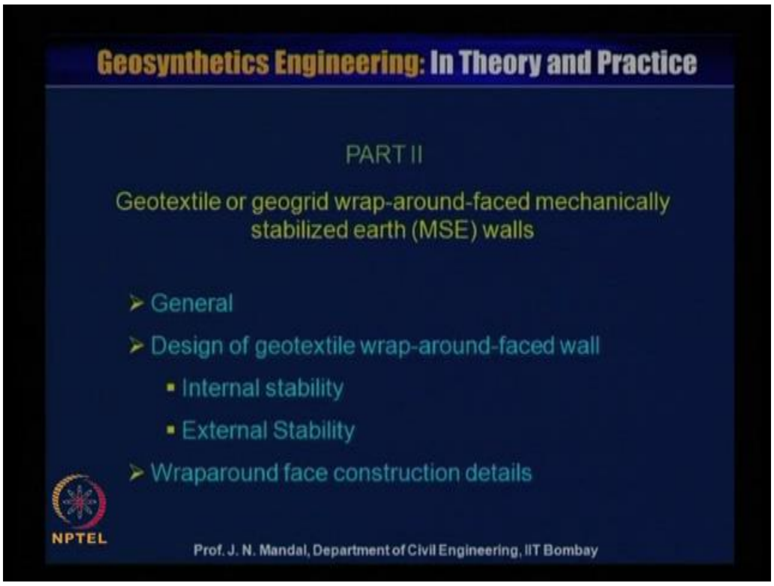

Now, I will address part 2 geo textile or the geo grid wrap around faced mechanically stabilized earth wall. So, this is to cover general and design of geo textile wraparound faced wall, internal stability, external stability and wraparound face construction detail. So, this is a kind of the woven geo textile material and we will use in the design this kind of the woven geo textile material, it can be wrapped.

So, this is wrap facing, this is the wrap facing, we can also use the nonwoven geo textile material, it is like this and it can be also wrapped. So, we will design this geo synthetics material either it is a woven or non woven, even then we can also use the geo grid material as a wrap as a facing.

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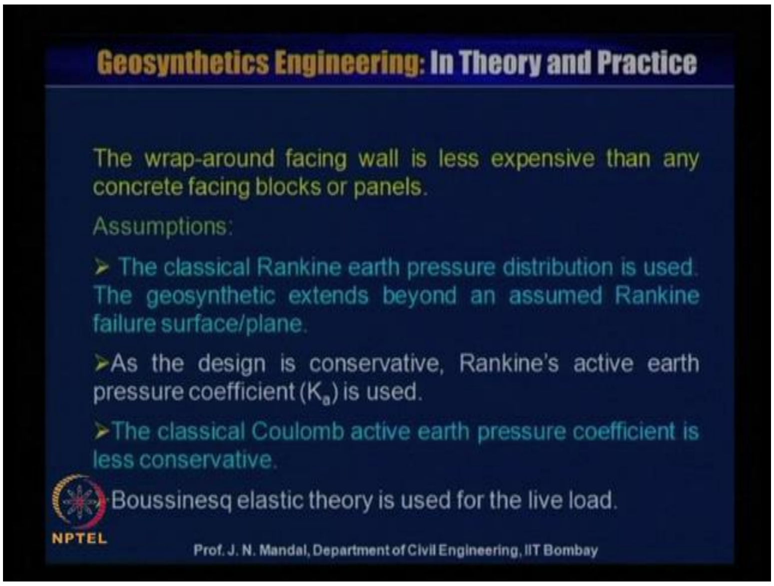

So, wrap around facing wall is less expensive than any concrete facing block or panel. Now, this design is based on certain assumption that is the classical rankine earth pressure distribution is used. The geo synthetics extend beyond and assume rankine failure surface or plane, as the design is conservative, rankine active earth pressure coefficient K a is used. The classical coulomb active earth pressure coefficient is less conservative, boussinesq elastic theory is used for the live load.

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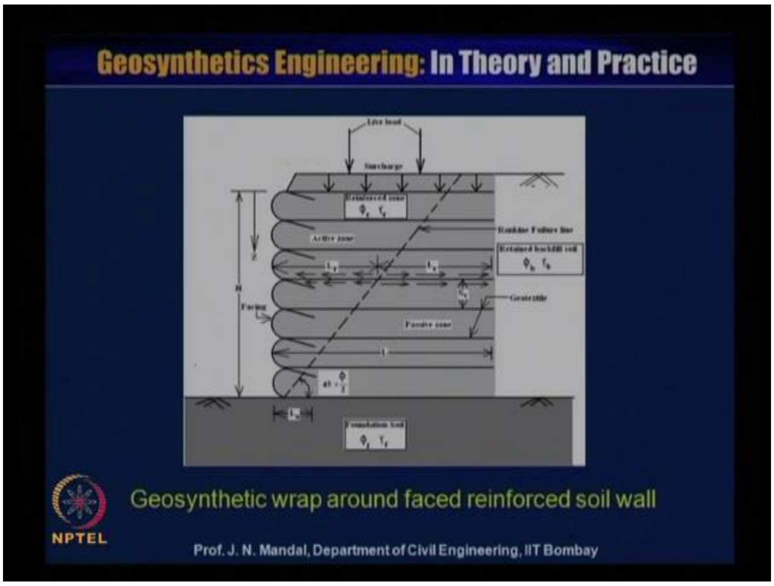

So, here I am showing that geo synthetics wrap around faced reinforced soil wall. So, here is the foundation and this foundation soil, has a property of phi f and the gamma f this is angle of internal friction, of the foundation soil and gamma f's is the unit weight of the foundation soil. This is the geo grid material and this is the wrapping like this and if filled up with the soil and then the next layer of the woven or nonwoven geo textile material and then it is wrapping. Like this you can construct a reinforced soil wall, whose height is equal to h.

And it also as a retained backfill soil, which unit weight of the backfill is expressed as gamma b and angle of internal friction of the backfill soil phi b. And also here, is the reinforced zone, where unit weight of the reinforced soil gamma r and angle of friction of the reinforced soil is equal to phi of r. So, this is the active zone and this is the passive zone, there is also the surcharge load here, on the top of the wall and apart from that there is a live load here, is the live load.

And this is the rankine failure line, which divided this reinforcement into two zone, this zone we call active zone and this zone, we call the passive zone and you can see how the friction develop between the soil and the reinforcement and shear stress is, mobilized along this direction and also along the facing element. And this distance what you call L of e it is called the embedment length or the bond length or the adherence lane and this is the L R, this is non active length in the active zone L R.

So, this is total length is L, So, L will be equal to L e plus L of R and this is height of the wall H and this failure plane making at an angle of 45 degree plus phi by 2 and this length is equal to L of 0. And spacing between the two geo textile material is designated as s of b. So, you can calculate at any depth z, what should be the length embedment length L of e or L of R or what would be the total length. So, geo synthetic wrap around face reinforced soil wall.

