Ground Improvement
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Lecture 58
Geosynthetics in Ground Improvement (Contd.)

Hi, everyone. Once again, I welcome you all to this ground improvement lecture class.

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And we are in the last module, where we are discussing geosynthetics in ground improvement. Before that we have discussed different types of ground improvement methods depending upon soil type. And now geosynthetics is a new material, not really new, but it is out, again it is 50 years lower, but in India application was not 50 years maybe at least 30-40 years. And so initially it was limited use now quite extensively being used.

And this has, geosynthetics has several applications, and ground improvement, one such application. And we have initially discussed the, their applications and then we have tried to see the application in the reinforced earth retaining wall, that means MSE wall, mechanically stabilized earth wall or reinforcement earth retaining wall.

So, we have discussed the design procedure and everything, and then finally, we took a problem. And that problem maybe, I have done half, and remaining half to be completed.

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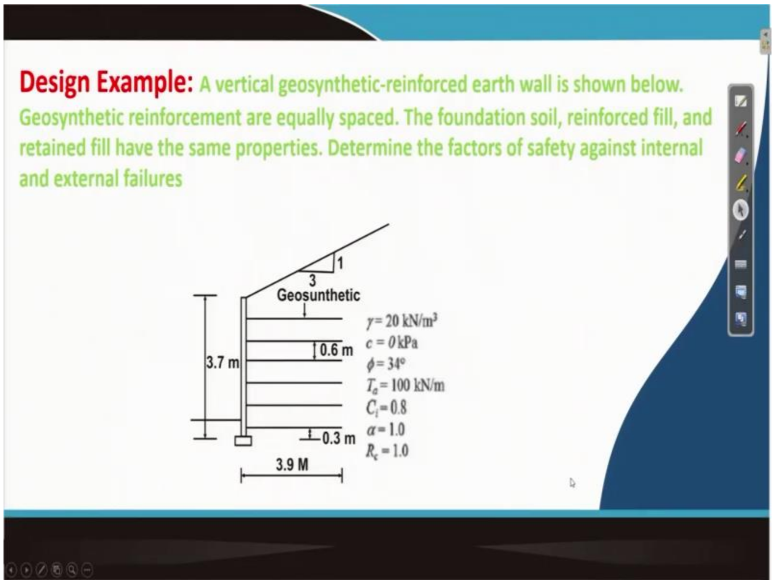

This is the problem, was considered generally this face sometimes it will be little bit inclined, but here for simplicity is given vertical, and there is a slope, can be horizontal, it can be inclined. So, this inclination is given. And the height of the wall is 3.7 meters from the, the base block. And there are six layers provided, reinforced earth, six layers of reinforcement is provided in the backfill.

And we need to design, or we need to check for this loading condition whether the factor of safety is enough. Factor of safety is internal factor of safety, external factor safety global factor of safety, we are not doing.

So internal factor of safety means we have to find out first maximum T in each member, and then you have to find out resistance, how much resistance developed, and the ratio of these two will be the factor of safety against pullout.

And from the T max again you can find out whether you can, you can fail in tear. So, that can be done. And connection failure, if the connection strength is given, that also can be checked. So, perhaps those part I have done.

And then next part was to check for external stability. And that external stability consists of two, three things. One is that factor of safety against sliding, then factor safety against overturning, then factor of safety is bearing capacity failure.

So, this part, mostly this second part, external fearing, external bearing (capacity), external failure, the factor of safety against external failure analysis, that part perhaps remaining. So, I will try to take that one. So, for that let me create a piece, and, and let me take that.

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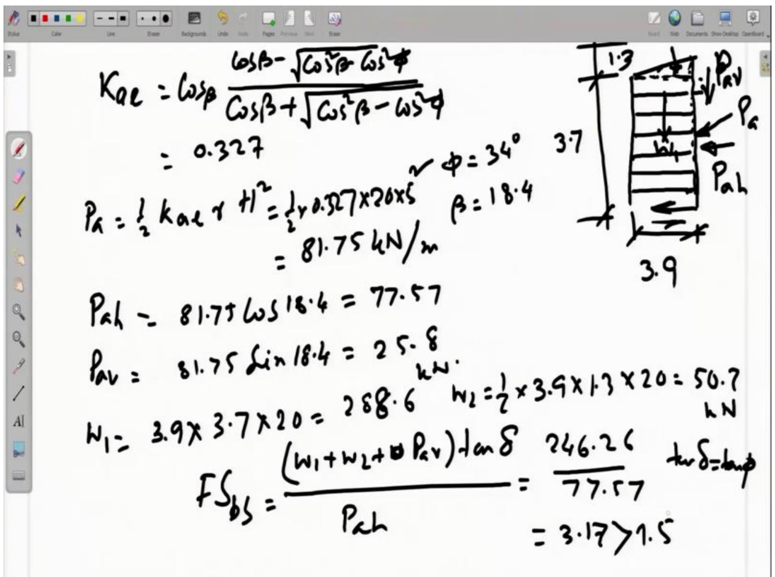

So, for this, initially for calculation of internal K_{ai} we have calculated. Now, when we are trying to find out external factor of safety, in that case, we will consider the wall like this and we will be having like this and then we will have six layers of input, reinforcement, 1, 2, 3, 4, 5 and 6, and then at the, we considered the wall, assume the wall here and then we consider, active earth we considered at the point.

