Ground Improvement
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Lecture 46
Soil Nailing

Hi everyone, once again I welcome you to this lecture Ground Improvement and we have already completed nine modules, I have reached now tenth module which is Soil Nailing and in fact so far whatever we have got that because of the internal stability of the soil that this weakness of the soil to improve the weakness of the soil because of their internal weaknesses, that means when there is a too much of voids or there is a lack of the frictions or cohesion.

Then the soil sometime will be having less strength more permeability, some high compressibility and to modify those we have discussed number of things over the time through nine modules before and today we will try to discuss something which is little different that as a soil mass when it is a notch in stable condition and then if you can make some arrangement then it can be stabilized.

One such technique is soil nailing and soil nailing is basically is a rods generally reinforcing, steel rods it can be anything else also but basically we use a steel rod and you insert in the soil and sometime by force sometime by making a drill and then with the grouting you can put it, in the different ways that soil can be inserted which will be act like a nail in the soil and that will help to stabilize the soil, the entire soil mass that technique is soil nailing, this is very loosely I have to told about the soil nailing but in very specific and technical way I will try to discuss one by one.

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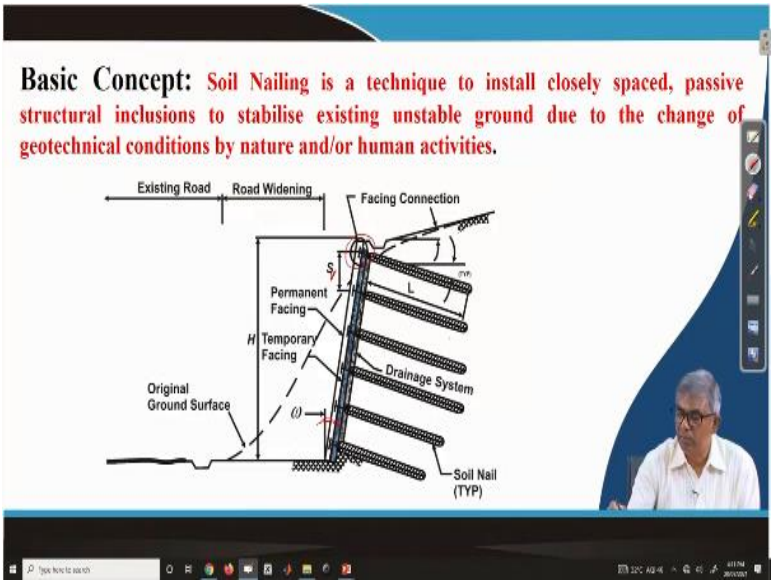

Let me take the first slide that is the basic concept as I have told you can see that it is a technique to install closely spaced passive structural inclusion to stabilize existing unstable ground due to the change of geotechnical condition by natural and or human activities. You can see whatever the because of the manmade or human or natural activity, natural or human activities and I will just give you the example of human activities first.

You can see here suppose this is the natural slope of the ground and quite stable but suppose I wanted to suppose, there is some road or something and you want to extend and go up to this, then you have to cut this soil here and if you want to make natural stability then soil you have to cut from here and slope like this, otherwise the soils will be collapsing. In that this much volume of earth work will be quite expensive to avoid that instead of doing so much of earth work we can make with a mild slope and this type of inclusion as in the form of soil nailing and if I do that then entire this zone will be stabilized. This is actually by a large soil learning that means we are actually close this space means if there is some 30, 40meter then you have to have some horizontal interval and again suppose it is 8 to 10meter deep then again, some vertical spacing will be there and always this nail will be inclined to the horizontal like a downward you can see, this is the way actually the soil nailing is done. This is the example of man-made activities and

because of the modification otherwise the earth was stable but because of this human activity that means widening of road these become unstable and to make stable we can do this arrangement.

And what is the natural change of condition? Sometime there may be erosion, sometime maybe landslide, slope may change and then to avoid further falling or destabilizing one can do this type of work to restore the things or stabilize the thing. This is the way actually soil nailing can be done and improve, stabilize the soil mass, so this is the basic concept.

Now let me take other aspects, so here you can see that this side is the earth and there are different components actually shown actually this you can see here and I have taken one small circle here you can see and this can be shown in the next slide what are the details connection here and you can see this is the reinforcement rods, generally these are all reinforcement in the middle and these are all on drainage layer and that this actually can be shown in the enlarged view, permanent facing is this one and temporary facing is this one, and this is the drainage layer, there three layers will be there.

And then nails head will be here and this direction whatever slope that is W, and this direction what about the slope that is suppose beta and this is a vertical spacing this is actually S_v, not S_r and this is other direction we cannot show that is S_h, so these are the different components and, sorry.