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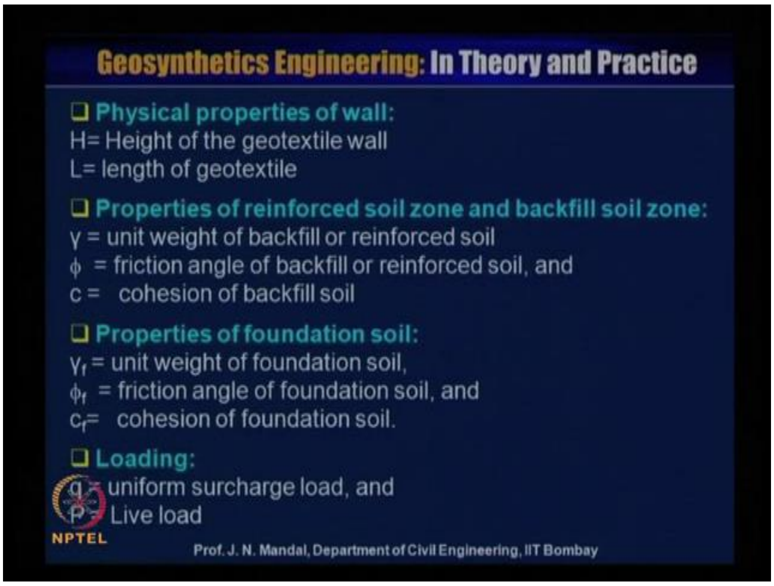

Now, for this what say that you require physical properties of wall that is height of the geo textile wall, length of the geo textile. You require properties of the reinforced soil zone and backfill soil zone, I show you gamma unit weight of the backfill or the reinforced soil. If it is a backfill gamma b, if it is a reinforced soil then gamma r phi friction angle of the backfill or reinforced soil, I show if it is a backfill is phi b and if it is a reinforced soil zone, it is a phi r. And C is cohesion or C a you can say adhesion.

Properties of the foundation soil gamma f unit weight of the foundation soil, by a friction angle of foundation soil and C r is cohesion of the foundation soil. And the loading, loading q is the uniform surcharge loading and p is the live load, which you have seen also in the figure earlier.

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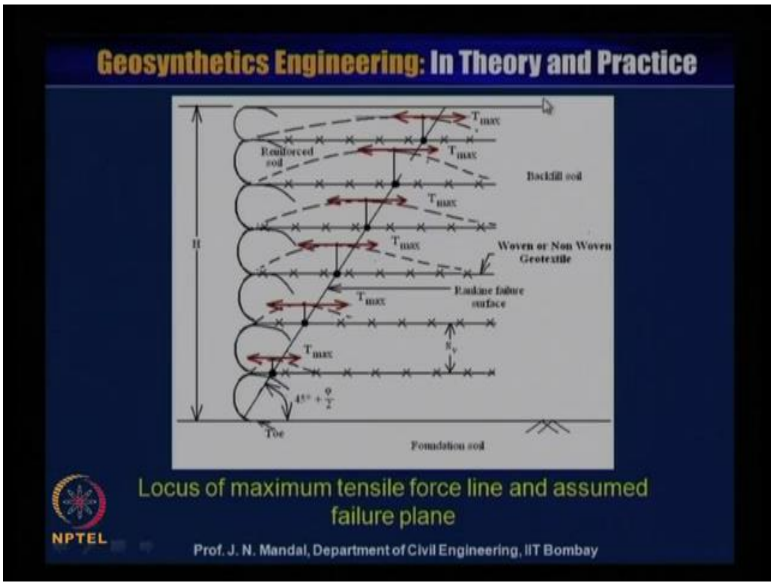

Now, this is the locus of the maximum tensile force line, it is assumed by this we can see maximum tension here. Either it is a woven or nonwoven geo textile material, this is that rankine failure surface it has shown, it has also earlier it has been shown.

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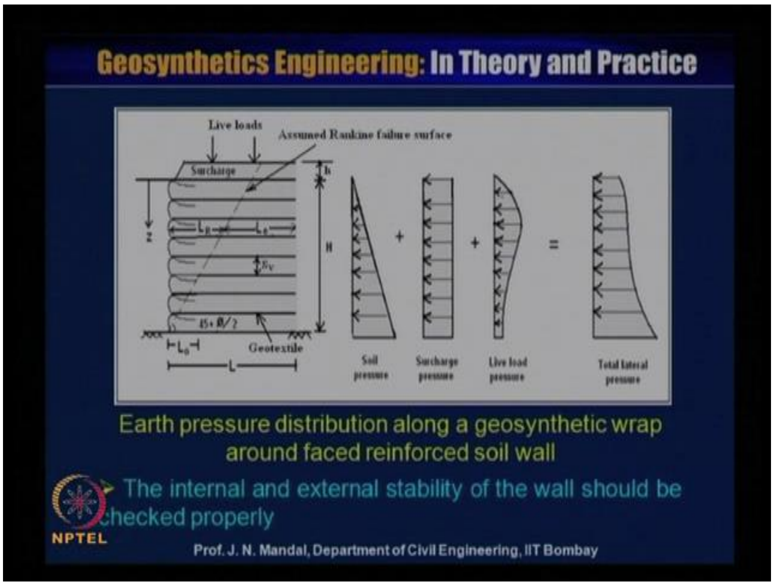

So, now in this wall what are the earth pressure distribution, along the geo synthetics wrapped around face reinforced soil wall. So, you need for the internal and the external stability of the wall and that is you should check properly, you can see here that if this is the wall and this is the assume that rankine failure plane. And this is the surcharge height is small h and there is also live load and the earth pressure, distribution along the geo synthetic wrap along face reinforced soil wall, what will be the earth pressure is acting on the wall.

This the triangular distribution due to the soil pressure. So, this is due to the soil pressure, this plus due to the surcharge pressure, so this is the surcharge pressure, plus there is a live load. So, this is the live load pressure, so all this pressure you have take into consideration for the design, so pressure due to the soil, pressure due to the surcharge as well as pressure due to the live load. So, this will give you what should be the total pressure.

So, total pressure will be equal to the soil pressure, plus surcharge pressure, plus live load pressure. So, first of all you have to calculate that, what are the pressure acting on the back of the reinforced soil retaining wall. So, we only design it is go for design for the internal stability, as well as external stability for the internal stability you need ultimate limit state.

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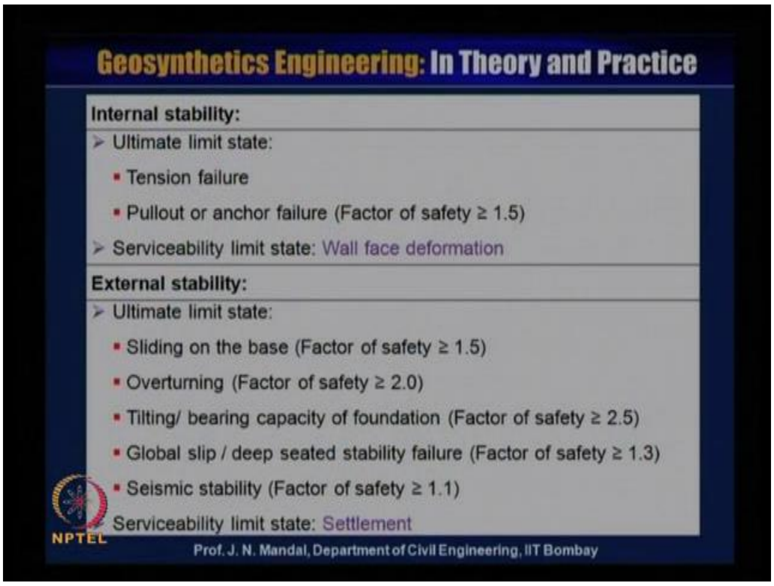

That means, this geo textile material may fail due to the tension, pullout or anchor failure and factor of safety should be greater than equal to 1.5. Also you have to check the serviceability limit state; that means, wall face deformation how much you should deform. So, that part you have to consider as a internal stability, this is all ultimate limit state, for external stability what will be the ultimate limit state, this geo textile reinforced soil wall plane, due to the sliding at the base.

And you require factor of safety should be greater than equal to 1.5 or the geo textile reinforced soil wall fail, due to the overturning and you have to check what will be the factor of safety, against the over turning and that should be greater than equal to 2.0, and also it may fail, due to tilting or bearing capacity of the foundation soil. So, the factor of safety should be greater than equal to 2.5 and global slip or deep seated stability failure; that means, factor of safety should be greater than equal to 1.3.