So, your wall will be modified, wall height will be this one and this wall height, already I have shown perhaps, last class, last lecture, and that was actually 3.7, this is 3.7, and this is 1.3 because this is 3.9, and slope is 3 horizontal 1 vertical, so it will be one-third of that, 1.3.

So now your wall height is 5 meters, 3 for 5 meters and there are a number of forces to be considered for calculation that will be, one force because of this soil weight, another forces this soil weight, and then active pressure will be acting something like this. And this is P_a, and this can be divided into two parts, that is P_{av}, and another part that is P_{ah}. So, these are the forces acting on it.

And, so first of all you have to find out the k_{ae} that will be cosβ, then cosβ minus under root cos square beta minus cos square phi., and then cos beta plus under root cos square beta minus cos square phi. So, phi again, here it is given, value is given something, 34 degrees, I think, and beta actually was calculated something, 18.4 degrees. So, this is tan inverse 1 by 3.

So, then you will get, if you put these values here, you will get a value equal to 0.327. And then P a will be equal to half k_{ae} γh square. So, that will be half multiplied by 0.327 multiplied by, gamma was actually 20, multiplied by 5 square. So, this will be giving you a value equal to at 81.75 kilo Newton per meter. So, P_{ah} and P_{av} can be calculated.

P_{ah} will be 18, 81.75 cos 18.4. So, that will be equal to 77.57. And P_{av} will be at 81.75 sin 18.4. So, that comes actually 25.8. So, now W_1 comes your W_1 will be this one, suppose this is W_1 and this is W_2. So, that is 3.9 multiplied by, this is 3.7, multiplied by 20. So this will be, will be equal to your 20, 288.6. And W_2 will be equal to have multiplied by 3.9 multiplied by 1.3 and multiplied by 20. So, this will be equal to 50.7 kilo Newton. This is kilo Newton.

And your, then factor of safety against base sliding will be equal to, so base sliding will be here. So, the because of these P_{ah}, this will try to push this side. The resistance will be developed in this direction. That the resistance will be equal to your total vertical load W_1 plus W_2 plus W, not W_3, that is the P_{av} and multiplied by tan delta, which will be equal to be P_{ah}.

And, so if I do that, and, so tan delta equal to tanϕ. If I take that, then if I put W as, everything here, this comes 246.26 divided by 77.57. So, that means it is coming 3.17, which is greater than 1.5. Generally, factor of safety against overturning requirement is only 1.5. So, that means it is safe. So, let me go to, another page, let me open.

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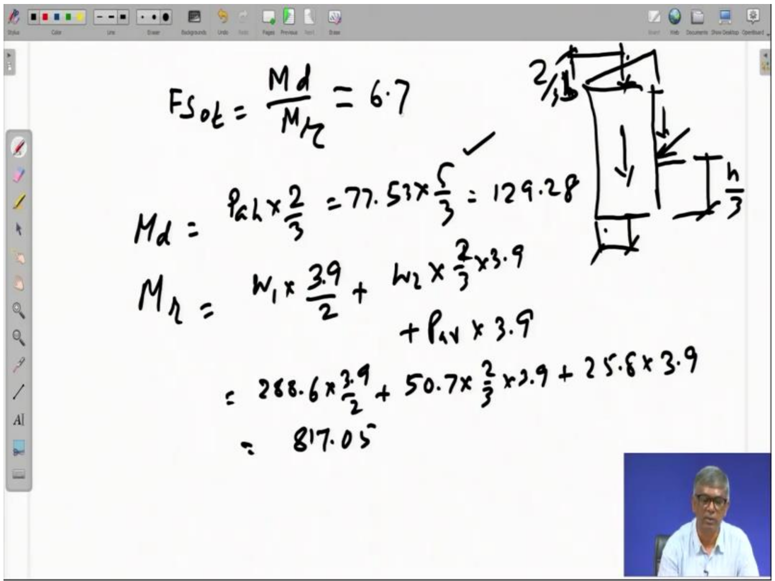

So, factor of safety against overturning, let me draw again the same figure, and factor of safety, so Md will be, we have to find out factor of safety against overturning, factor of safety against overturning will be equal to M_d divided by M_r. So, Md will be equal to P_{ah} multiplied by 2 by 3, so which will be equal to 77.57 multiplied by 5 by 3.