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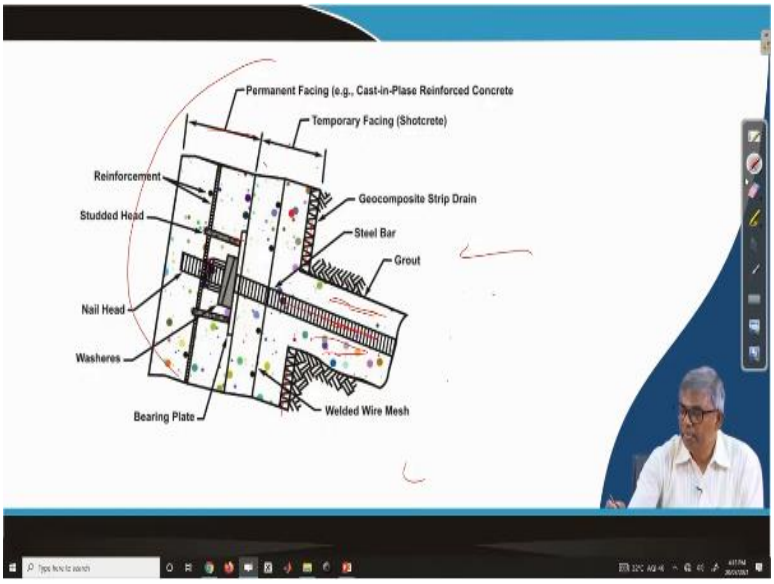

Let me go to the next slide, you can see that as I have told you that circle mark is enlarged here and you can see here detail and you can see here this is the main nail and then if it is a grouted then if we made hole and then nail is provided then this grouted portion that is to hold the soil within the soil mass that entire grout rod together, so this portion is grouted and this is the rod and this side is earth.

And then you can see as we have mentioned that the beginning there will be a drainage layer and there will be some temporary layer, this is the temporary layer this one and this is the drainage layer, this is general drainage layer, this is the temporary layer here and this is the permanent facing and then there are reinforcement will be there different direction, then this is the washer and this is the washer and this is bearing plate and this is washer and this is nail head and then there are to be in place the studded head will be there they connected. This is all detail of the connection of soil nail.

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Then let me go to the next slide to show you some more information you can see now that the soil nailing as I have mentioned that it can be directly pushed or it can be the different ways it can be constructed, so what are the different ways it can be done, there will be grouted nails that means we can make a hole and with grout and the nail can be input, the grouted self drilling nails we can drill and then it can while drilling it will go inside that is self draining nails.

And jet grouted nails there is another, then helical nails, then driven nails and then shooting nails, there are so many types of nails but out of that commonly used grouted nail, this is easy to construct and it is suitable for many soils, because of that this is the type of, though there are different types of there nails are available, generally grouted nails are used more popularly and other support are used different occasion, that details I am not showing here.

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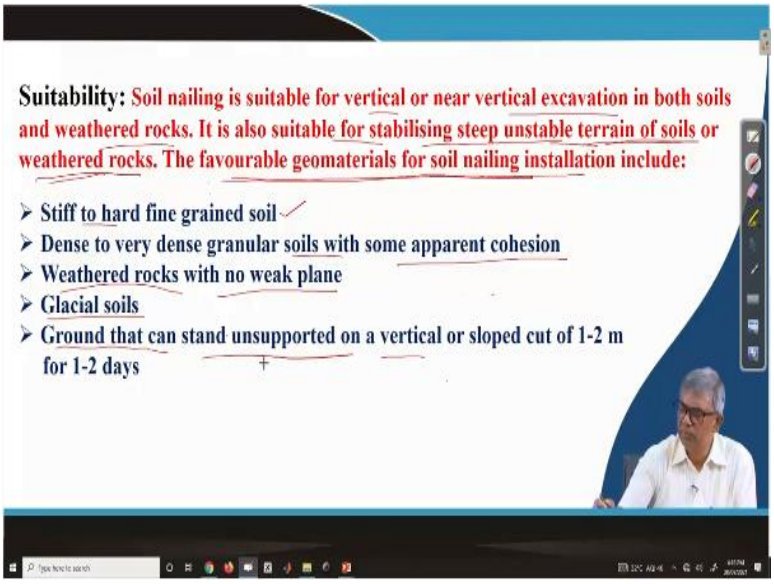

let me go to the next slide, suppose for everything whenever we have discussed that any method first of all whether it is suitable or not because of that you have to check suitability and where it will be suitable that we have to check and suitability of soil nailing, soil nailing is suitable for vertical or near vertical excavation, which I have shown in the beginning and vertical or near vertical excavation and both soils and weathered rocks, soil, rock both it can be like.

