Ground Improvement
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Lecture - 03
Ground Improvement Methods (Contd.)

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Good day to all of you. Once again I welcome you to this Ground Improvement Lecture 3. We are in module one and in module one actually our scope is to only go through introduction part and still we are in introduction. In introduction we are covering entire Ground Improvement methods. In general all methods will be mentioned, but we will not discuss in detail.

Already we are in the module one that is two lectures we have already completed. First lecture some highlights I mentioned, second lecture is about the different ways of classification done by different people and they have different basis. Finally, we have started our own way of classification. Present, I have mentioned that Excavation and Replace. It is the first method of classification.

And then second classification was Shallow Densification these two I already completed and next one is Deep Densification this also we completed. So, three, one is Excavation and Replacement, then Shallow Densification and Deep Densification these three things we have completed now, several modes are there, let me see.

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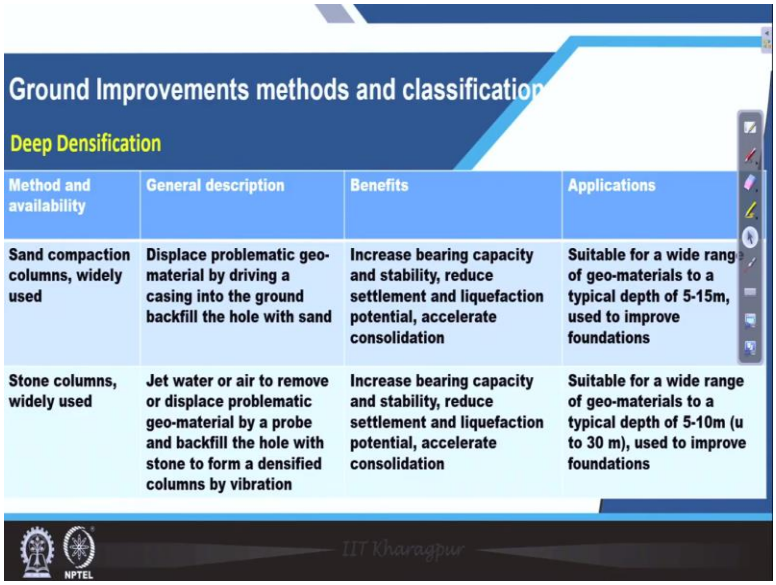

Next one is about again Deep Densification, it is continuation. There are different ways we can do, one is by Weight falling up weight and then we can do by Vibration compaction there are another a few more methods out there, that is Sand Compaction columns. It means we can buy a Displace problematic geo-material by driving a casing into the ground backfill the hole with sand.

That means, suppose a hollow tube or is a particular diameter with bottom closed we can penetrate in the particular ground. As a result what will happen that, the volume of the tube, the amount of, volume of the tube the same volume equal to the volume of the tube will be compressed, the same volume of soil equal to the volume of the tube will be compressed. So, surrounding soil and then this tube will not be kept inside the soil because this will be again then it will be expensive.

So, because of that this tube finally will be filled with the sand, good quality sand and compacted sand and then the tube will be lifted. So, ultimately what we have done by some means, we have made a hole displacing the problematic geo-material inside over a particular depth and then fill with a sand column. So, that is a way actually Deep Densification so it is quite deep can be done.

So, that is a general description of there is displace problematic geo-material driving a casing into the ground backfill with, backfill the hole with sand. So, that is the method and benefits actually same all any ground improvement techniques actually the objective is that some density

increase, strength increase, etc. So, here actually increase the bearing capacity sometimes the soil bearing capacity to be increased by this is the way it can be done.

Increased bearing capacity and stability, reduced settlement and liquefaction potential, accelerate consolidation also so sand column if we use then that consolidation also get accelerated. So, that is also use and then applications are suitable for a wide range of geo-material to a typical depth of 5 to 15 meter and it is used to improve foundations actually. And then Stone columns that is another deep dynamic deep compaction is a stone column.

This can go up to 30 meters also some time. So, here also by through water jet, one can make a borehole up to certain diameter and certain depth and then those boreholes will be filled up with aggregates of stone and then that will be compacted heavily. And finally, it will be like a stone column and if the stone column again if there are several of them side by side and this will be ultimately will take certain amount of load. And then overall soil along with the ground become strong.