So actually, while is something like this, and this is about 5meter, and it is acting, the P_a will be somewhere here, and if I consider, so this height actually will be, why I took, so 1 by 3, this will be h by 3. So, h actually, 5, so it is 5 by 3. So, this will be giving you 129.28.

And M_r will be equal to, will be equal to W_1 multiplied by, actually, 3.9 by 2 plus W 2 multiplied by 1 by 3 multiplied by 3.9 because W_1 is this one. So, it is acting from here. So, this distance will be 3.9 by 2. And W_2 is acting here. It is acting somewhere here. This will be two-third from this. It will be, not two, one-third, it is two-third because it is two-third from this distance. This is two-third this distance, so two-third h, or, or b, two-third b. So, if it is b, two-third b. So, 3.9 two-third.

And plus P_{av}, which is acting, assume here, multiplied by 3.9. So, so this if I do, so W 1 is 288.6 multiplied by 3.9 by 2 plus W_2 is fifty, 50.7 multiplied by 2 by 3 multiplied by 3.9 plus P_{av} is 25.8 multiplied by 3.9. So, if I get, this will be equal to 817 point. 817.05.

So, if I put now M_d by M_r, this gives you value equal to 6.7, which is much, much greater than the required value. So, this can be, again factor of safety against overturning is safe.

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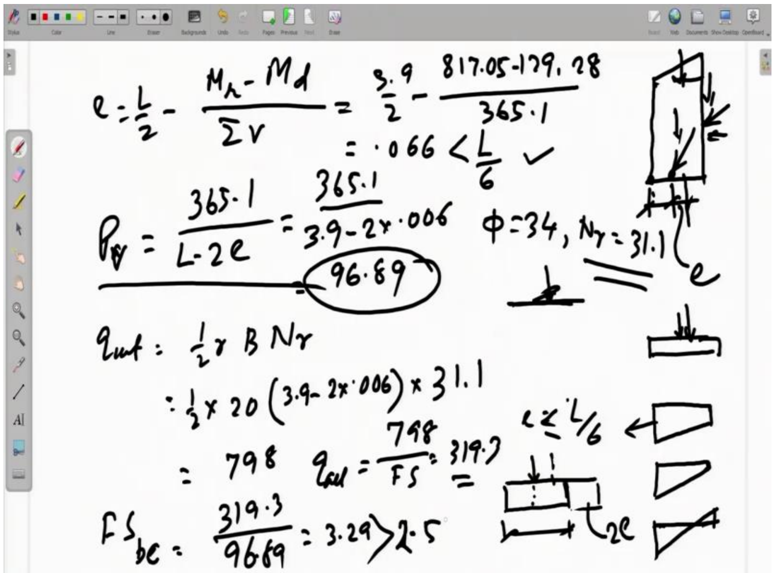

So let me take, next is actually to be, you have to find out the factor of safety against bearing capacity. So, when we do that, again let me draw this figure, this one. So, so there are a number of forces acting, and we can say this, we can say this, we can say this. So, because of that, all forces the resultant force may be acting somewhere here. So, this resultant force, the distance you have to find out.

So that is actually, we have, we can find out, and the midpoint of this will be, suppose here. This actually, this difference, this is e, actually. So, that means e actually equal to L by 2 minus, that the CG, from, that this point. CG, how we can find out? M_r minus M_d divided by σ_v. If I do that, then we will get 3.9 by 2 minus 817.05 minus 129.28 divided by, σ_v is 365.1.

So, if I get this then you will get a value equal to point, 0.066 which is less than L by 6. So, the, they said it should be less than L by 6 so that it will not, there will not be any tension occur.

Depending upon the application, suppose if there is a footing, depending upon your point of application, if the midpoint then it is average everywhere, but if it is eccentric like this then what will happen, then your, or pressure will be, a different pressure diagram.

One can be something like this. One diagram will be something, this side will be more, and it will be like this or it can be something like this. So, that means, throughout the base of the footing is uniform, sorry, average, compressive. This is most the expected one.

And, but limiting value is that maximum it can be 0. It can be, lowest value can be 0. And if it goes beyond 0, means it will be negative that means, the tension will occur in the base of the footing which will be, that means, separation of soil will take place. So, that we do not expect or do not allow, because soil is not good for tension.

Because of that we have to keep this to make, to maintain 0 your e value should be less than equal to L by 6. So, that is what the requirements that is satisfied. So, now when it is, load is applied eccentrically then sometime we find out effective foundation width.