So, seismic stability you have to check and check the factor of safety should be greater than equal to 1.1 and also you have to check serviceability limit state; that mean, what should be the settlement. So, you have to check serviceability limit sate for the wall face deformation and also serviceability limit state for the settlement. Now, when you construct this wall and how you can construct this wall.

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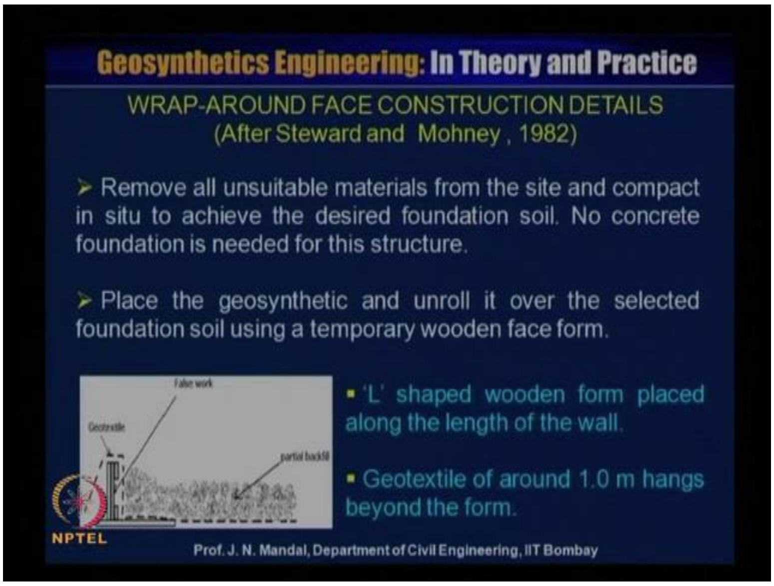

So, this wrap around face construction detail after steward and Mohney in 1982.

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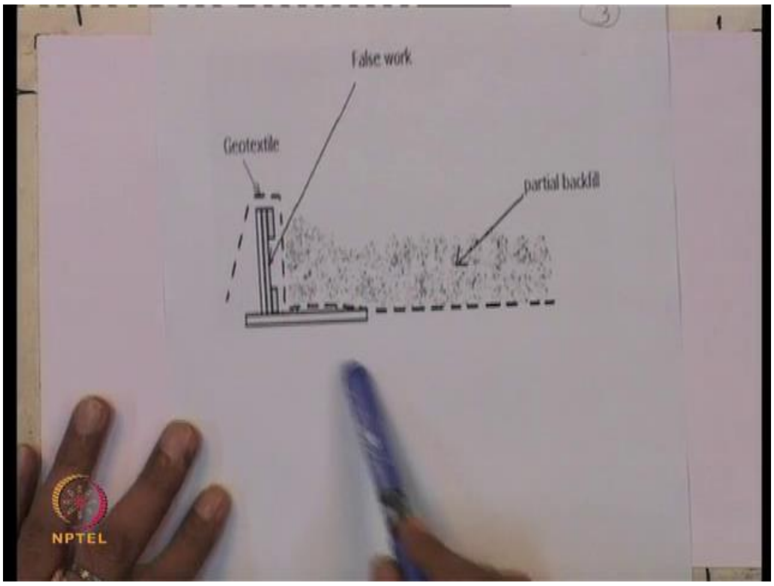

So, what you have to do that you have to for example, this is the ground surface and you want to construct a wrap around face retaining wall. So, you have to remove first of all that all unsuitable material from the site and compact, in situ to achieve the desired foundation soil. So, no concrete foundation is needed for this structure and then you place the geo textile this is dot, dot this is the geo textile material, place the geo textile.

And unroll it, you can have it in the roll form, you can unroll it over the selected this foundation and using a this is the temporary, wooden fence form this is the wooden frame form, this is the false work. And it is a L shape, wooden form place along the length of the wall and geo textile of around 1 meter hang, this one meter hang behind this form. So, this is first stage and then you have to fill up with the soil and compact it compacted it to the desired height.

Now, you are placing this, backfill material and this up to about 200 millimetre to 400 millimetre and compact it, with a light weight hand operated vibratory compactor. But, you have to maintain this, depth of the backfill material within 200 to 400 millimetre, in order that this geo textile material may not be damaged during the compaction. So, you should maintain, this height.

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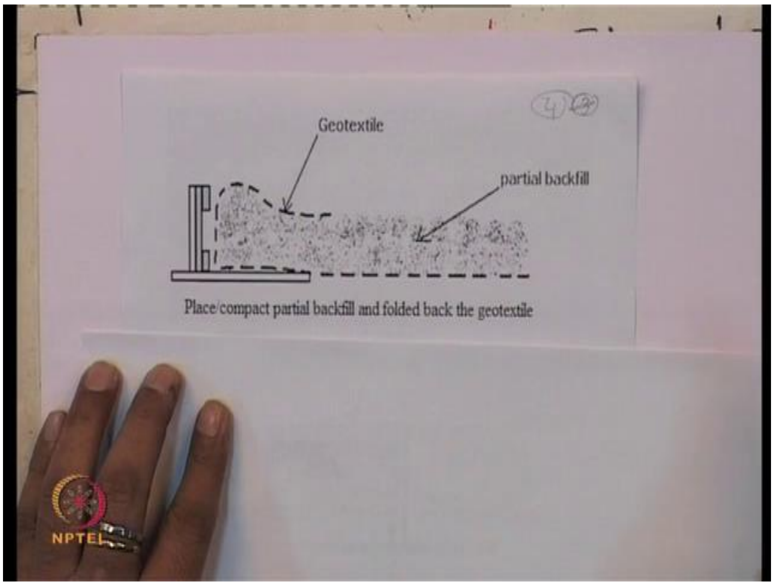

Now, next is you are to this makes the geo synthetics is folded back, over the backfill material. So, minimum return length should be 1 meter, so this to this it should be minimum, this should be minimum that is what you call the overlap length and which is called the L of 0 this should be minimum 1 meter, in order to satisfy the stability of adequate pullout resistance. Now, this wooden face form now, is to be removed you have to remove this, this wooden face form is to remove. From the front wall and then this is to be placed over the here, compacted here.

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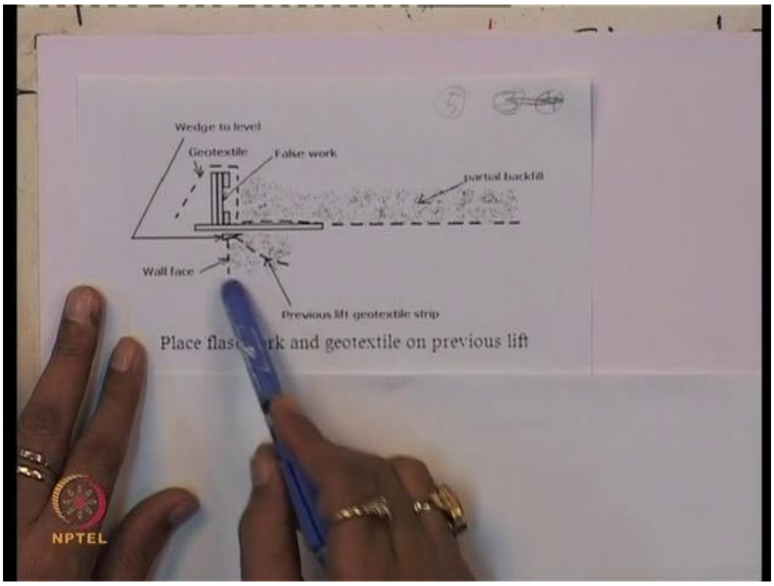

So, you have to remove it and place in the compacted layer like this, you can place of the compacted layer. So, this is initially previously it was here, this is the previous lift geo textile strip, this is the wall face. Then this is the wedge to level and then you wooden face is removed from, here and then you have to place over this compacted layer, the same procedure, you place the geo textile again and geo textile will hang, up to 1 meter this is nothing but a false that wooden block.

