Ground Improvement
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Lecture 38
Grouting (Contd.)

Hi everyone, let us once again continue on ground improvement and module eight, Grouting. And this is a typical ground improvement technique which I have already mentioned through a few lectures and today I will try to discuss on types, the different types of grouting which I have mentioned already and their application.

And the many other ground improvement technique we have mentioned, they are not, it is not suitable for a particular type of soil, different soil different technique has to be there, so similarly here also it will be there.

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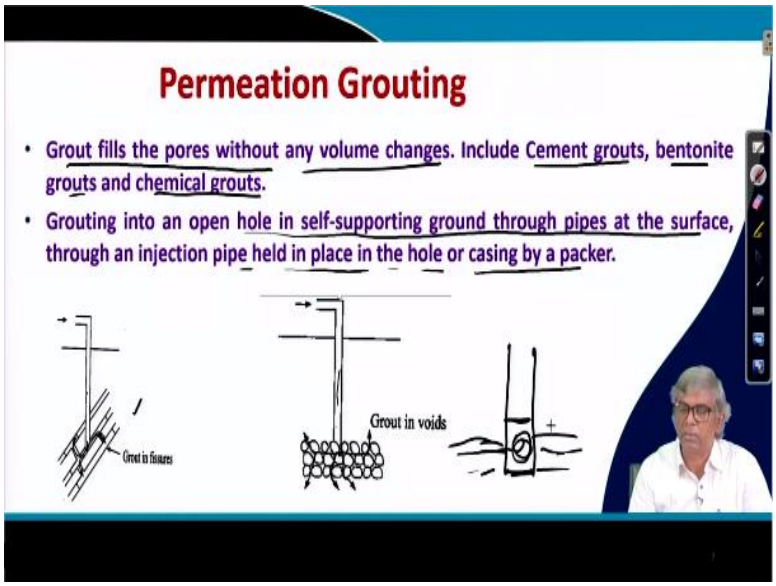

let us take first slide, already perhaps I have mentioned at the very beginning that permeation grouting and this permeation grouting, means that it will not be under pressure, it will be grout solution will be there and it will be move through the interconnected void spaces and two schematics are given here.

One actually applicable for rock this one, this through the fissures in the crack in the rock, the grout if it is there, if I push grout here it will move like this, it will move like

that, it will move like that, it will be wherever there is a weaker zone, it will enter and then after solidification it will be strengthened.

Similarly, when it will be a granular soil then you can see the soil, if you see the inner view then there are the grains and they will be there large number of grains and it will be contact with each other and the way it is shown it may not be so organized it may be very random but if I assume these are the grains then if I push grout through this and then the grout on center and then it will be moving somewhere at this point.

Then it will move through this like that through the interconnected void space, it will try to move as far as possible through, because of the permeability characteristic of the mix and the void characteristics of the soil. This is your permeation; this will be done through permeation grouting and so here as it is mentioned that you can see grout fills the pores without any volume change.

Here actually if this is the original volume this volume was lot of void spaces, this grout enters, and occupied the voids and it will become more denser, that is all it will happen but no way the volume will change that is why this is the most important. Permeation grout fills the pores without any volume change and it includes cement grouts, bentonites grouts and chemical grouts.

Any types of grout which can be used the all three categories and but they enter so grouting into an open hole in self supporting ground through pipes at the surface, like this and if it is a self supporting this can be given like this through an injection pipe held in place in the hole or casing by packer.

Sometime it will be like this we want to permeate through this then packer will be given two, packer here, packer here or sometimes single packer, double packer so you can put grout here and some pressure then it will be permeated, through this surrounding place. Either by vertical pipe and put and grout or sometime like that packer system also can be done if the permeability is little less than in that case this can be used,

This is permeation grouting and what are the use of permeation grout, application of permeation grouting, there are number of application of permeation grouting, let us see that.

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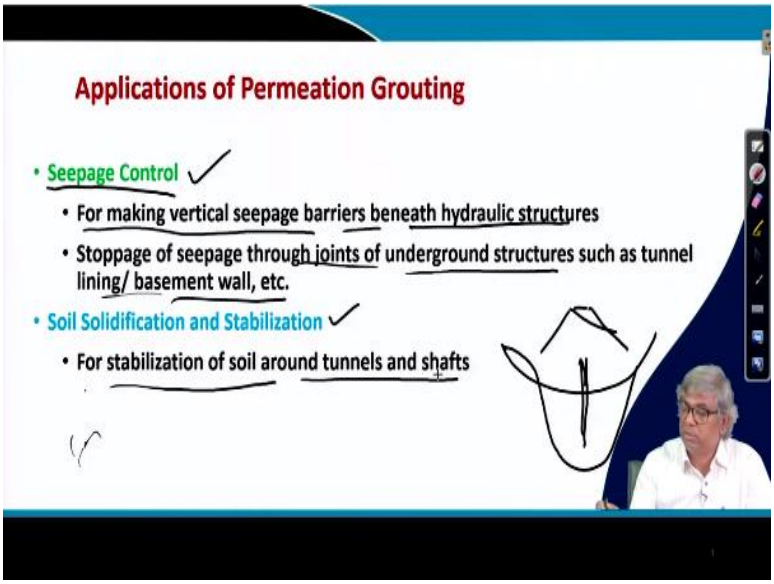