Suppose this is the footing, and load is applied here. And this becomes center. So, this I, better not to use. Suppose, this is the one, and load is applied here and center is somewhere here. Then what do? We do we find out the effective width, that means with respect to this, we make symmetric. So, that means this width will become, that, so this will become, this width will become, if this is, total length is L, L minus 2 e. So, this portion will be, this will be equal to twice e. P_v will be equal to, 365 is total vertical load, divided by L minus 2 e. So, that is average, approximate. So, L minus 2 e, so 365.1, L is 3.9 minus, 2 multiplied by 0.006. So, this value gives you something like 96.89. And now, we can find out q ultimate, q ultimate.

Since it is sand, so it will be half gamma B N γ. This is the formula to be used because there is no cohesion, there is no surcharge, we assume at the surface. So, if I do that, so this will be half, gamma is here 20, and B become this L minus 2 e, that means 3.9 minus 2 multiplied by 0.006, and half gamma B, N gamma actually for, for actually, for phi equal to 34 degrees, $N\gamma$ will be equal to 31.1, you can, one can get from the chart. So, if I put 31.1, so you will get q ultimate equal to 798. So, 798.

So, q allowable can be calculated. 798 by factor of safety. So, this will be approximately 319.3. So, now factor of safety against bearing capacity, B_c, will be equal to, so this is available, 319.3 divided by, applied pressure is this 96.89, so 96.89. So, that gives you a value equal to 3.29, which is greater than 2.5. So, that is a requirement, the performance requirement, factor of safety of bearing capacity.

So, this is the one that, that means we have done all internal failure check, internal failure check, actually two parts. Most important part is to find out the T_{max}. So, T_{1max}, T_{2max}, T_{3max}, T_{4max}, T_{5max}, T_{6max}. Similarly, P_{01}, P_{21}, P_{31}, so, like that, up to P_6. And then you have to find out that ratio of that actually, factor of safety against pullout.

And then T_{max} divided by T allowable, if you do, then you will get the factor of safety, T allowable by T_{max}, then you will get the factor of safety against pullout. And then connection strength is given, then T_{max} divided by connection strength, that also will get the factor of safety. So, this part is done.

So, with this, overall global factor of safety, I have not done. So, one can go through the book and can see, do it. Same thing, actually. It is like slope stability analysis. We are not doing, I am not doing here because there is, too much of involvement will be there. It will be, as an assignment I can think of, one can take home, assignment, but here it is difficult to do. Long time, it will require, and you, for you also it will be difficult to understand, maybe.

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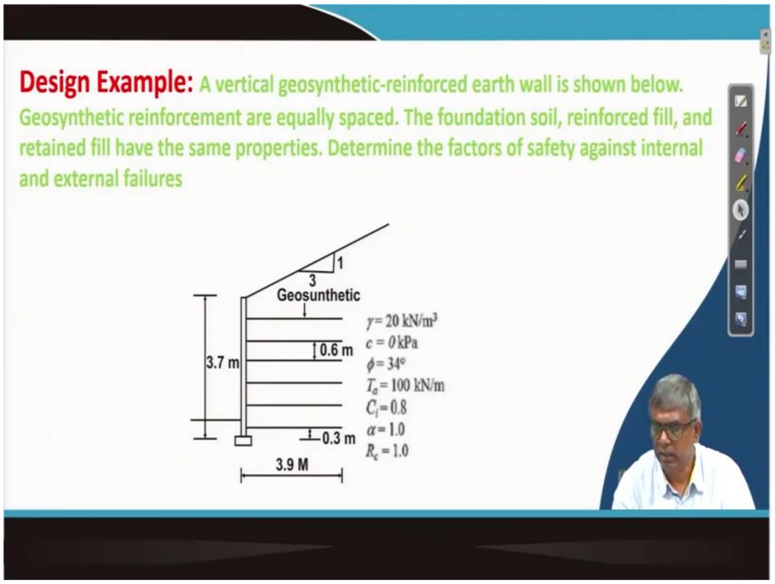

I will be. So, that means, the MSE wall, how to design? That means, if you have, based on the site condition and height and all, we can decide certain things and then we can assume the length of the reinforcement and spacing and then all those things and based on that you can find out what is the factor of safety. If you get too big factor of safety in all aspect, then you can again change the design and check.

And when you find that one of the factor of safety or all of the factor of safety coming less than the required, then again you have to modify. Like that, final design can be achieved. So, this is the problem, and this problem of course, I have done here.