And the same procedure continue, until it reaches the desired height of the wall. So, like that you can construct, this wall. In general if the height of the wall is more than 2 meter it is necessary to provide the scaffolding, you can provide a kind of the scaffolding in front of the wall or wraparound facing cannot be kept the open.

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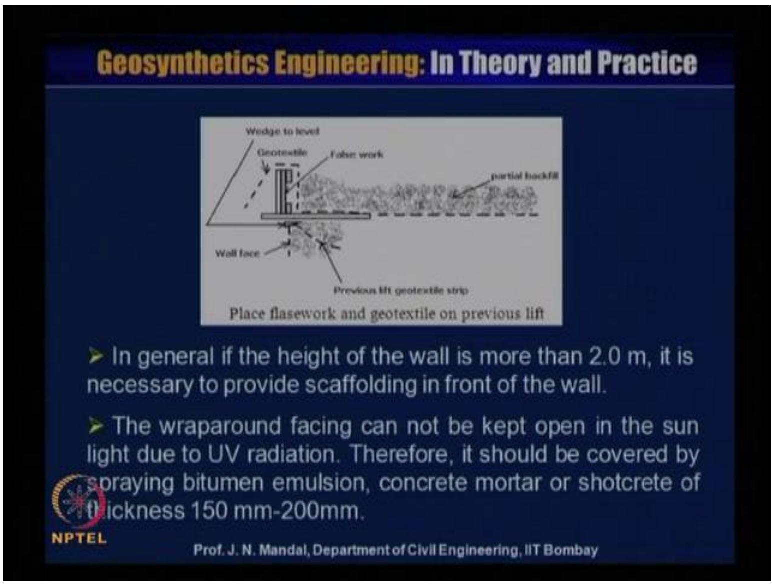

You cannot keep this any that geo textile wall in the opening, into the sunlight due to UV radiation. Therefore, it should be covered by spraying the bitumen emulsion, concrete mortar or shotcrete of thickness about 150 millimetre to 200 50 millimetre. Suppose, in case of the geo grid, so in case of the geo grid.

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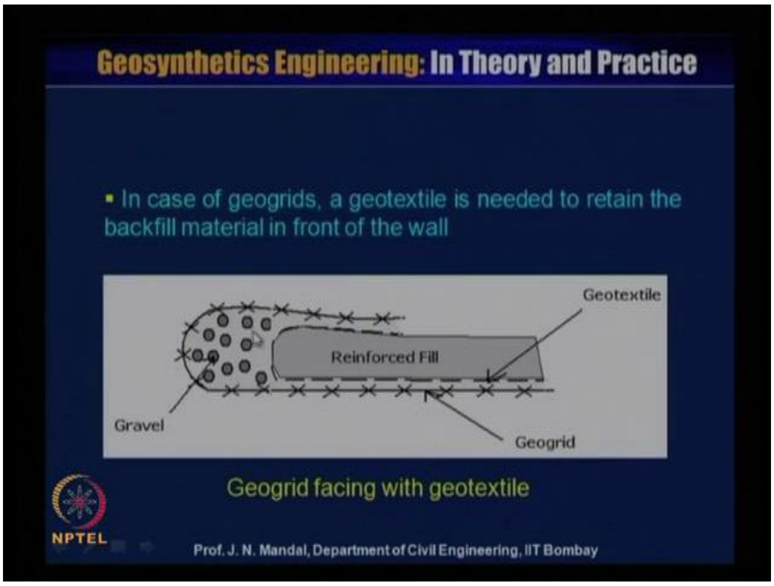

So, you can provide a geo textile material here, it is needed to retain the backfill material in front of the face wall. So, this is the geo grid material and then you are wrapping like this and you can provide with this is a gravel, which will also act as a drainage and then you place the geo textile material and can wrap it because this is the reinforcement fill. So, this reinforcement filled material, should not come out from the geo grid material or this reinforcement fill material will act also as a separation and also as a good drainage material.

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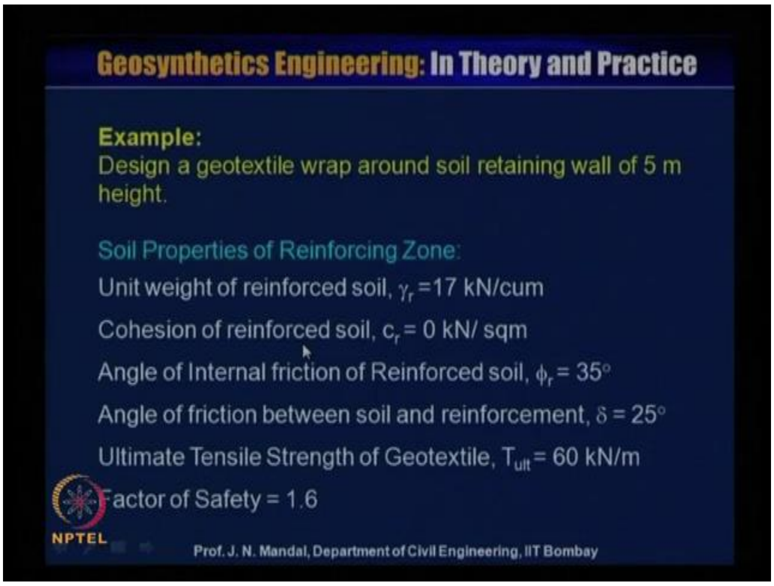

Also the grass can grow on the back of the wall. Now, design of a geo textile wraparound soil retaining wall of 5 meter height, this is one example. And we are giving that soil properties of the reinforcing zone, that is unit weight of reinforced soil gamma r is 17 kilo Newton per meter cube, cohesion of reinforced soil C r is 0 kilo Newton per square meter, angle of internal friction of reinforced soil phi r is 35 degree, angle of friction between soil and reinforcement delta is 25 degree, ultimate tensile strength of geo textile T ultimate 60 kilo Newton per meter and factor of safety is equal to 1.6.

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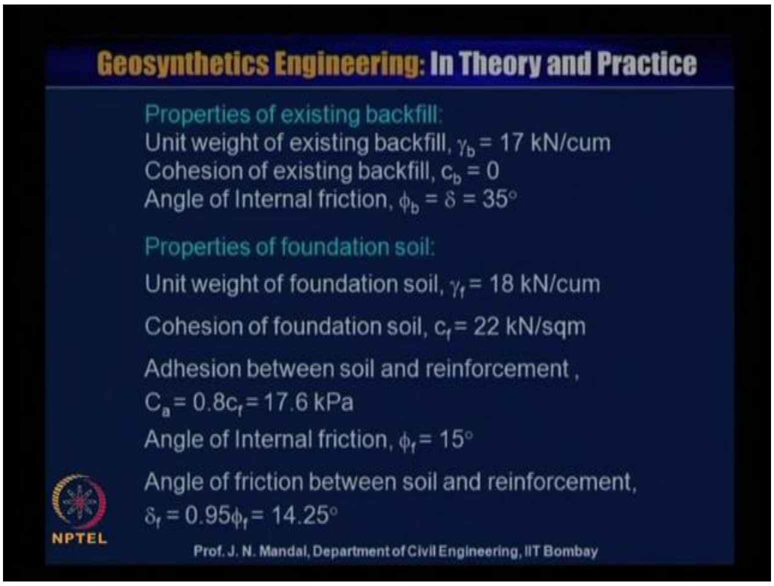

Now, properties of the existing backfill, unit weight of the existing backfill gamma b is 17 kilo Newton per cubic meter, cohesion of the existing backfill C b is equal to 0, angle of internal friction phi b is equal to delta is equal to 35 degree. Properties of foundation soil unit weight of foundation soil that is gamma f is equal to 18 kilo Newton per cubic meter then cohesion of foundation soil C r 22 kilo Newton per meter square. Adhesion between soil and the reinforcement C a is 0.8 into c are you know, what is the c r and then you can calculate C a is about 17.6 kilopascal, angle of internal friction phi r is equal to 15 degree, angle of friction between soil and reinforcement delta r is 0.95 of phi if that is 14.25 degree.