Permeation grouting application will be as seepage control that is one of the most important applications of grouting. One is seepage control, for making vertical seepage barriers beneath hydraulic structure. Hydraulic structure means like this something like this and so if water moves like this then the foundation will be weaker instead of movement like this some vertical barriers can be there, water will be move like that so that directly it will not spoil the foundation.

This is actually for making vertical seepage barriers beneath hydraulic structure and stoppage of seepage through joints of underground structure such as tunnel lining, basement wall etcetera. There are sometime underground structure, there will be some joints and through those joints there can be leakage and that can be stopped by using this type of permeation grouting.

This is first application is seepage control and second is soil solidification and stabilization, that means by injecting permeation grouting and then subsequently it will be solidified that ground will be improved, so that is also another application for

stabilizing of soil around the tunnels and shafts. That is the application by permeation grouting, these two basic applications, I will show the schematic diagram of all at the end together, I could have shown here also but it is there at the end.

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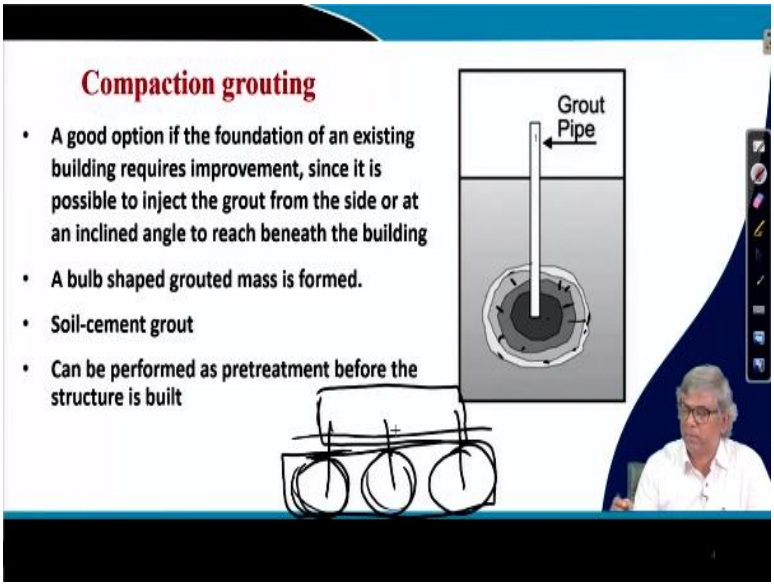

Let me go to next one, the compaction grouting. Compaction grouting as we have mentioned before that it will be like that, if this is the one so through this grout with in pressure it will be applied and you can see with pressure it will occupy some volume and when it will be heavy pressure you will try to occupy more volumes.

When fluid is pressurized then you will try to occupy in more volumes and that pressure will be released and how it is possible, then surrounding soil will be getting compacted, you can see that the soils, up to this soil is supposed compaction, and this much is the fluid. Initially soil was here, the soil is displaced and grout is entered, so as a result this surrounding soil is densified.

Here there are number of applications particularly, good option if the foundation of an existing building requires improvement. For example, existing building is there and there are some distresses is observed and to be improved, it is possible to inject the grout from the side or at an inclined angle to reach beneath the building, that means without

disturbing the building we can inject and that helps, that compact the ground and that sometimes helps in rectifying the problem.

And what happens when you inject a compaction grout bulb shape grouted mass is formed, bulb shapes you can see this is the one, this is the shape and there are different types of things that soil cement grout can be used and then it can be can be performed as a permanent pre-treatment before the structure is built.

That means suppose there is a site and we can number of points you can make permeation grouting and then suppose this because of this area is compacted, this area is compacted and then this entire area you can say is getting compacted and then if I build anything it will be suitable. Otherwise suppose originally this before grouting the ground was soft and unsuitable for building, so you can beforehand.