It is also suitable for stabilizing steep unstable terrain of soils or weathered rocks, so generally the excavation is the natural one as I have told you that because of this natural that is unstable terrain of soils or weathered rock, if you find that it is unstable and it needs to be stabilized this can be used and favorable geo materials for soil learning so what condition, what geo material suitable for soil nailing is listed here. Steep to hard fine-grained soil, steep to hard fine-grained soil, that means clay, soft clay it will not work.

Dense to very dense granular soils with some apparent cohesions, so if there is no cohesion very difficult to make it useful, dense to very dense granular soil with some apparent cohesion, that weathered rocks with no weak planes, so we are nailing but if there is a weak plane get separated then it will not be effective, so that is a weathered rock with no weak planes.

Then glacial soils, then ground that can stand unsupported on a vertical or sloped cut of 1 to 2 meter or one or two days, that type of soil, this is a general guideline, ground that can stand unsupported on a vertical or sloped cut of 1 or 2meter height for one or two days that type of soil can be used this nailing, this is suitability.

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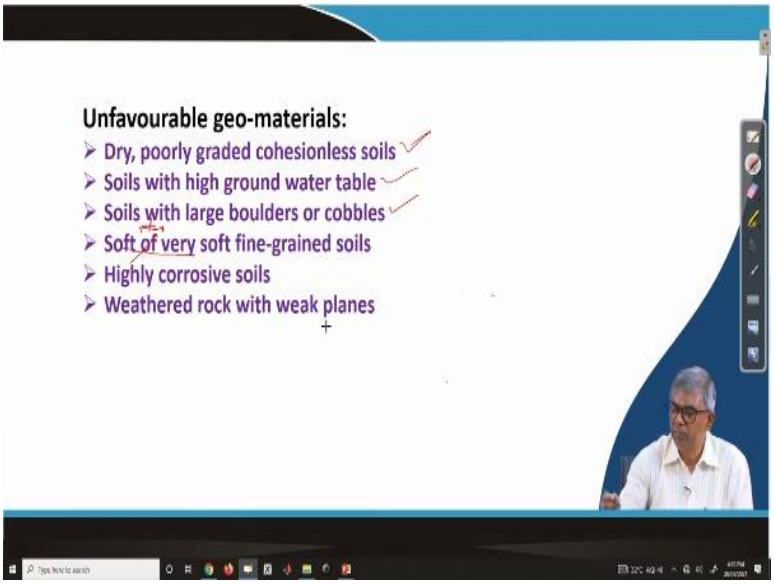

And similarly, unfavorable condition, you can see here, the dry poorly graded cohesion-less soil, cohesion is required that is what cohesion dry, sometime it will be dense, if very dense is suitable but with a dry poorly graded cohesion less soil then this will not be useful, soils with high ground water table that is also not suitable, then soils with large boulders or cobbles that is also not presentable, soft to very soft, very soft fine grained soil too, this is a typo, soft to very soft fine grained soils and highly corrosive soil because we are using steel rods, if it is corrosion effect is there that it will be not be useful, highly corrosive soil then it will not work and weathered rock with weak planes, already we have mentioned when suitability weathered rock is suitable but if there is weak plane it is not suitable.

Here as an unfavorable geo material condition it is listed here, that means what we have seen that dense to very dense sand is useful but your dry and poorly graded cohesion less it will not be suitable, similarly soil with ground water so we have mentioned there the

ground water should be below the base of then only it will be working, here soils with high groundwater will not be suitable.

Soil with large boulders and cobbles obviously it will not be useful and then it will be difficult to nail it and soft to very soft fine grained soil we have mentioned that medium to highly steep soil is suitable, that means soft soil is not suitable and highly corrosive soil is not suitable, weathered rock with weak plane not suitable that we have just contrary to the what we said before in the favorable geo material, here so these are the things unfavorable, that means geo material, where you cannot think of doing soil nailing.

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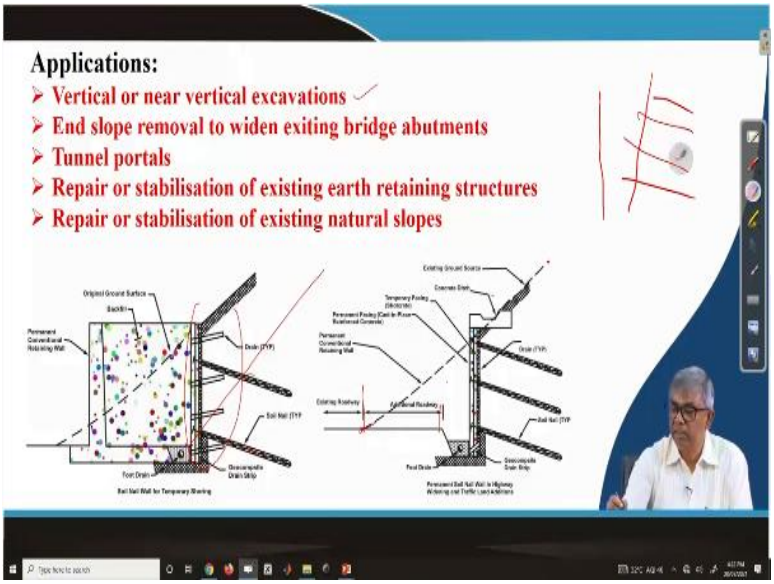