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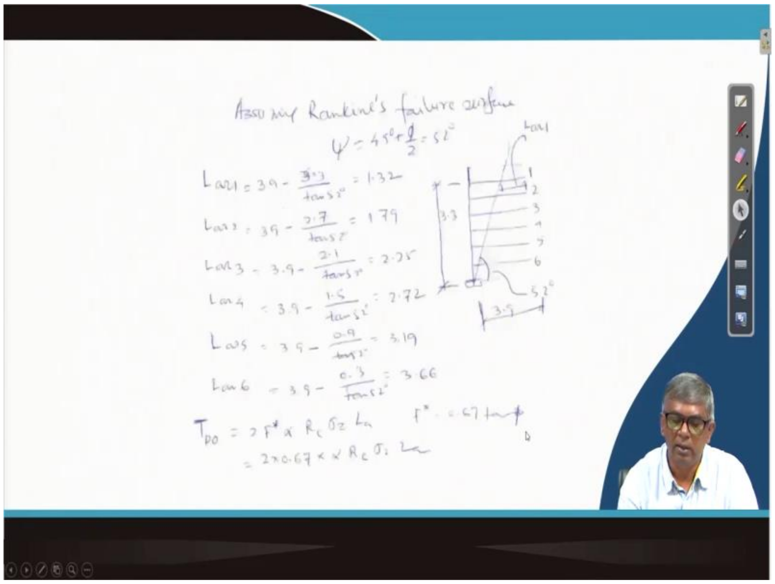

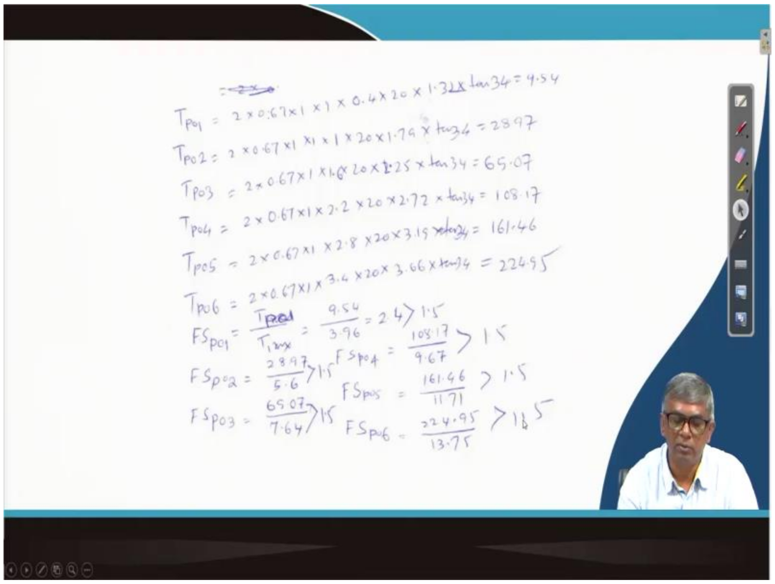

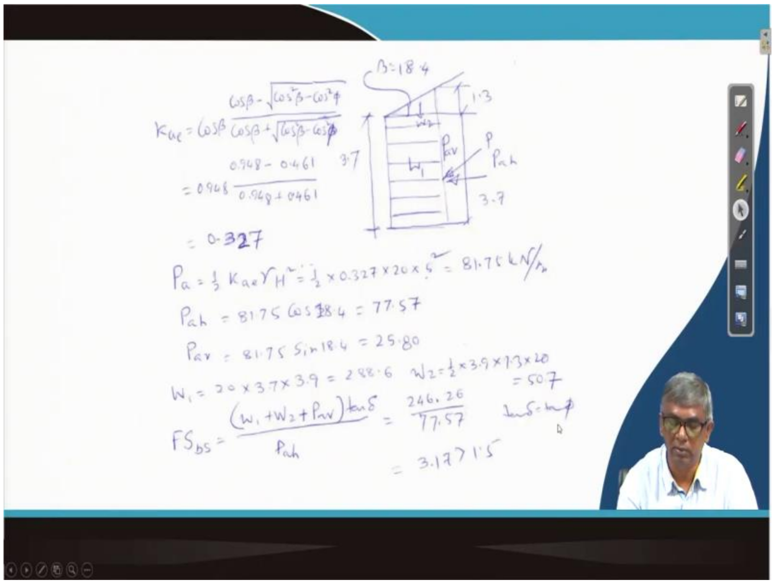

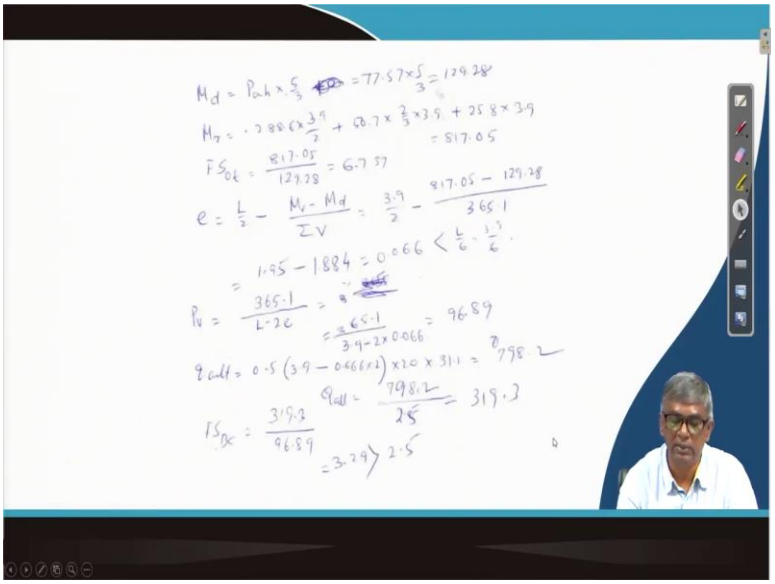

So, I have the, whatever problem I have, done same thing I also kept here. You can go through.