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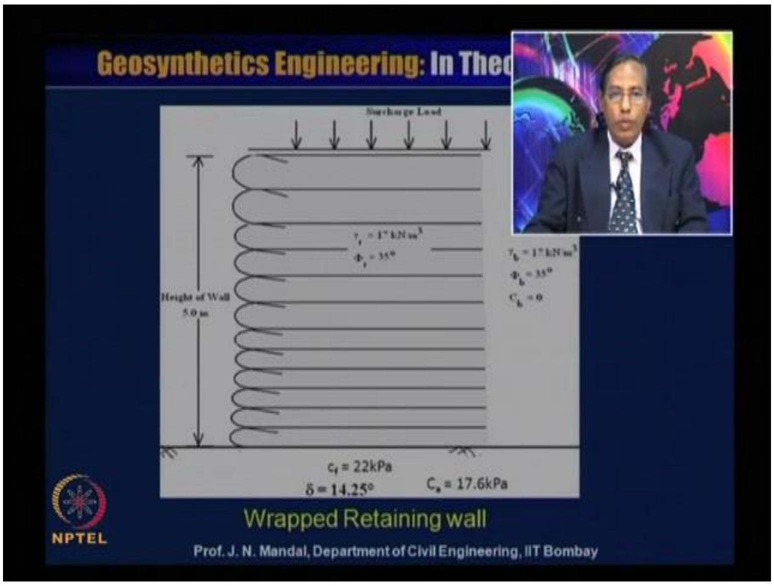

So, this is the wrap retaining wall which properties is given, this is height of the wall is 5 meter and this is the surcharge load and here, is gamma r phi r is given here, is the gamma b phi b is given here is the foundation C a delta and C a is given. So, you have to design this wall.

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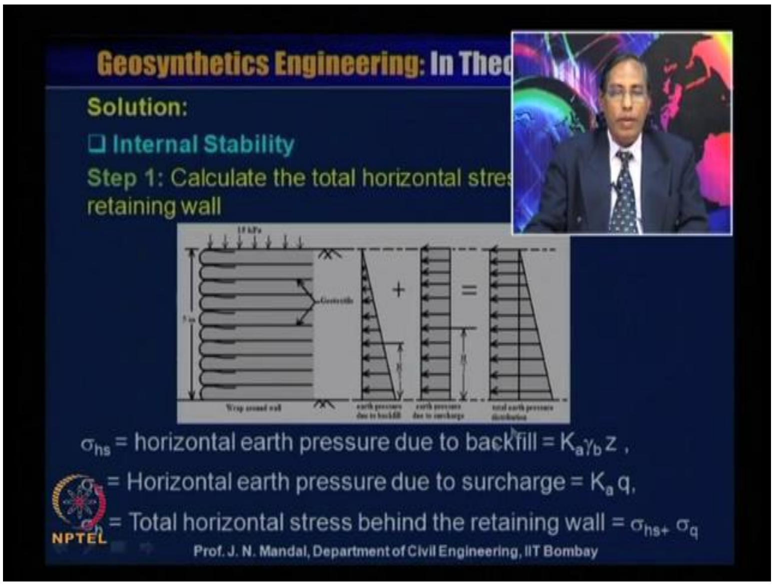

Now, the solution for the internal stability step 1, calculate the total horizontal space behind the given retaining wall, this is the wall and this is the soil pressure due to the backfill, that is designated at sigma of H s. So, horizontal earth pressure due to the backfill will be equal to K a into gamma b into z at any depthK you can calculate what will be the horizontal earth pressure due to backfill. This plus this horizontal earth pressure due to the surcharge load here, there is a surcharge q is 15 kilopascal.

So, surcharge is given, so you can calculate what is the sigma of q, the horizontal earth pressure due to surcharge will be equal to K a into q. So, you know K a because you know phi v we can calculate K a and you know will be the q, so you can calculate the horizontal earth pressure due to surcharge. Now, this total pressure will be equal to the horizontal earth pressure due to backfill, horizontal earth pressure due to surcharge this is the total pressure. So, this is total horizontal stress behind the reinforced wall; that means, if it is a sigma h s plus sigma h q. So, total horizontal stress behind the retaining wall is equal to sigma h s plus sigma q.

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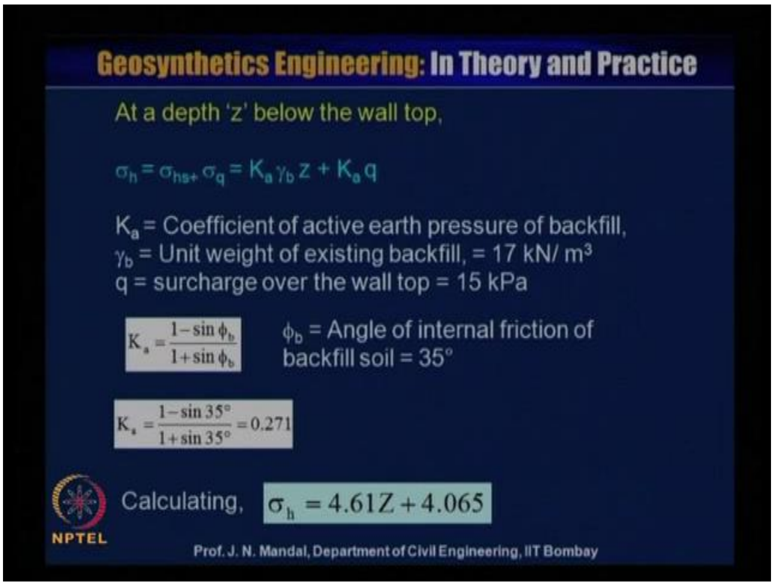

Now, at any depth z below the wall top, you can calculate; that means, you know sigma h is equal to sigma h s plus sigma q and sigma h s is equal to k gamma b into z plus K a into q. Where K a coefficient of active earth pressure of backfill, gamma b unit weight for the existing backfill that is 17 kilo Newton per meter cube and q is equal to surcharge over the, wall top that is 15 kilopascal. So, you can calculate the K a using the equation k a is equal to 1 minus sin phi b by 1 plus sin phi b where phi b is equal to angle of internal friction of backfill soil that is 35 degree.

So, K a will be 1 minus sin 35 degree divided by 1 plus sin 35 degree is equal to 0.271. So, if you calculate that sigma of h, so sigma h is equal to K value you know 0.271 gamma b value is known 17 kilo Newton per meter cube. So, and K a value also known q value also known, so you can substitute these value K a gamma b and K a and q, so you can have the sigma h in terms of the z. So, if you calculate sigma h is equal to K 0.271 into gamma b is 17 into z that mean it will give 4.61 z plus K is 0.271 into q is 15, so it will give 4.065. So, you can calculate that sigma h is equal to this in terms of the z. So, you have calculated.