One of the most important applications as we have mentioned that you can inject and then on the existing building and all and otherwise also in poor soil, in the pre-treatment can be done, that means we can number of points we can do compaction grouting and each compaction grouting point you can see area of influence of each point is like this and if I join them, that means and approximately this much area is densified or it improved.

Now this because of this improvement, now this side become suitable for construction, this is the way it can be done.

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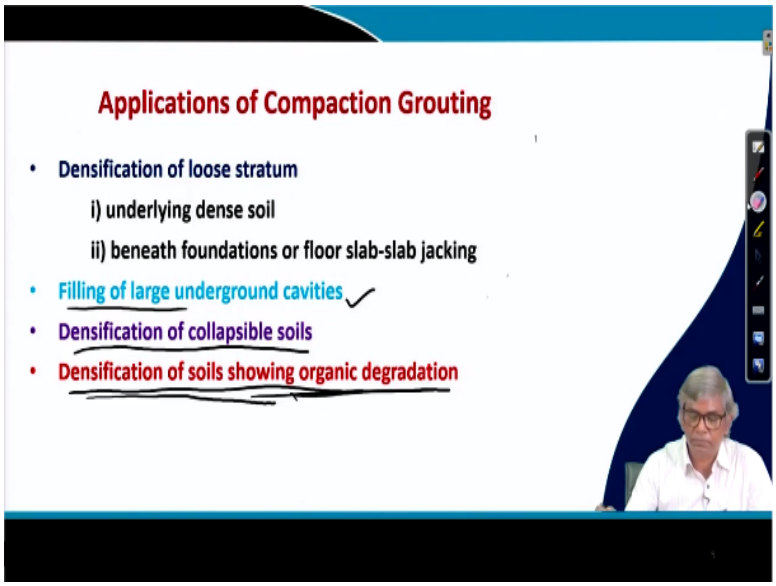

And what is the application of compaction grouting, let us see a few applications there are a number of them. Application of compaction grouting you can see densification of loose stratum, and you can see underlying dense soil and beneath a foundation or floor a slab jacking, floor slab jacking and that I will show you at the at the end, there will be number of schematic figures will be there, how it is done.

And another application is filling of large underground cavities, you can see this one, there is a void inside the ground then we can treat it by compaction grouting and densification of collapsible soils, that means whatever the soil you can by compaction grout, the soil which is supposed to be collapsible and if we can do compaction grouting then it will be densified and because of this densification it will be improved.

And densification of soil showing organic degradation that also so that we can by this the chemical solidification that also can be prevented. These are application for compaction routing.

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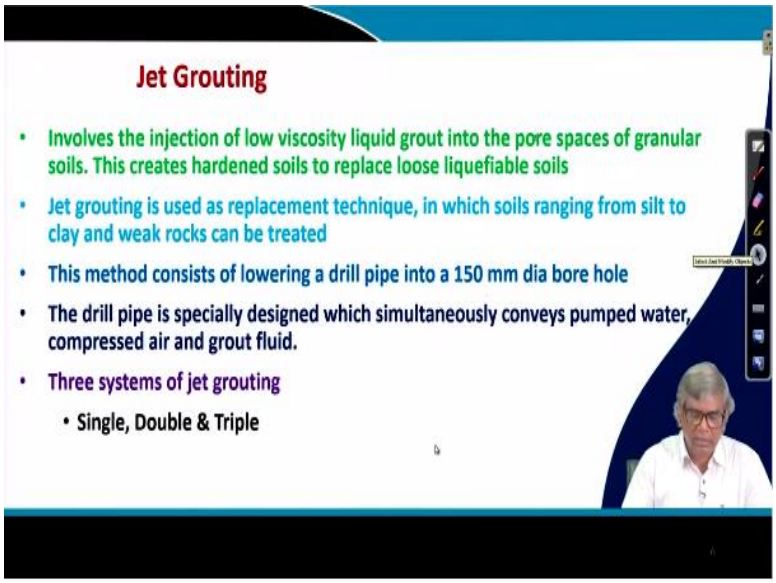

And then jet grouting. Jet grouting from the term itself is quite obvious that there will be some jet will be injected in the something will be injected in the form of jet and that fluid and that will cut the soil and then and will mix with soil and then finally it will be a column like things will be formed and which will help to improve the ground.

Here in the jet grouting involves the injection of low viscosity fluid grout, liquid grout into the pore spaces of a granular soils, that means, what I have mentioned that injection is there that through injection that low viscosity liquid grout in the pore of the granular soil it will be injected and this creates hardened soil to replace loose liquefiable soil, so wherever there is a liquefiable soil this can be replaced by this hardened grouted mass.