So, this one the what is the general description of the ground of this stone column actually jet water or air to remove or displace problematic geo-material by a probe and backfill the hole with stone to form a densified column by vibration. So, that is the thing already I have mentioned. And what is the benefit we get increased bearing capacity and stability, reduced settlement and liquefaction potential.

This is of course, the objective of any ground improvement technique and then application will be suitable for a wide range of geometrical to a typical depth of 5 to 10 meter and use to 30 meter typically, it is used up to 30 meter to improve the foundation.

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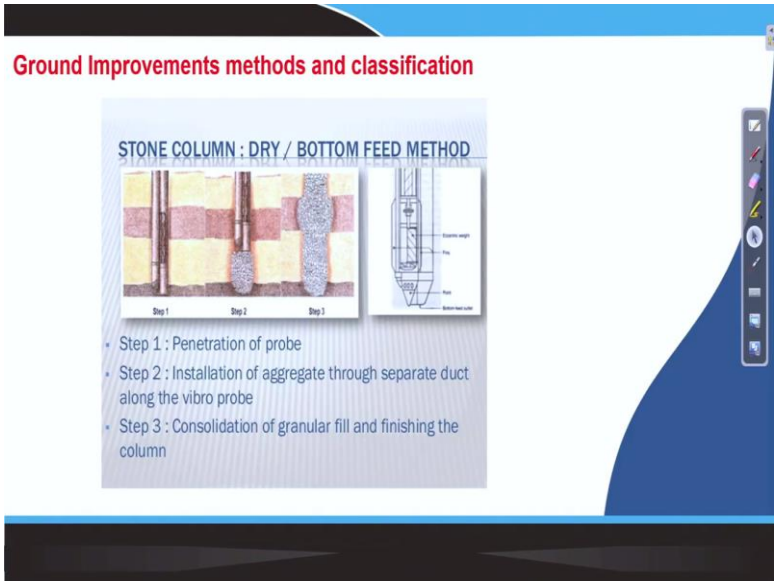

The next method so this is actually typically shown a diagram of the stone column actually you can see that this is the one first shown the step one that Penetration of probe then step two, the Installation of aggregate through separate duct actually then along the vibro probe and then step three Consolidation of granular field and pre leasing the column. So, these three steps actually, sometimes it is done that is Dry Bottom Feed method actually. Stone column this is called Bottom Feed method.

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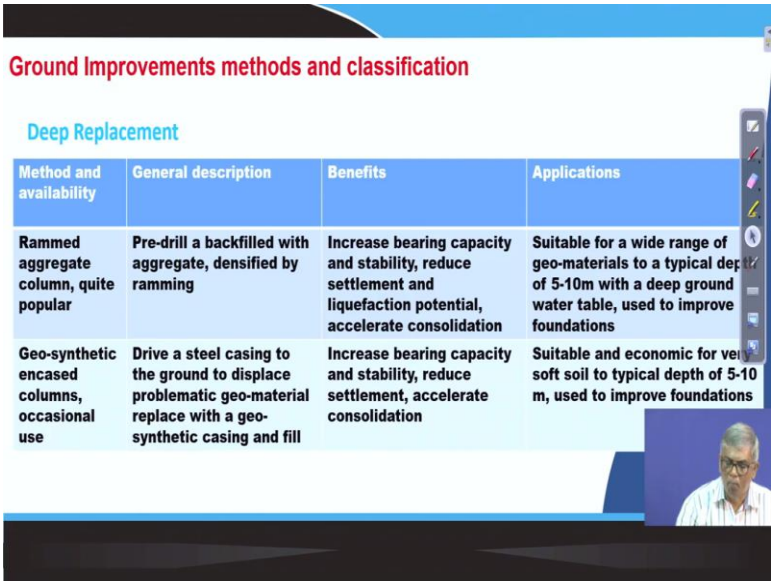

Then there is another method of ground improvement is a Deep Replacement. So, it is almost like a similar to the stone column and sand replacement here also same thing, Rammed aggregate column and quite column are relatively popular. The name is rammed aggregate column and it is quite popular and it is actually pre-drill, drill a backfield with aggregate densified by ramming. So, this is the description and what are the benefits we get?

We get increased bearing capacity and stability, reduced settlement and liquefaction potential. So, of course, this is about all objective or target of any ground improvement technique and where we can apply suitable for a wide range of geo-material to a typical depth of 5 to 10 meter with a deep groundwater table. That means, if water table is very close, then sometimes it is difficult.