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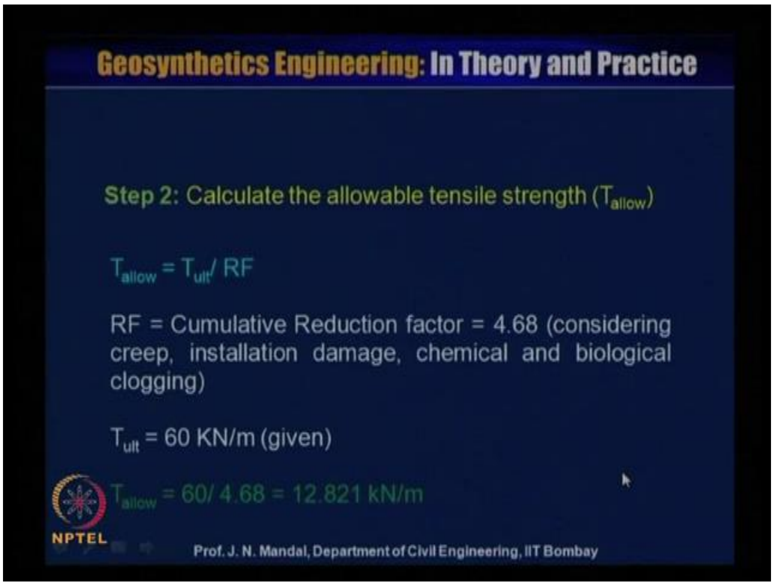

Now, step 2 you have to calculate the allowable tensile strength that is T allowable. So, T allowable is equal to T of ultimate by reduction factor. Now, this is reduction factor which you call the cumulative reduction factor, that here we are considering that 4.68 and you have to select that, this all this factor that is what will be the factor for the creep, factor reduction factor for the creep, reduction factor for the installation damage and reduction factor for the chemical and the biological clogging.

So, these are the reduction factor, you can obtain from the reinforced soil retaining wall and this all you can call the cumulative reduction factor. So, you are considering with the cumulative reduction factor RF is equal to 4.68. So, we know that T ultimate is equal to 60 kilo Newton per meter given, so T allowable will be equal to 60 by cumulative reduction factor 4.68. So, it will give 12.821.

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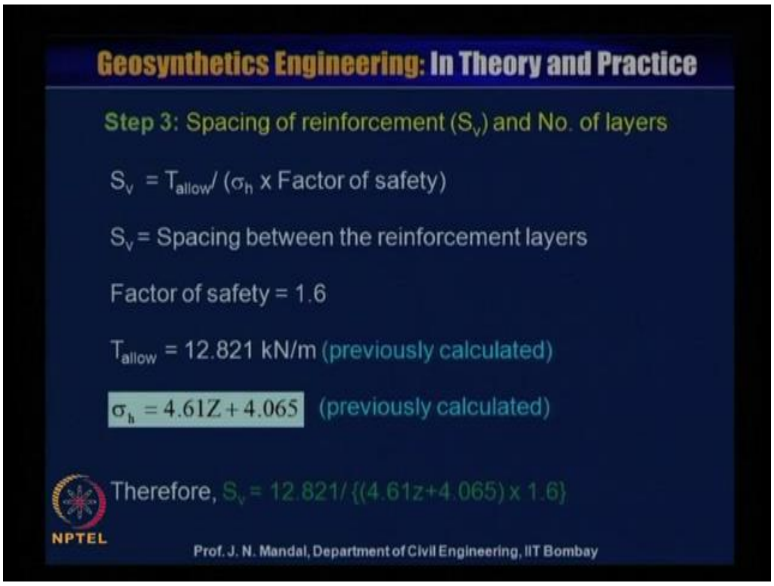

Step 3, you have to spacing of the reinforcement S v and the number of the layer. So, S v is the spacing will be equal to T allowable divided by sigma h into factor of safety or S v is the spacing between the reinforcement layer and factor of safety is equal to 1.6. So, T allowable will be equal to 12.821 kilo Newton per meter, which we previously calculated and we know, also previously that sigma h is equal to 4.61 Z plus 4.065. So, therefore, this S of v this S v will be equal to T allowable, we calculated 12.821 this divided by this sigma h in terms of the Z that mean 4.61 Z plus 4.065 into this factor of safety that factor of safety is 1.6. So, you can obtain the S v in terms of the z.

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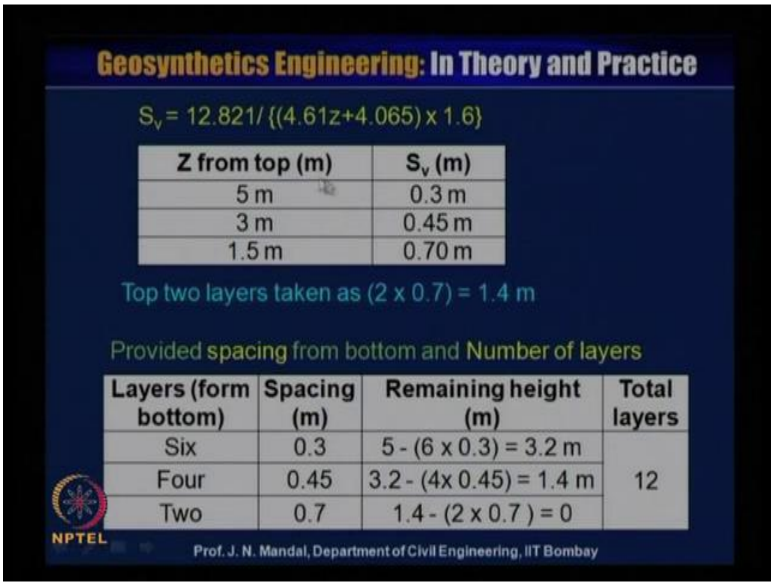

So, ultimately we will have that S v is equal to 12.821 divided by 4.61 z plus 4.065 into 1.6. Now, you have to select the z from the top, so we are providing that 5 meter and spacing is 0.3 meter. So, when depth is z is 5 and what is S v, so you substitute with value of z is equal to 5 because this is the height of the reinforcement is 5 meter. So, S v spacing between the reinforcement will be 0.3 meter now, you can consider middle somewhere.

So, you have to assume some z value, let us say z value from the top is 3 meter. So, you substitute this z value, here 3 meter, so you can calculate what will be the spacing. So, spacing will be equal to 0.45 when the z value is 3 meter, next this 1.5 meter, so at the 1.5 meter you substitute this value, you can obtain S v 0.75. So, top two layer is taken as this 0.7 meter; that means, 2 into 0.7 meter is equal to 1.4 meter.

Now, provided spacing from the bottom and the number of layer, so this is the layer from the bottom. So, if we can six layer from the bottom and spacing is 0.3, so what will be the remaining height; that means, 5 is the height of the wall minus 6 into 0.3. So, this is 3.2 meter and then you are providing four meter, it is 4.5 meter spacing, so this will be 3.2 remaining height, 3.2 minus 4 into 0.45; that means, this equal to remaining height 1.4 meter. And then layer from the bottom two and spacing is 0.7; that means, 2 into 0.7, 1.4 this is 1.4 minus 2 into 0.7; that means, it is 0. So, we can see here, that total layer how many total layer it will be.

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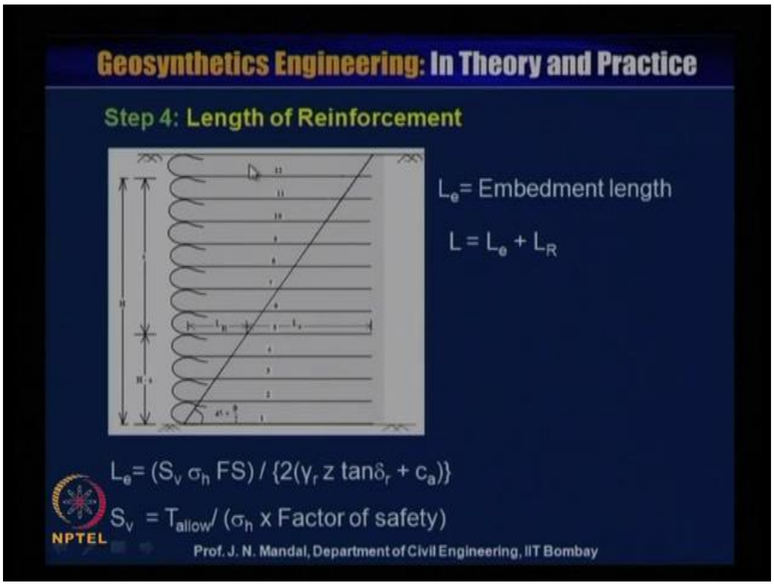

So, here is the number of the layer of the reinforcement that is the 12.