And jet grouting is used as replacement technique, replacement technique means deep replacement which I have discussed also, one replacement method is that wherever there is a weak soil we can excavate and then we can bring the good soil and that is one technique, easiest technique which we have discussed in the introduction part itself and there is a deep replacement we have discussed, where that we are not really removing the soil but we are displacing the soil by some means and then those displaced area, that volume created by displacing the soil we can fill it with some material.

Here that grout is the working as a replacement, so this is the jet grouting used as a replacement technique in which soils ranging from silt to clay and weak rocks can be treated, so these are the areas where this replacement technique can be used also as specified and this method consists of lowering a drill pipe into 150 mm diameter bore of bore hole, so that means we have to make borehole and then through the pipe we have to inject and drill pipe is specially designed and which simultaneously conveys pumped water, compressed air and grout fluid.

Here I will discuss that grouting, jet grouting will be of three types, one is single jet or single fluid or double jet or double fluids and triple jet or triple fluid. I will show that in the next figure that sketches and there are the drill pipe as it is mentioned that drill pipe is specially designed with simultaneously conveys pumped water, compressed air and grout fluids. Depending on those three different types of jet grouting's are there and you can see that single jet, double jet or triple jet or single fluid jet grouting, double fluid jet grouting or triple fluid jet grouting, so these three are shown in the next sketches.

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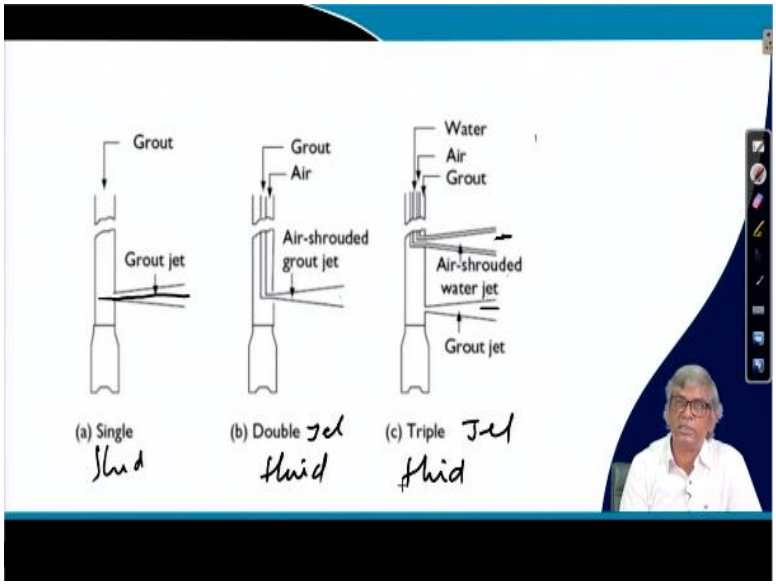

You can see here this is the one and you can see grout, only grout is in the form of jet is injected in the soil and because of the pressure it will cut the soil and it will mix with soil and form the column, and here you can see here air and grout both will be there, air

shrouded grout jet will be here and because of that soil will be cut and then mixed with grout.

And here you can see the three jets will be there, air shrouded water will be here from here and then grouted jet will be here and this together ultimately the same function but different ways it can be done depending upon type of soil. This is the three different type of, single jet or single fluid, sometime it is called double jet or double jet or double fluid and it is triple jet or triple fluid jet grouting, three different techniques there for injection purpose of the grout.

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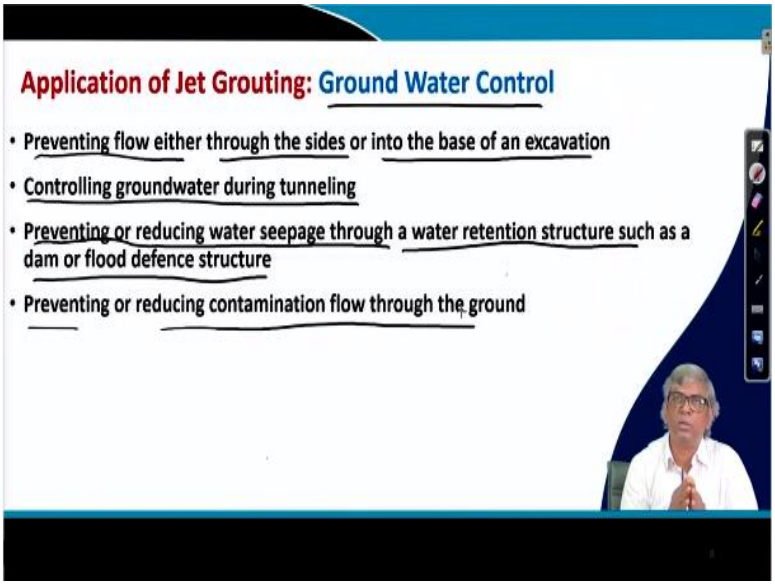

Now let us see the application of jet grouting. There are three different types of application will be there for jet grouting, the one is, first one is the ground water control and here you can prevent flow either through the sides or into the base of the excavation, that is one, wherever we will see that there is a chance of water movement then we can jet grouting can be done and that can be prevented a flow.