So, deep groundwater table actually is the requirement and use to improve the foundations. And then Geo-synthetic encased column and this is also used but occasionally used. And drive a steel casing to the ground to displace problematic geo-material replaced with a geo-synthetic casing and fill. So fast actually drive a steel casing and then this is the method of this geo-synthetic encased column.

So, drive a steel casing to the ground to displace problematic geo-material and then in that whatever hole or vacuum created that will be replaced with a geo-synthetic casing and fill. And if you do that, then what benefit we get is again that increased bearing capacity and stability reduced settlement and that is of course, the essential requirement for any ground improvement technique is suitable and economic for very soft soil to typical depth of 5 to 10 meter.

So, these are all important things actual what are the right applications so different methods are mentioned here and what is the typical area it can be used that is also mentioned there. So, sometime in the question when there is a multiple option questions will be there. So, some method will be there and how much depth so, there are different depths will be mentioned and you have to pick up and choose the correct one which is mentioned here.

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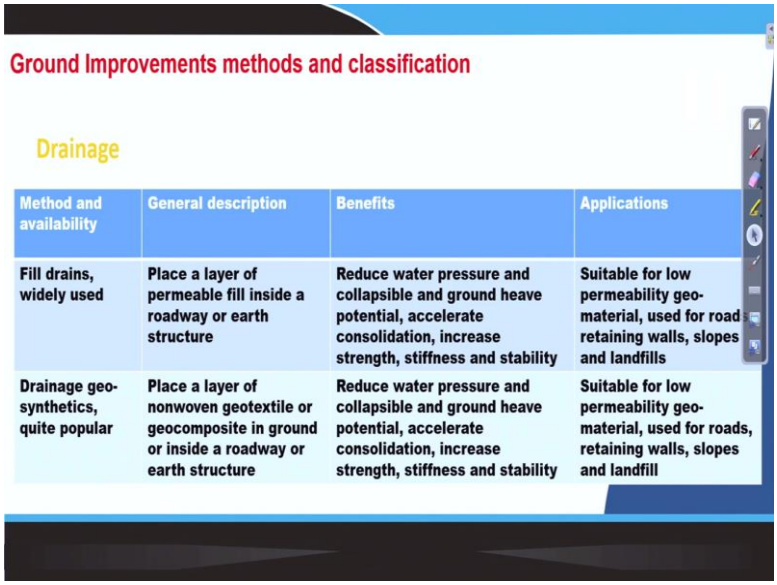

Then another method of ground improvement is actually is a Drainage actually. So, in the previously we have seen that different investigator also or different people also classified that is also by enlarge they have mentioned this method, here we are mentioning all these purely at a ground improvement method by drainage and so it is actually the method name is Fill drains and this is widely used.

And then how it is, how it works, it place a layer of permeable fill inside a roadway or earth structure. So, that means, the below the road there can be a layer by which actually if water enters that water can pass through that layer. So, that is the, if you do not allow to pass this water and if it is below the water for strengthen for the time, then what will happen the entire road may collapse. So, because of that, for every road, there will be a drainage layer.

So, if the water enters then through that drainage layer it will pass and it will be taken away from through some drain. And what are the Fill drains what is the benefit? actually reduced water pressure and collapsible so, that means if the water is stored there, because of this water pressure sometime there are many occasions failure can happen and then ground heave also did the water is stored there ground heaving also possible that can be reduced.

Accelerate consolidation means, if you want to do consolidation by surcharge and when you do the surcharge loading, then water will come out at the top or at the bottom when water comes at

the top, if you have a drainage layer as I have mentioned, then through that drainage the water can pass very quickly and if there is no drainage layer then it will take time. So, that is the one.

So, accelerate consolidation also for that it use increased strength, because once you fill strength and if you put then water goes away then water goes away means strength will be increased and stiffness and stability also will be improved. And where it can be suitable for low permeability geo-material and used for road retaining wall, slopes and land fields. So, these are the typical area where we use Fill drains.

Drainage geo-synthetics is actually quite popular and how it works place a layer of nonwoven geo-textile or geo-composites in ground or inside a roadway or earth structure. So, this is actually again like instead of fill drain, you can use the geo-synthetics that is actually a synthetic but it is having high probability, water can pass through easily. So, if you keep that type of material, it also helps to permit the water that no water will not be stored there.