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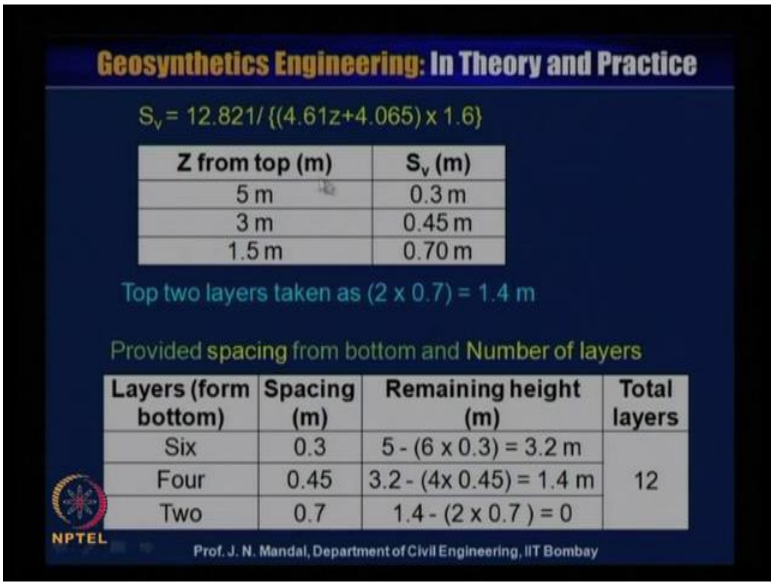

Total number of the layer will be equal to the 12. So, this is the 6 plus 4 then plus 2. So, total layer will be the 12.

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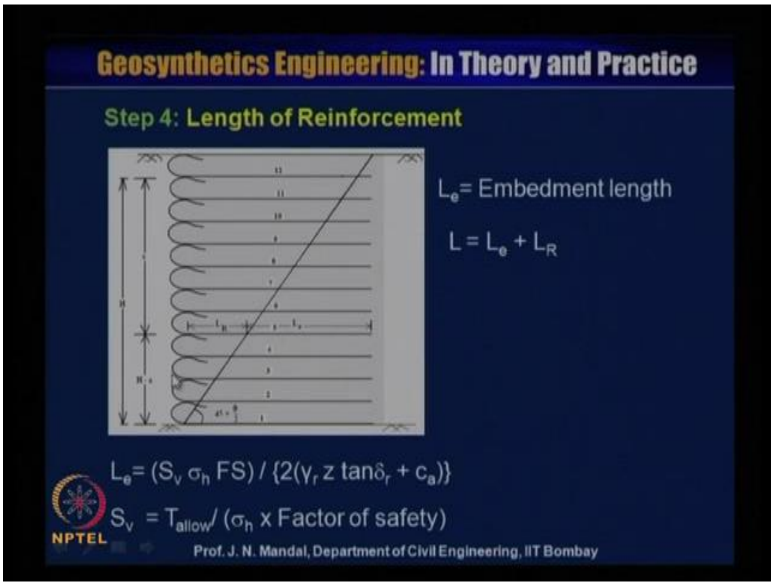

So, you have to length of the reinforcement in step 6. So, here 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 top, then you have to calculate what will be the length of the reinforcement. And here, this is the L e it is embedment length and this is the L R, so this is the total L will be equal to L e plus L of R. So, this is the H and at any depth z this is H minus z and this is the failure length, which is making at an angle of 45 degree minus phi by 2. So, we know that L e is equal to S v into sigma h into factor of safety divided by 2 into gamma r z tan delta r plus C of a. So, S v will be equal to T allowable divided by sigma h into factor of the safety.

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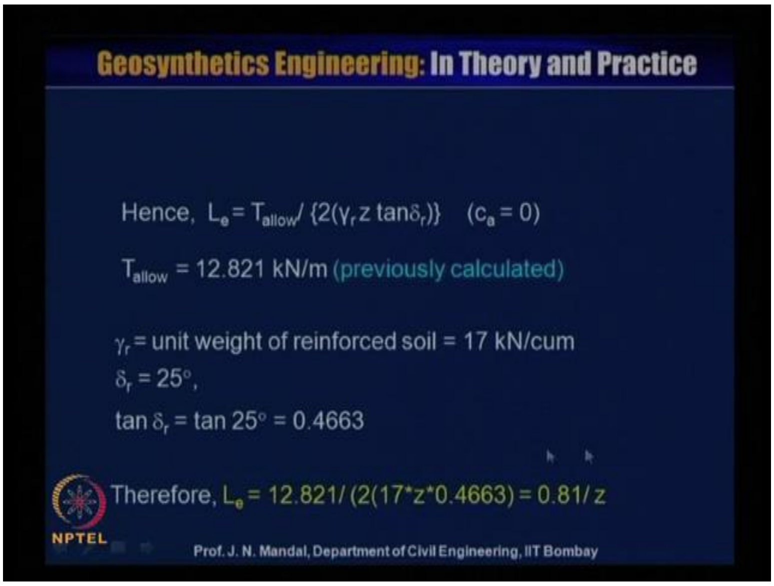

So, hence L e is equal to T allowable by twice gamma r z tan delta r because C a is equal to the 0. And T allowable we calculated that is 12.821 kilo Newton per meter it is previously calculated. So, gamma r is unit weight of the reinforced soil that is 17 kilo Newton per meter cube, delta r 25 degree, tan delta r is equal to tan 25 degree is equal to 0.4663. Therefore, L e will be equal to T allowable is given 12.821 and this 2 into gamma of r, gamma r is 17 this is 17 and this is the z and tan delta r is equal to 0.463, so 0.463. So, this L e in terms of z this is 0.81 divided by z. So, L e is equal to 0.81 divided by z for various values of z, so you can calculate what will be the L of e.

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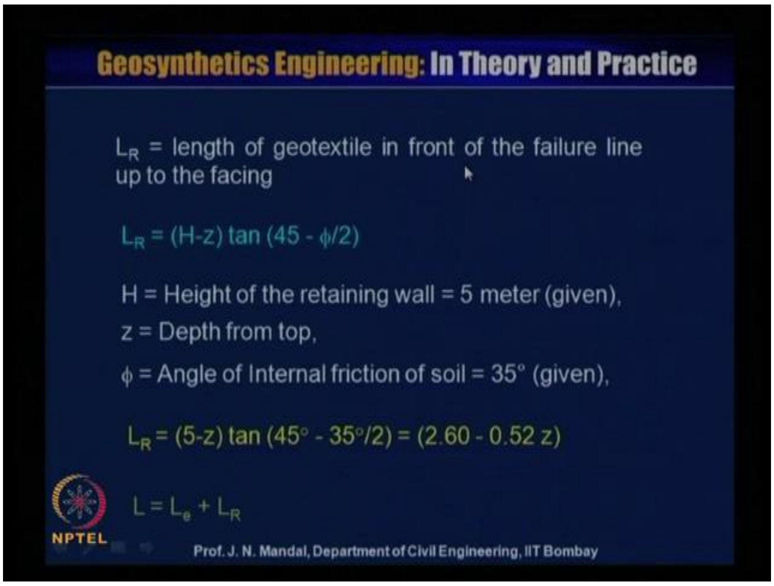

So, if you draw the L e you can calculate L R that is length of the geo textile in front of the failure line, up to the facing L R is equal to H minus z into tan 45 degree minus phi by 2, you have also earlier discussed about this. So, H is equal to height of the retaining wall and z depth from the top and phi angle of internal friction of the soil 35 degree given. So, L R can be calculated, L R is equal to H is 5 meter height minus z into tan 45 degree minus 35 by 2 that is equal to 2.60 minus 0.52 z. So, for any value of z, so you can calculate L of R, so you can calculate total length is equal to L e plus L R. So, from this equation we can calculate L of R.