The controlling groundwater during tunneling, during tunneling also if there is a chance of upper soil will be loosened and then will fall, before that we can do jet grouting, then preventing or reducing water seepage through a water retention structure such as dam or

flood defense structure, that means dam particularly preventing or reducing water seepage.

So generally, dam structure through that water if movement is there then dam will be deteriorated, it has to be prevented or it has to be minimized for that that is a jet routing can be done and preventing or reducing contamination flow through the ground, that is another important there is either ground.

Sometime we have ground water which will use and if you find that there is a chance of some fluids, movement towards some groundwater or some ground and then you can prevent that movement by doing jet grouting, these are ground water movement where there is a chance and whereas there is a civil engineering structure, geotechnical structure and because of this movement of water there is a chance of getting deteriorated.

We have to reduce or prevent the movement; there we can do jet grouting. Here number of points are there mainly the main purpose is only to prevent or reduce the movement of water through the structure or base of the structure this is actually by and large. One important thing is that jet grouting can be done for ground water movement control, that is one by and large the point here.

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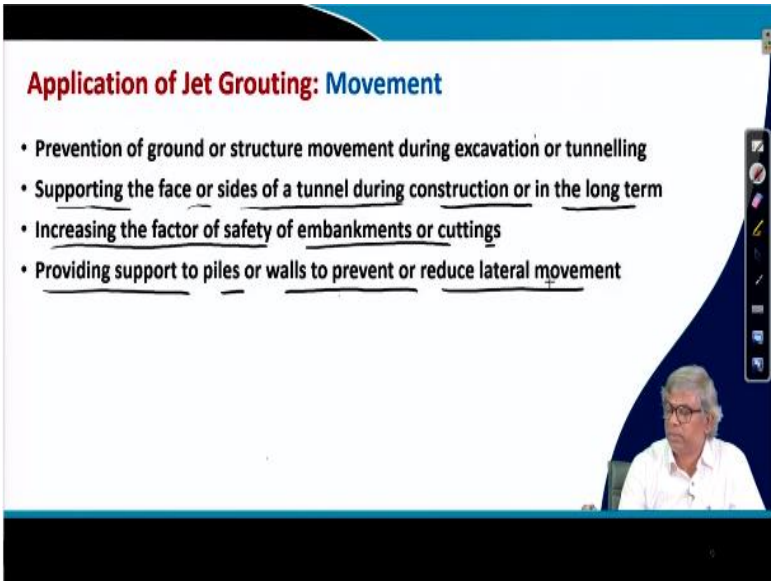

And then second point that movement, that means entire soil mass during some activity there can be there is a chance of soil movement, to prevent the soil movement sometime we can do the jet grouting so that is the different areas, here we can see that prevention of ground or structure movement during excavation or tunneling, during excavation the top soil there can be chance of subsidence, if you can do by jet grouting and you can solidify and then that chance will be reduced.

Then supporting the face or sides of tunnel during construction or in the long term that is another application. Increasing the factor of safety of embankments or cuttings that is also another, jet grouting can be done to improve the safety of embankments and cut. And providing support to piles or walls to prevent or reduce lateral movement, that is another application, these are all four applications whatever is mentioned it is only to prevent the movement of soil which may cause the danger to the actual structure.

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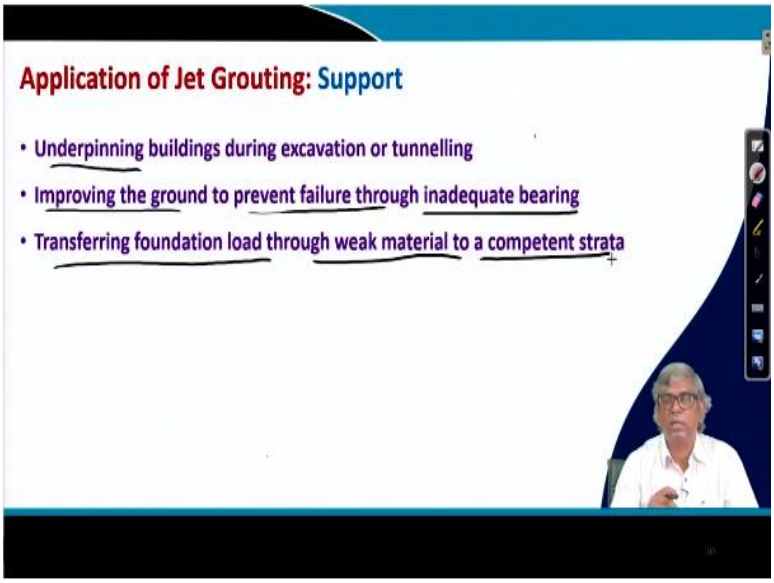