And this is the applications, application of soil nailings are quite wide range of application will be there and you can see here through three case sketches I will show you and before that let me explain what is the vertical or near vertical excavation. This is one where you want to cut like this or you cut like this, then the soil cannot stand without support of unlimited length, if you want to make some height which is beyond that height up to which it will be self stabilized then you have to do something, either you have to put anchor or you have to put nail or you have to do some other mechanism.

Here if you do this then you can soil lane like that you can do, here you can see some examples are shown here. Suppose, if you want to make a retaining wall somewhere here

and soil is somewhere like this and then that you have to the heel of the retaining wall will go up to this, that means you have to excavate so much and then while doing this so much excavation and if you want to do, then you have to do it like this slope so that is not permissible, because of that we can the point up to which that effect of retaining wall will go or boundary of retaining wall from there you can start excavating by providing soil nail like this.

Soil nails are this, soil these are nails and these are drains, if there is water here it can come down and through that it can be collected, this is actually there will be a soil nail wall and then after construction of that this can be backfilled. This is one mechanism then another mechanism suppose here, a permanent we can do soil nail wall in highway widening, suppose this is the one and if you want to widen, this was the highway limit and you want to, this was the cut, slope of the soil and if you have to extend this then you cannot just cut like this, so because of that actually we can provide soil nail which we have shown in the beginning and we can make this is the structure, we can make soil nail wall we can make.

This is the vertical to near vertical excavation in slope removal to widen extra extending bridge abutment, this is the one, then tunnel portals, then repair or stabilization of the existing architecture structure, repair or stabilizing existing natural slope, this one example I will show in the next slide.

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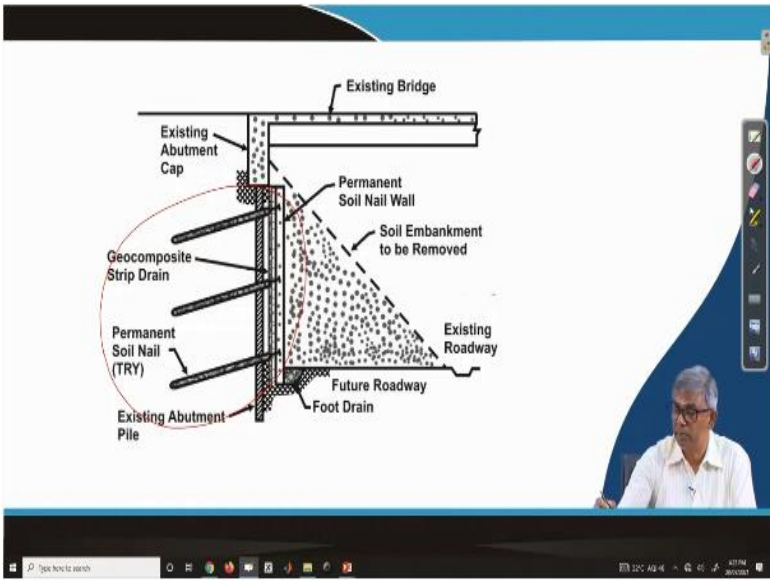

That here original abutment was this one and this was the pile foundation suppose and there may be some restoration is needed in that case we can have soil nailing in front of that like this, soil nailing in front of this soil nail wall can be made and this soil embankment to be removed, this if you want to remove then permanent soil, so originally this was the abutment and this was the soil position.

If you want to cut this one then we can provide this soil nail system here. This is the modification of existing abutment for widening purpose, this is some application in three picture or schematic diagram, and I could explain there can be many, if you see any text book on ground improvement.

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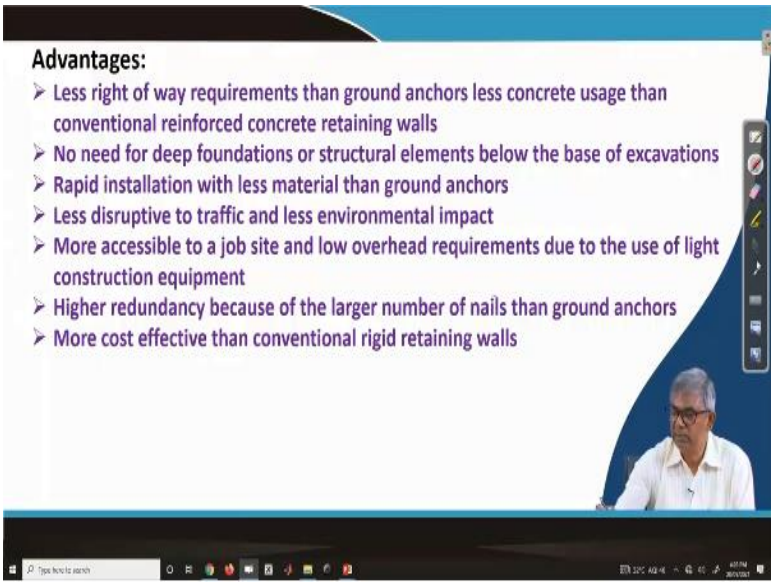