So, what are the benefits we get out of these if you use these then you get a reduced water pressure same because when you will drainage actually if there is a provision many retaining wall fails because of this development of poor pressure, water pressure. So if there is no drainage provides provision is there behind the wall then during rain, the water will be stored there and because of this water pressure. Sometimes it can leads to collapse. It can also happen.

So, that is why the purpose of this type of drainage is reduced water pressure and collapsible and ground heave potential accelerate consolidation increased strength of course, the objective and were generally used suitable for low permeability geo-material used for road, retaining walls these two are same only method is same only material is different. Fill drains means we use sand layer and drainage geo-synthetics means that will geo-fragment. There is a synthetic material with highly porous that can be laid and used as a drain. So, that is both by enlarge they are same.

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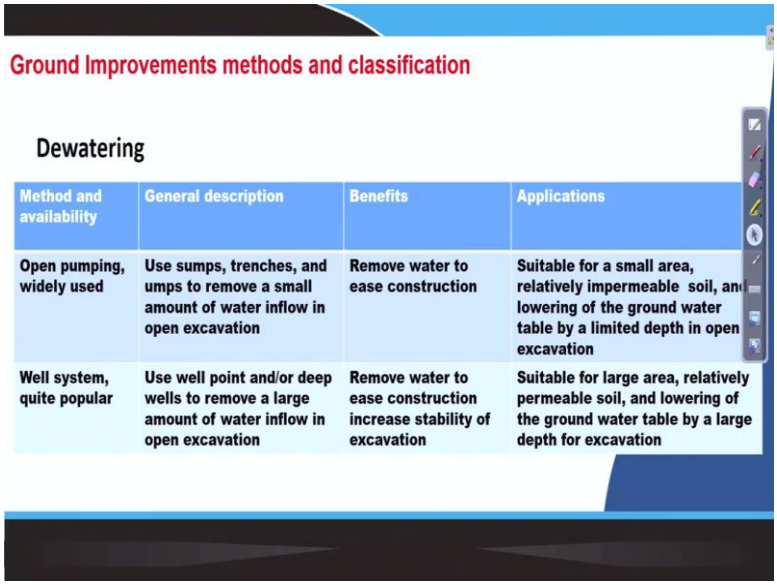

Then there is a ground improvement technique is Dewatering. As I have told that, if the water table is close to the ground surface, then the construction activity will be difficult, because if you want to excavate for foundation it will be difficult and so, to overcome that difficulty, sometimes you have to lower the groundwater table. How to lower the groundwater table? You can pump water through the soil continuously and if you do continuously that pumping, then slowly water table will be reduced.

And that has to be designed actually how long what type of pump etc. It is used and to lower a particular level of water level that can be designed of course which will be discussed in the later stage. So open pumping actually that is one method dewatering can be of different types that one is open pumping you sumps, a trenches and sumps to remove a small and a pump actually there is a typo here.

And pumps to remove a small amount of water inflow in open excavation. So if there is a beside the road walk if you keep a trench like this all water will be stored there. And then finally, you can from ground also if there is water that also will be stored there if there is a rainwater come, that also will be stored there. And then finally through drain either by pumping or by mechanical way, it can be transfer that is called open pumping.

And benefit will be when remove water to ease construction be. So, open pumping generally remove water for ease of construction and where it is suitable, suitable for a small area relatively

impermeable soil that means, if you trench if you put and if it is highly permeable water will go inside the soil and that also may cause problems. So, comparatively impermeable soil and in the smaller size of work then this method can be used.

Lowering of the groundwater table by a limited depth in open excavation. So, if there is only one meter or half a meter if you want to lower then this method will work. But, if it is more than that method. It will be different. So, Well system that is the one when you want to lower a significantly deep then well system will be to be used. Use well point or a deep wells to remove a large amount of water inflow in open excavation then that is called Well system.

And by this, remove water to ease construction it increase stability of excavation also. So if there is water table because of the flow of water the well will excavate then the site soil will be collapse. So, to avoid that the impure water can be removed. And suitable for large area that we wanted a large area to be developed and large construction site then the permanently water table can be removed for a larger area by continuous pumping by well point system.

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And these are the actually typical you can see here these are all well point actually these are well point this is actually different well point actually they are at well pump it is pump of different points and then through these actually water is discharged away from the construction site. So, that water table will be lowered permanently.