Then further it can provide, the jet grouted soil can provide a support that also already you have mentioned at the beginning you can see here, the underpinning, that is underpinning means the below the existing structure when we do the activity that is underpinning, underpinning buildings during excavation or tunneling during excavation of tunneling if it is above below the structure sometime it is going then below the building we can do some activity that is actually jet grouting can be done.

Then improving the ground to prevent failure through inadequate bearing, so when there is a particular soil inadequate bearing capacity is there and then if I build then it will fail obviously, the chance of failure is more to improve or to make sure that there no failure, we can do the jet grouting and improve the soil beforehand and transferring foundation load through weak material to a competent strata, that is also if you can jet grouted soil, mass is there then that will help to transfer the flow to a particular competent strata.

These are again, ultimately the jet grouting, the application is what is the control of water, movement of water, movement of soil and then support, these three different types of application will be there ultimately. The first one movement water what it does, it reduces the pores or it is a jet grouted column can be made which is having very less bearing permeability so it will prevent movement of water.

Similarly, movement means then when that will be soil will have tendency of movement during excavation or some other activities then we can grout the material, that ground will get a big mass together it will be there, that there will be no movement and there can be support that means we can do underpinning, we can do treatment of the soil, that is providing the better support, these three different applications for jet grouting.

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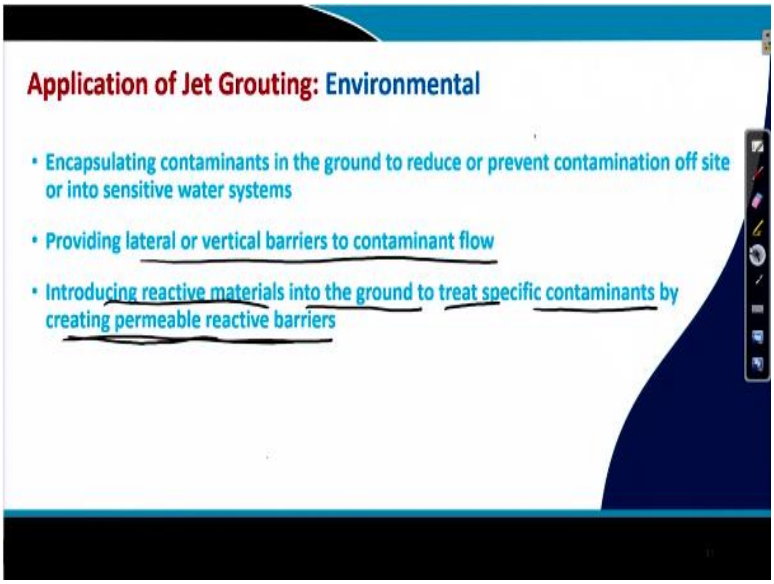

And then there is also environmental application and this is basically contaminants to prevent the contaminants to move into this particular area, this encapsulating contaminants in the ground to reduce or prevent contamination of site or into sensitive water system, this is the application and providing lateral or vertical barriers to contaminant flow.

If there is a, we can foresee that there is a contaminant flow in a particular direction then we can make a jet grouted wall type of things and so that this barrier can be made which will prevent this flow and also introducing reactive materials into the ground to treat specific contaminants, ultimately whatever we are grouted that material finally it will react to the contaminants and creating a permeable reactive barrier.

That is also another application can be there, this is ultimately the jet grouting will have four different applications, one is movement of water, prevent movement of water, then there is a movement of soil mass, then creating support and then the environmental, there are four.