And then some advantage and disadvantage. Advantages will be less right of way requirement than ground anchors and less concrete uses than conventional reinforced concrete retaining wall. This if you want to do the soil nailing and then if I want to do the same thing, I could have done by conventional retaining wall but cost will be more that is the first point and less right of way is required because for construction, if I want to do retaining wall then right of way actually lot of things are required, some area will be required but here we can do almost vertical so because of that this advantage is.

No need for deep foundation or structural elements below the base of the excavation, so you can see that sometime you do if I mean, below that you need to do some pile foundation or this but here actually there is no need. A rapid installation with less material than ground anchors, anchors of course, I will discuss later on, here very rapidly it can be done, in fact it can be done anchor and soil nailing almost similar so because of that its comparative statement is given here, it is rapid installation with less material than ground anchor, so ground anchors we will discuss later on.

Less disruptive to traffic and less environmental impact, that is also there because since right of way required less, disturbance to traffic also will be less and more accessible to job site and low overhead requirements due to the use of light construction equipment,

obviously it will be accessible to any site and since there will be no heavy equipment is required, it is easy to do.

And high redundancy because of the larger number of nails, so very large number of if one fails, still there are many to keep you intact, to keep the soil mass intact, that is why is large number of redundancies, that will help to stabilize the system and more cost effective than conventional rigid retaining walls that also I have told in the beginning, these are all a very good number of advantages will be there for when you adopt soil nailing for stabilizing the slope.

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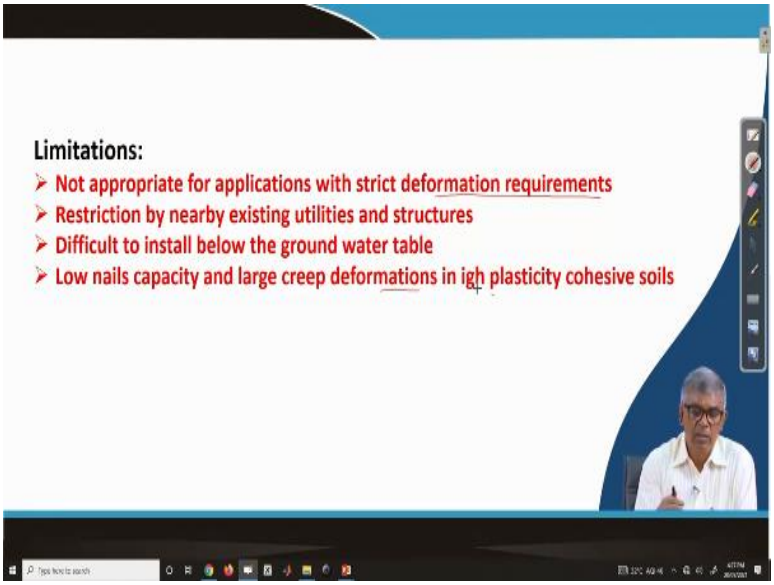

Then limitations also there, not appropriate for application with strict deformation requirement, suppose if you want to the deformed wall should not deform this much and you want to restrict then sometime it may not be able to satisfy that, there can be that is and then restriction by nearby existing utilities and structure, sometimes it is there and there are some existing utilities then you cannot put nailing because this may disturb.

Difficult to install below the ground water, already we have mentioned that below ground water table this cannot work, no nail capacity and large creep deformation high plastic cohesive soil, because of that in fact soft soil is not suitable, these are the limitations for use of soil nails.