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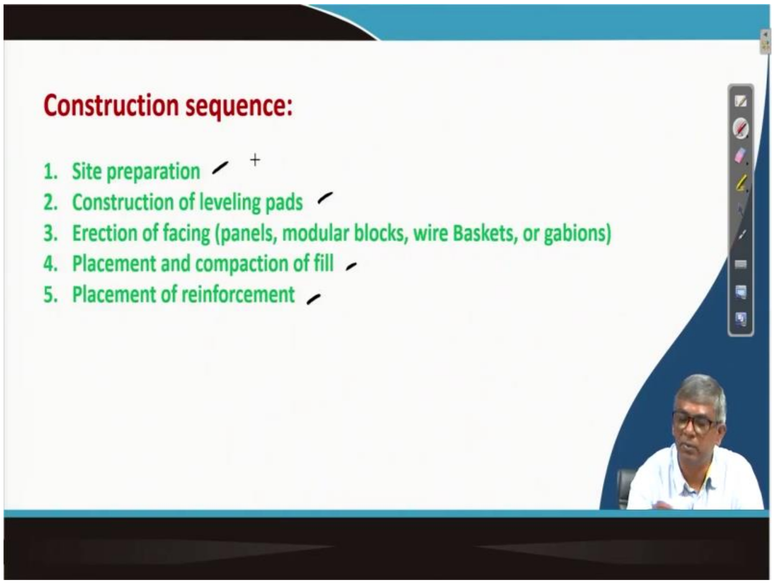

Later on, remaining actually, a few things, small things actually, may be, related to MSE wall, I want to take up. And that is actually construction sequence, how you do the construction of retaining wall. There will be site preparation, there will be construction of leveling pads, then erection of facing panels, then placement and compaction of fill, and placement of reinforcement.

This is the sequence; one by one you have to do. You cannot start from here. You have to start from here only. And what is the meaning of this, the site, site preparation means what exactly?

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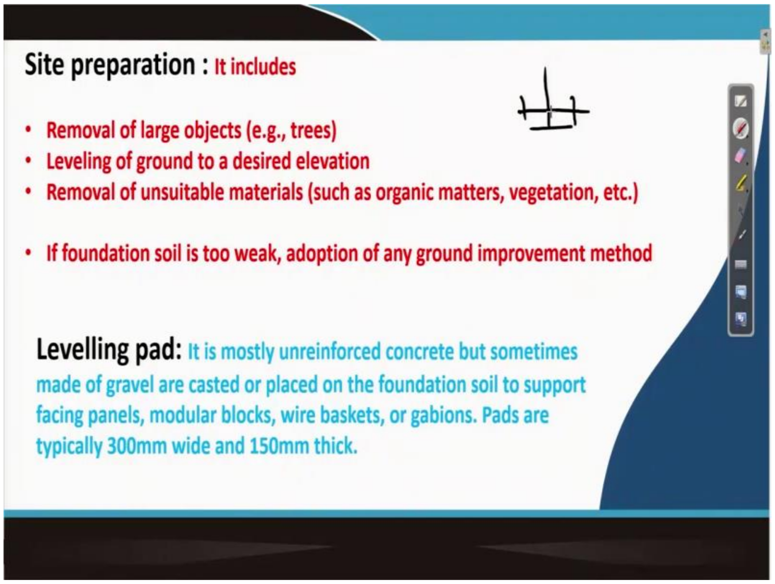

Site preparation means actually the removal of large objects. If there is a way, on the way to our construction if there is a trees or big boulders, that has to be cleaned. And then you have to level the ground. And removal of unsuitable materials, organic material, anything is there that also to be removed. Also, finally see the, if the foundation soil is not that good then there will be some ground improvement technique to be applied, and ground to be made suitable for construction of the wall.

And then next step will be the construction of leveling pad. Leveling pad is actually what? Actually, it is mostly on unreinforced concrete, but sometime made of gravel are casted or placed on the foundation soil to support facing panels.

So, facing panel means actually, there will be precast panel, we, I have told number of times that it has to be placed one after another, and, sidewise and height wise, and to make that length and height we get. And modular blocks, either the facing panels or modular blocks. Sometimes wire baskets or gabions. Before putting that you have to maintain a level. So, you have to, leveling pad to be constructed.