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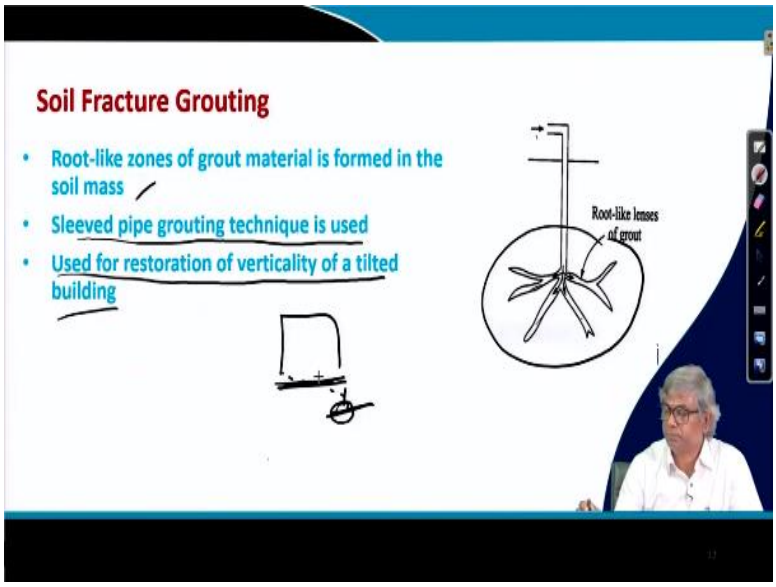

And then soil fracture routing which we have mentioned before, you can see soil fracture grouting what is happening, already I have mentioned perhaps through these with pressure if the whatever the shear strength of the soil is there and if through the grout if you can apply more pressure, then within the soil itself the fracturing will happen and through this fracture your grout will enter and then it will be like root like things will happen inside the soil and that will ultimately helps to strengthen the soil mass here.

Root like zones of grout material is formed in the soil mass, as it is shown in the figure and sleeved pipe grouting technique is used and used for restoration of verticality of a tilted building, sometime there is a building suppose and there is a tendency of tilting or it has become like this then in that case we can inject grouting here like this and when it will be injected like this will be volume will increase and then slowly it will be lifted and the soil the foundation will be leveled, so this is also typical application of soil fracture grouting.

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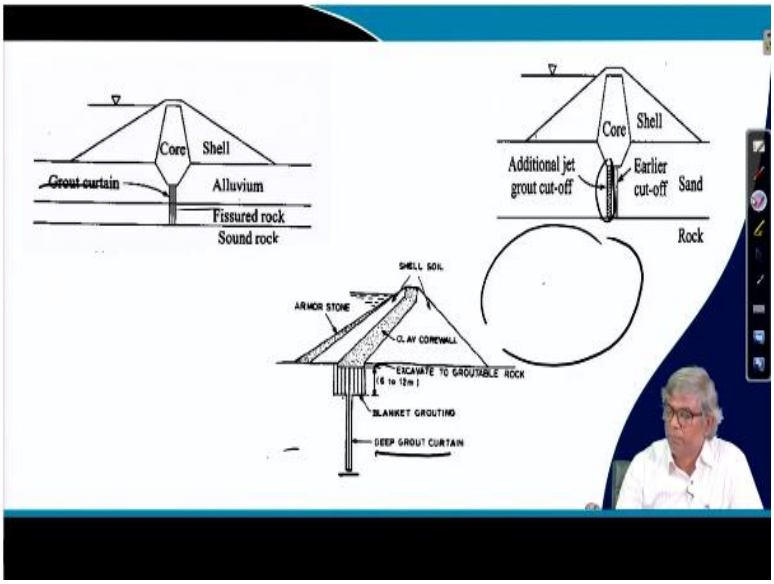

Now I will be giving you as I have mentioned that few schematic diagram of the various application, you can see here that we have mentioned that as a barrier the seepage control you can see that this is the water retaining structure or dam and there is a different types of soil below this and if there is no head and water is retained here this much then because of this high head there will be tendency of water move through this and because of that we can curtain, grout curtain can be made so that water cannot move through this.

If it is prevented then this will be foundation will be same. Similarly, here alternatively sometime there may be a cut off wall is made by some means and this is the cut off, original cut off walls and still little to strengthen further or reduce the movement of water additional jet grout can be made here to give again final cut off for totally.

And next one is you can see that this is the blanket grouting, there will be certain area is ah grouted and formed like a blanket and this cannot be done up to great depth then it will be expensive and difficult to do but to prevent movement of water we can make a deep grout curtain, so this deep grout curtain so from here to where this much grout curtain can be made, that way through this water movement can be prevented. This is some application preventing movement of water, here preventing movement of water or seepage control.