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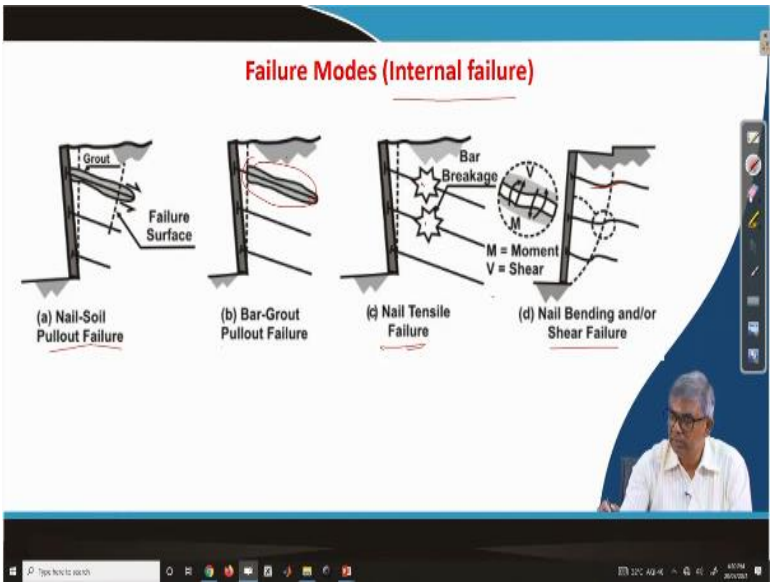

And then next most important aspect is the failure mechanism, that soil nail wall can fail in different ways and you can see I can show you that internal failure, external failure, global failure in three different groups is there and then again in each group there are again several subgroups will be there. You can see here that this is the failure modes internal failure, internal failure means within the soil and nail there will be some failure and you can see in this again there are number of them.

Nail soil pull out failure, so nail soil pull out failure, that means grouted nails are there, entire thing whatever strength it could develop and if the load in the wall is more than entire thing may come out, that means whatever resistance required it cannot develop by this whatever you provided, then it will fail and that is why you call nail soil pull out failure, that we can see this entire thing, entire thing with wall will come out, that means walls are moving with nails also coming out from the soil mass, that is the failure.

Then bar grout pulls out failure, the second bar grout pull out, so here this is the grouted zone and, in the grout, and this is soil then grout and then inside this a rod, but if between the rod and grout, if there is insufficient bond then sometime there will be rod only from the grout may come out, you can this what, the grout is there and in the soil itself only that nail is coming out, that is bar grout pull out failure.

And then you can see here nail tensile failure, when it will be nails and number of nails are designed and installed but if the load is such that whatever develop tensile strength is and if the available strength has strengthened the rod is less then obviously it will break and that is the breaking nail tensile failure, so this is it may break like this because of the heavy tension.

And then nail bending and or shear failure, you can see if that happens and then that too much of bending or because of the shearing, then the proper direction and also will change as a result the nail will be ineffective. This is about the failure modes and that is again internal failure modes, there are again external.

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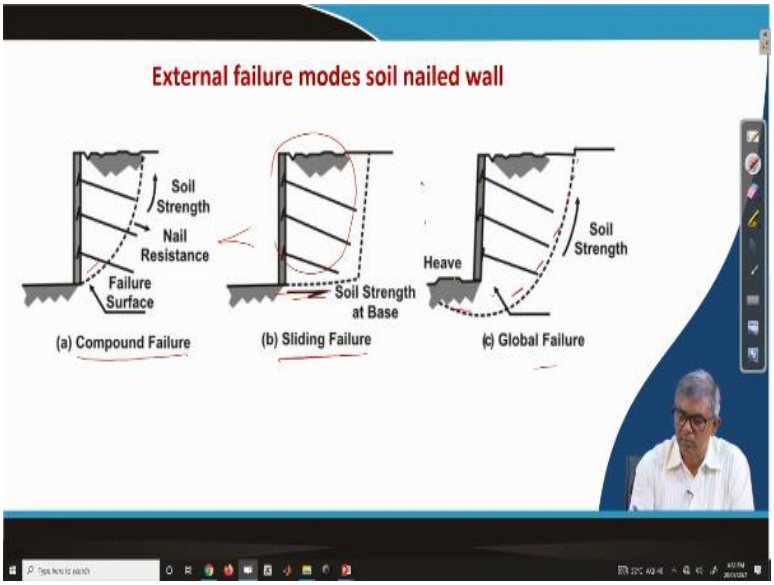

The external failure mode of soil nails wall and you can see again here number of them. Compound failure, you can see here that entire compound failure means it will be the soil will fail or if the nail will fail and here like this, so this is a compound failure and then soil, that will be sliding failure, there may be, this portion soil nail is quite tensile strain, quite bond strength between the soil and grout nail and between the grout and nail all those things are good.

But there may be whatever as this is the total body and whatever force develop horizontal force that it will have tendency to enter things move in this direction, whatever resistance

developed at the base, if it is insufficient then entire mass can slide this direction, that is sliding failure of the soil nail wall.

And then global failure, you can see here there may be this portion of soil nail may be stable but there will be somewhere it there may be weak zone and the entire thing may slide, that is called that global failure.