And pads are typically 300 millimeter wide and 150millimeter thick. So, this is the first part of the construction of, so, if the ground is somewhere here, generally, then we generally excavate, and then we place the leveling pad, and then from here we start first panel. So, this is the work.

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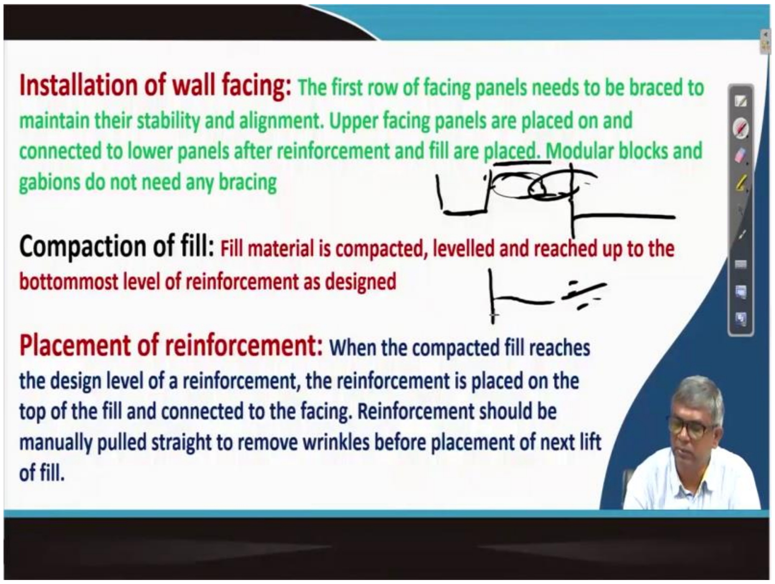

Next one will be installation of wall facing. And wall facing means actually the, as I have mentioned, after leveling pad, you have to, facing element you have to put. The first row facing panel needs to be braced because there is no support, there is, no connection to reinforcement. Initially it has to be erected. So, need some brace, brace, maintain their stability and alignment.

So which direction, whether it will be this direction, or this direction, or vertical. So, to maintain alignment and stability, you have to first, you have to give support, lowermost panels.

And upper facing panels are placed on, and connected to lower panels. So, one panel is supposed here, one panel is here, then other panels will be placed here and connected. If there will be some locking arrangement. I have shown by line diagram but it is having some two dimensional, of course three dimension is there, third dimension, that is, thickness. But it is two dimensional, you can observe it as a big shape.

And they will be connected, and then after connection reinforcement will be connected like this. And then of course, before that you have to fill and compact, all those things to be done. So, and connect it lower panels of reinforcement and fill are placed. That reinforcement and fills, that there were.

Modular blocks and gabions do not need any bracing. So, gabion blocks are so large, if the level ground, if you put itself, because of gravity, it will be stable. And similarly, wire basket also same thing, modular blocks also same thing. They do not require any support because there are smaller size.

But it is the facing elements quite long, dimension is quite large. And it is thin. Because of that, because of that, the stability purpose and to maintain alignment initially, has to be, there should be some bracing. So, it has to be supported. Bracing means it has to be supported.

So, after doing that, is has, then you have to fill the material, and then connect the, with reinforcement. And compaction of fill means actually, as I have mentioned that we have to dig and then you had to put the leveling blocks. And in between the front, the soil may be disturbed. So, this has to be compacted, and reach up to the first level of the reinforcement.

When you reach to the first level of the reinforcement, then you actually, you have to place the reinforcement and connect to the, so this is the placement of reinforcement. When the compacted fill reaches the desired level of reinforcement, the reinforcement is placed on the top of the fill and connected to the facing. Reinforcement should be again, manually pooled.

So once, this is the facing element, and connected and then if you put like this, it will, it may be like this, and wrinkle also will be there, and so, the, actually the mechanism of reinforced earth actually, when you get tension, then it will develop some resistance between the soil and reinforcement.

But if it is a, like a raft, then when you get tensed, tension, you will get initially too much length you will get to adjust tension. So, it will, it, there will be no friction will develop between this. So, because of that what you have to do, after laying the reinforcement it has to be manually, and pooled, and there will be, should not be any wrinkle and anything and it will be made straight, horizontal, that any tension you apply, then immediately it will transfer to the soil. That is a, thing has to be maintained.