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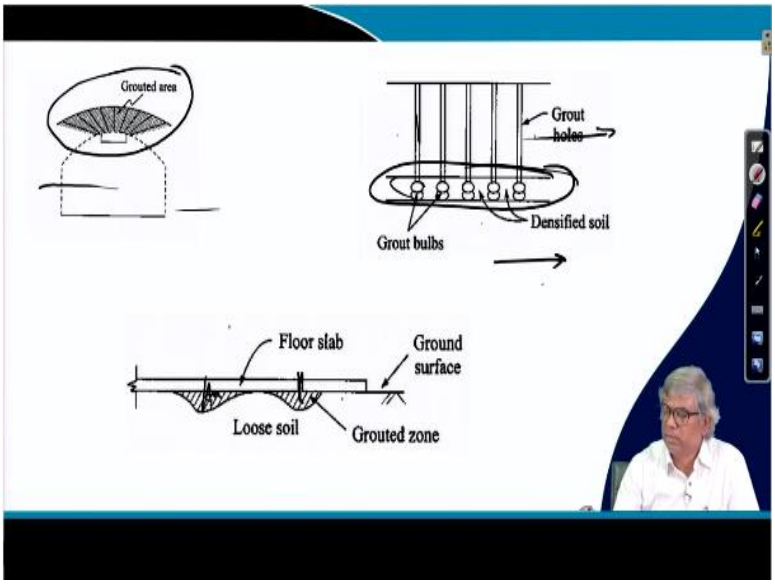

And here you can see these are that during tunnel this area, this soil if this area is grouted, sorry, if this area is grouted and then it will be strong enough then on this it will be, load will be reduced and less chance of collapsing of tunnel. Similarly, here suppose this is a good soil, this is also good soil in between there is a thin layer of weak soil.

Then you can see this grouting can be done like this and it can be this layer can also be strengthened and that this will be safe to support the structure and this is a slab jacking, you can see this is a slab and below that there is a swamp with zones in that case we can, can be grouted then it is called slab jacking.

If there is a weak soil and this is the slab and because of this non uniform deformation their cracks can happen, cracks can happen and slab can be broken, to make it intact, you can inject the grout, this weak point and to give a uniform support of the slab. This is some application as support, whatever I have shown before so this is some application as support.

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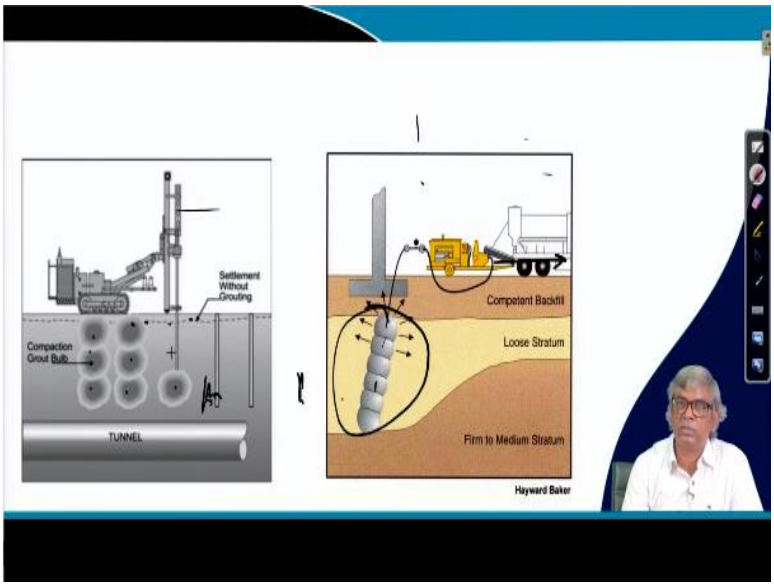

And this is some combination this is support fracturing and all, this foundation supposes, having weak soil below this and if I build suppose existing structure is here and there is a tendency of our estimated foundation settlement is supposing more in that case we can do the grouting below the foundation, this foundation can be entire foundation, below the foundation can be strengthened like this through grouted soil mass.

And this is again another application that when tunnel activity this soil, the existing soil is such that it can have a settlement like this, this dotted line is shown but if you can grout like this, above the ground the tunnel soil then this soil will have reduced, the settlement of the tunnel, this is another application, this is both support and underpinning work.

In this my purpose was to explain different kinds of grout and where they are applied and their application, through this I could explain and now I will try to, when we try to grout in a particular media or soil or rock and it has some, you have to quantify how much quantity of grout is required, what pressure to be applied so that means there are some calculations, so how to do that.

That means theory of grouting is essential, perhaps in the next lecture I will try to explain those things that means what theory can be applied based on that at least we can quantify certain things like what is the pressure required or what is the amount of grouting

required and what is happening inside all those things through theory of grouting, I will take in the next lecture, thank you.