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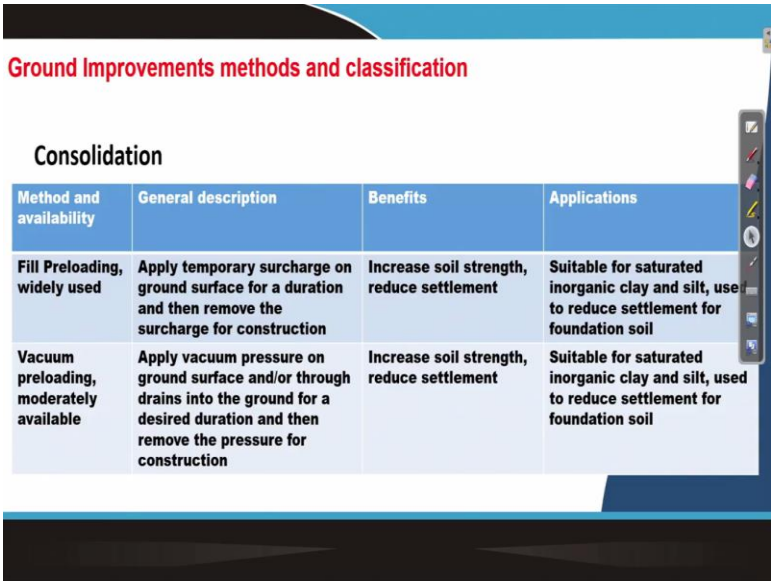

Then, the Dewatering, Well pumping etc was there, then Consolidation is another method of compaction ground improvement and this again can be done in differently one is Fill Preloading, another is Vacuum Preloading. So, fill preloading means actually, if there is a saturated fine grained soil, if I apply a different amount of the surcharge and because of that surcharge, then immediately pore pressure will develop and over the time this pore pressure will develop by seeping out of water from the soft soil.

And then when water will be seep out, then what will happen that voids will created and already surcharge is applied, that surcharge load because of these effective stress will be increased. Then because of the increase of effective stress that soil grain will come closer and it will become more compact strength by that way soil will be densified. So, the consolidation is one of the densification method for fine grained soil and this is actually by Fill Preloading that means certain amount of surcharges can be applied.

And this how it works again, whatever I have mentioned that apply temporary surcharges on ground surface for a duration and then remove the surcharge for construction. So, you have to keep up over a particular time until and unless this the definite amount of consolidation is achieved we have to keep the surcharge. Once we see that definite the desired amount of consolidation is achieved then we can remove the surcharge and then we can construct.

If you construct then further consolidation will be reduced. And what is the benefit out of this method, you will get increased soil strength and of course reduced settlement and where it is applicable suitable for saturated inorganic clay and silt, use for reduce settlement for foundation soil. So, if you find particular site, it based on calculation that if you consider to build this structure, it will undergo this much amount of settlement then that is not permitted.

In that case you have to pre-consolidate the soil. So that final foundation settlement will be reduced to some limited value. Then Vacuum preloading, this is actually is a quite advanced method nowadays being used but not very common. This is actually the we develop excess pore water pressure by using surcharge and by applying vacuum that can be developed and that way actually water can be taken out from the soil and that is the way if you do that is called Vacuum preloading.

So, you are not physical loading you are doing by in the form of vacuum you are preloading actually. So that apply vacuum pressure on ground surface and or through the drains into the ground for a desired duration and then remove the pressure for construction. That means, how long we can keep this preload vacuum pressure, until and unless consolidation is achieved up to a certain desired value.

Once you see that it is reached then you can remove and then you can go for construction. And then what are the benefits gain? Like as same benefit for fine grained soil consolidation. It means it increased wit soil strength and reduce settlement and where it is applicable actually suitable for saturated inorganic clay and silt. It is used to reduce settlement for foundation soil. So, that is again similar only thing is both are same only one method by physical loading other method by vacuum loading.