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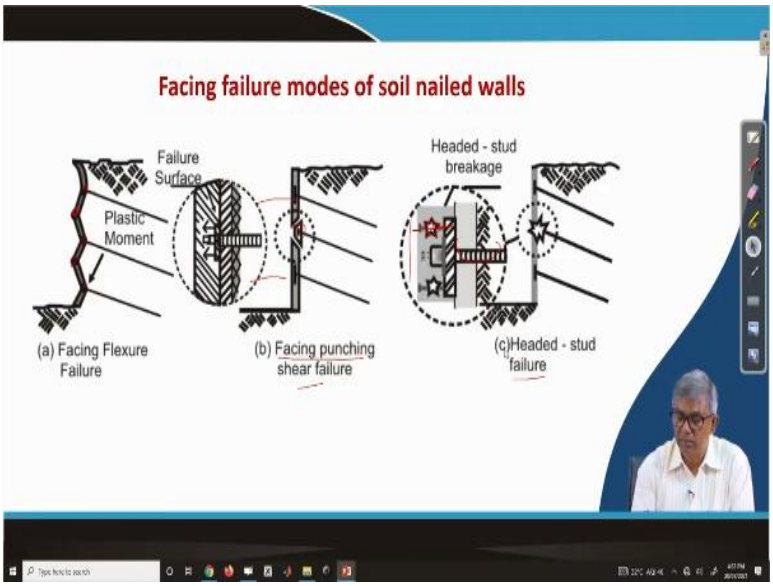

You can see the facing failure modes of soil nail wall, as I have told you in the three groups, I have divided internal, external and facing failure. Whatever I have shown and details of facing element I have shown, there you can have this facing flexor failure, you can see it can be like this, it can bend like this, if it bends like this then there may be weak point here, weak point here, weak point here, weak point here we point here like that this may cause the failure of the wall.

And then there will be facing punching failure, we can see because of the heavy tension the entire this nail and will be here and this one will be separated like this, so there will be punching of the nail and then there will be headed stud failure that means this portion this may fail, so this is connected between these two and this may fail and if it fails with this, this is the one from here to here there is another layer it is connected, if it fails then entire things also will fail. These are all different modes of failure which I wanted to

discuss here, so considering this aspect finally we have to design the nail wall, that means what will be the spacing, what will be the etcetera, etc., those things but before going to that again.

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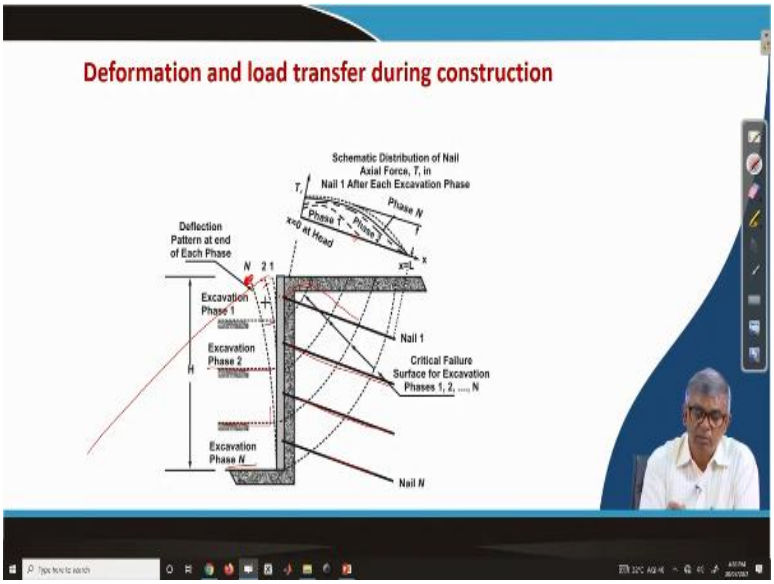

Let us show you the deformation and load transfer during construction, you can see here then when soil nailing will be there, initially there will be intact soil will be here suppose, then you have to excavate up to this maybe first level of nail will be there and then the movement, how it will be the movement, it will be little movement will be there then when you will be excavating up to this and then second level of movement nails will be provided then what should be the wall movement, may be this much.

And then when you excavate up to this and then this level of nail is provided then what will be the movement, movement may be soil wall movement may be like this and then we go up to this and then finally you nail this one and then final movement, the soil movement of the wall or the space will be different stages you can see it can be with increase of depth lateral the deflection pattern will change.

And again, with this on the nail again how the load transfer will happen, you can see here phase one, phase two, phase three there are three diagrams are shown, phase one actually later, less amount of it will be at the close to the surface, it will some value, then it will be

with distance will be increasing it will reach to a maximum somewhere suppose it if it is distributed like this and then it will become 0 at some distance.

Similarly, when it is stage 2 it will be the effect will be increased further and at the level 3 again it will be increased further, so that is the way load transfer will happen. So, nail 1, nail 2 etc., it is shown in this diagram. Schematic distribution of nail axial force and this is when excavation progresses and the nails are applied, then how the deflection of the wall will happen that is given in this direction.