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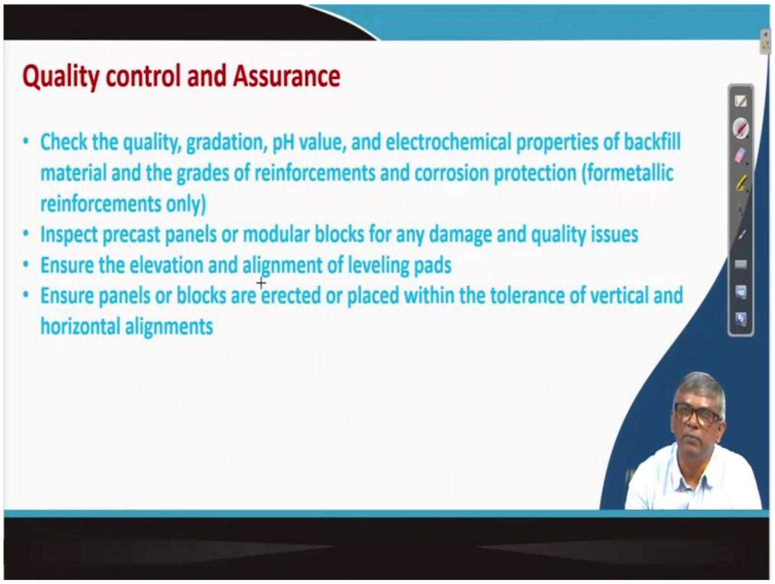

After that, quality control and assurance. Obviously, I have mentioned number of things that how will be the gradation of the soil, backfill soil etcetera. So, check the quality, gradation and pH value and electro-chemical properties of backfill material. That is important. Already, what is the effect, already we have discussed. That has to be checked.

Inspect precast panel or modular blocks for any damage and quality of, quality issues. So, if there is any crack or anything and if you put that one in the wall, then from there, that will become the weakest part and wall may collapse from there. So, it has to be, we inspect each and every modular brick, modular blocks, or facing elements.

And then ensure the elevation and alignment of the leveling pads. That is also, it has to be done. Ensure panels or blocks are erected or placed within the tolerance of vertical and horizontal alignment. So, there can be tolerance, how much you can achieve. If it is inclined more than that, then it has to be corrected.

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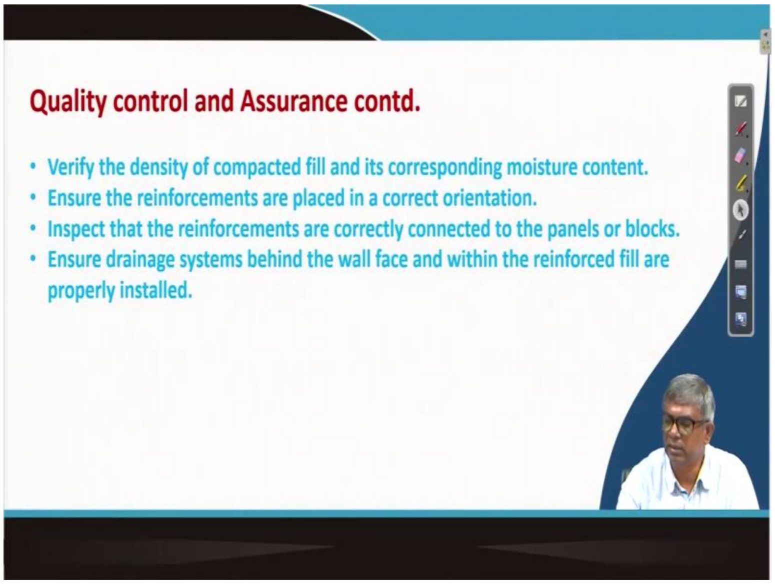

Then next is the, verify the density of compacted fill because pile, at a particular density, particular friction angle will be developed, and if it is, loose soil is there then the friction angle will be less, then resistance between the soil and reinforcement will be less. So, the density, what is achieved, that has to be checked whether it is as per requirement or not, and moisture content etc., of course, it has to be checked.

Ensure the reinforcements are placed in a correct orientation. As I have mentioned that it has to be a horizontal perfectly. It should not be like this. So, it started from here inclined by 10 degree or 15 degrees or even 5 degrees, that will also give a lot of problem.

Inspect those reinforcements are correctly connected to the panel. So, that is also very important. When it gets tension, it should not come out. Then connection also has to be proper.

Ensure drainage, that is another, is the most important part, that behind the wall there will be a drainage layer, and that has to be designed, constructed very accurately. Otherwise, because, because during rainy season, if the water cannot drain out then there is a development of the water pressure, and that may cause the failure of the wall. So, these are the things related to MSE wall.

Starting from design, then, then analysis, and then quality control, the requirement, all those things, I have discussed about MSE wall. And with this, I will close this lecture.

And maybe geosynthetics can be applied in many applications, as I have mentioned, but I am not able to do that. There are some places, there is a course dedicated only on geosynthetics. There actually, you can apply, you can take up all those things.

But as an example, in addition to the MSW wall, I will take one more lecture on the application of reinforced earth geosynthetics in reinforced slope. That also, I will not a lot go for design. Only some example, what will be different from the actual slope that I will discuss in the next lecture. Thank you.