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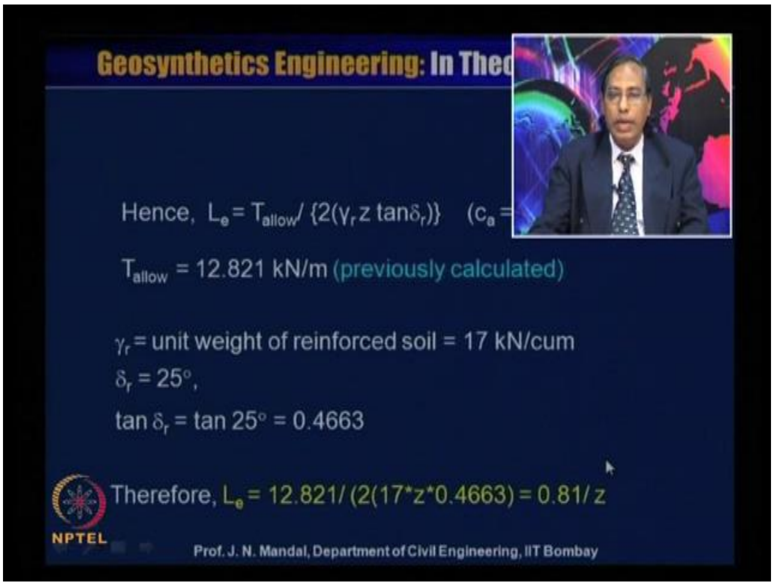

And for this equation, you can calculate L e because z at any z we can calculate.

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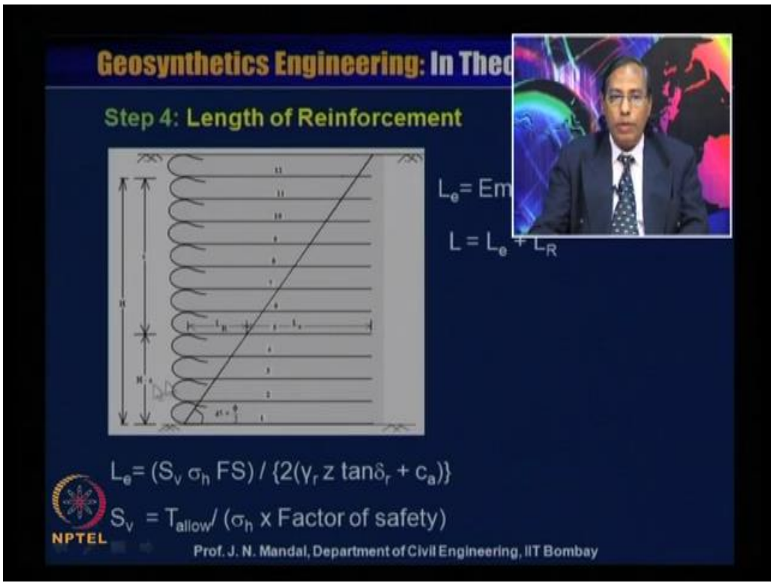

And this is L R, if this 45 degree plus phi by 2, this is 45 minus phi by 2. So, these L R we have considered H minus z tan 45 degree minus phi by 2.

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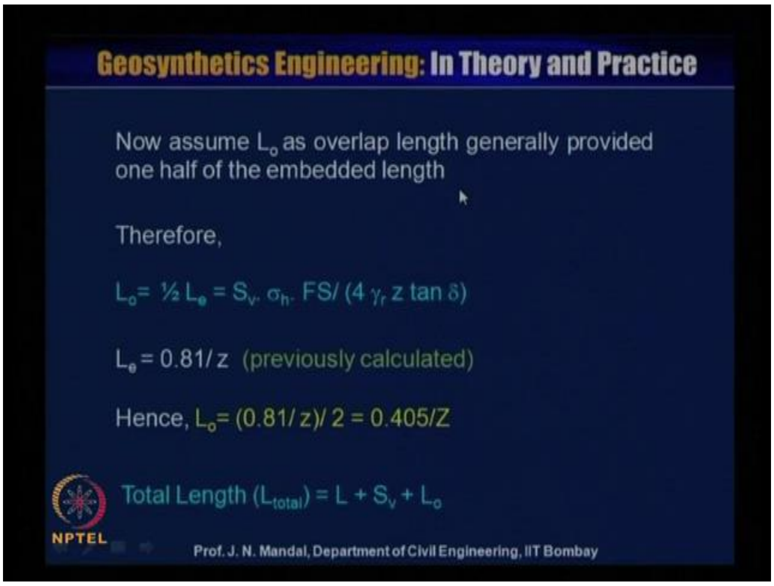

So, this is what it is written here, at that depth because at any depth this is 5 by z, so L e can be considered. Now, assume that L 0 and overlap length, generally provided 1 and half of the embedment length therefore, L 0 is equal to half of L e that is S v into sigma h into factor of safety divided 4 gamma r z into tan delta. So, as you know L e is equal to

0.81 by z which, we previously calculated, so L 0 will be the half of this L e, so 0.81 by z by 2; that means, 0.405 divided by z.

So, if you know any z then you can calculate L 0. So, then you can calculate what will be the total length; that means, L total will be the, total length then what will be the spacing between the two geo textile material S v plus this is the L 0. So, it is like this when you calculate that in terms of the total length.

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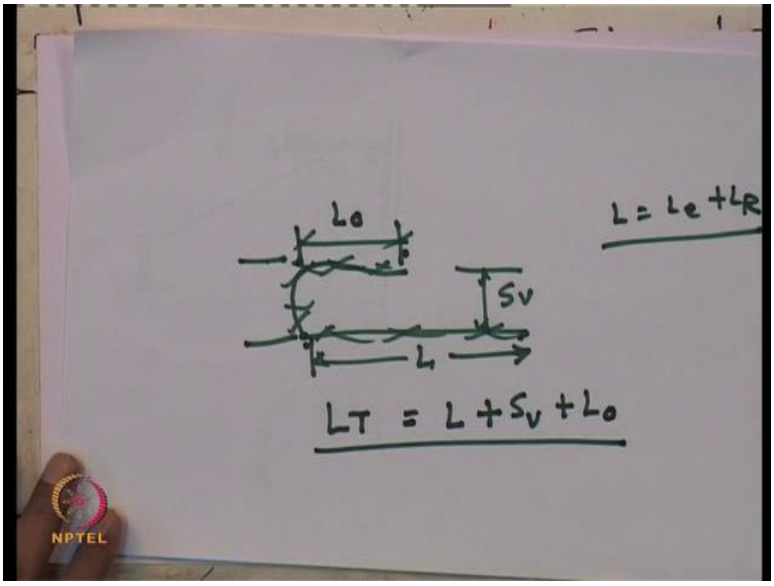

So, if this is the geo textile material and this is the spacing and here, is the spacing is equal to S v here, is the total length; that means, L e plus L of R. And here, this is spacing and here, is the overlap length that is what you call L of 0, so total will be L plus S v plus L 0. So, that is why L of total is equal to L, L also is equal to L e plus L of R, so this is L plus this is S v plus this is L of 0. So, you can calculate what will be the total length of the geo textile material. So, I ended up this lecture today, if any question.

Thank you for listening.