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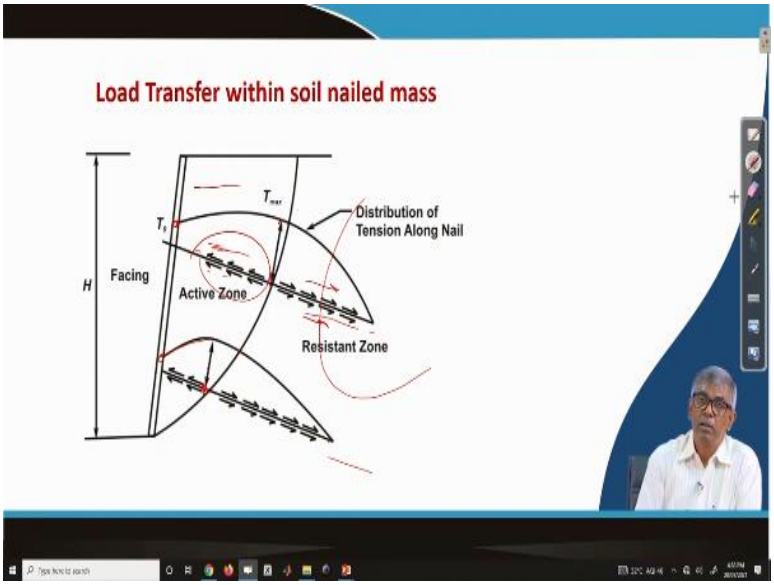

And then load transfer within the soil nail mass, you can see that when, this is the wall, and this is the nail and then there will be a failure surface and when the beyond failure surface, this soil will be intact that is resisting zone and this soil is active that will be moving this direction away from this backfill. when the soil moves this direction then obviously this shear direction will be this and when it is this rod is pulling this direction then direction of shear will be this direction, so this is the one because that means active zone the direction of development of shear stress will be along this towards the wall and direction of shear will be towards the backfield within the resistance zone.

This is the one actually or so if this is the level there is rod, so up to this is the direction, beyond this is the direction. Similarly, another rod, another nail is here or this much

distance will be in this direction and this much direction this direction and if I try to find out distribution over length then it will have some value at the head and then it will be increasing up to some distance and then it will be decreasing, a little bit increasing maxima at the close to the failure surface it will be reaching maximum and then it will be decreasing and will be becoming zero.

Similarly, here it will have some value at this phase and then it will be increasing and increasing at this point maximum then it will be decreasing at some rate. This is the distribution of shear strength along the length of the nail during the.

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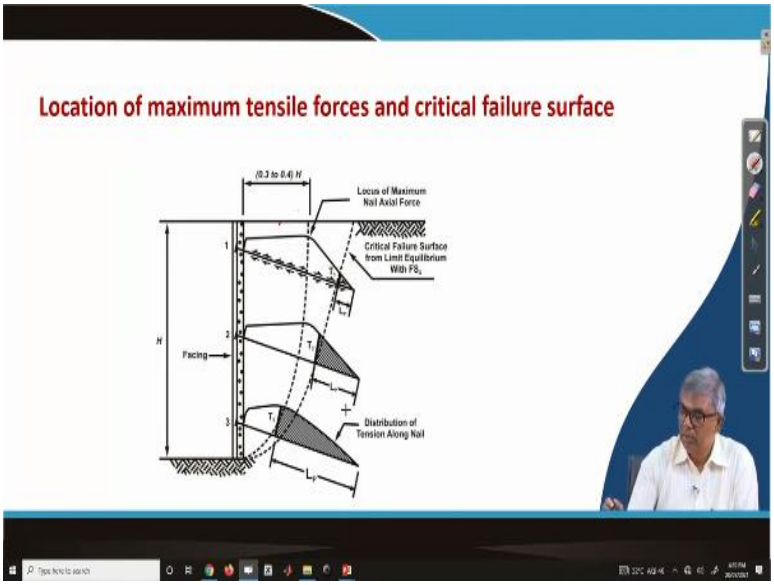

Again this is location of maximum, so already we have mentioned, this is the failure surface, this is the failure surface, wherever there is a failure surface so that is will be the maximum one, so this is actually, so if this is the failure surface then this will be the L_p and if this is the failure surface this is the L_p, so like the if this is the failure surface this is the L_p, so like that we can decide which can be used in calculation, which I will show you in the next module and so these are all various aspect of soil nail which I wanted to discuss here.

And next part I will try to discuss that is your design aspect, that means whatever aspect you have mentioned for the failure mode, then the active zone, passive zone then the

direction of shear all those points to be considered and finally to be designed and that various design aspect I will discuss in the next module, thank you.