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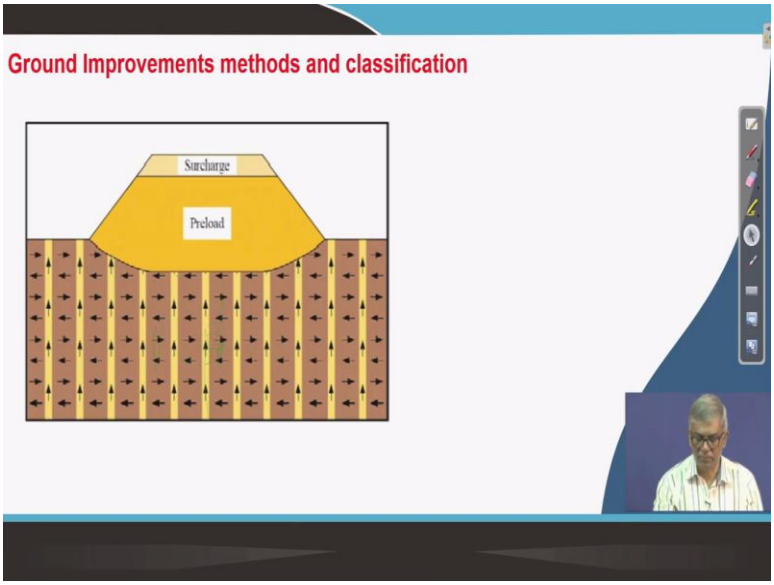

And this is the way you can see here in this diagram you observe the soil, this is the soft soil it is to be consolidated. And if you apply this much amount of surcharge, then over the time, actually soil will undergo this then you can see that it was the level which was initially here and then you can see, initially the level was here and because of the surcharge it has come here.

So, that means this much amount of settlement soil is initially soil height was this much and now soil how this is much reduced. So, that means now, after the removal of this if you construct there, this the lesser amount of settlement will happen because of the foundation loading. And you can see all the surcharge if you do then this way actually also soil can be consolidated, but it will take longer time.

To make actually or to accelerate this you can see these are the drains, different drains are created and these drains are filled up with sand or some other material, highly permeable and if that happens and if you apply load through these then what happened water here this area, water in this area, water in this area, water in this area, they will try to move instead of this direction, it will move this enter into this because this way water can move faster.

So, this is actually not only preloading, preloading and vertical drain together. This is a method preloading and vertical drain together and this is actually pre-consolidation.

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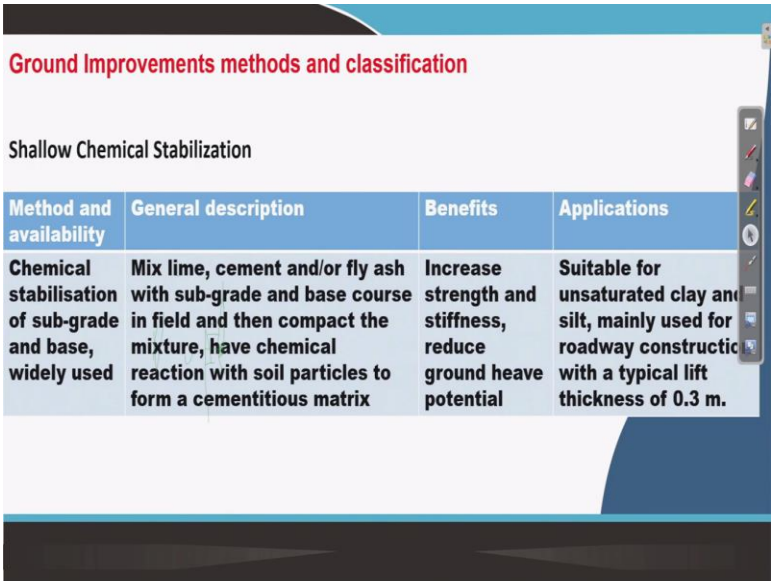

Next one is a Shallow Chemical Stabilization again, Shallow Chemical Stabilization in the surface soil like the embankment to be made and the soil we are using maybe some lime or something can be added and mixed later then roller then sometime we can keep and with some reaction soil will be improved to that is why. So a chemical stabilization of sub-grade and base widely used.

Mixed lime, cement or fly ash with sub-grade and base course in field later it compact the mixture have chemical reaction with soil particles to form a cementitious matrix. So, that is the one that means close to the ground surface if you add some cement or some lime and then allow some time to react and then by reaction the better material stronger material will form that method is called Shallow Chemical Stabilization. And benefit will get form it is increased strength and stiffness etc. Every year something suitable for unsaturated clay and silt mainly used for roadway construction with a typical lip thickness of 0.3 meter.

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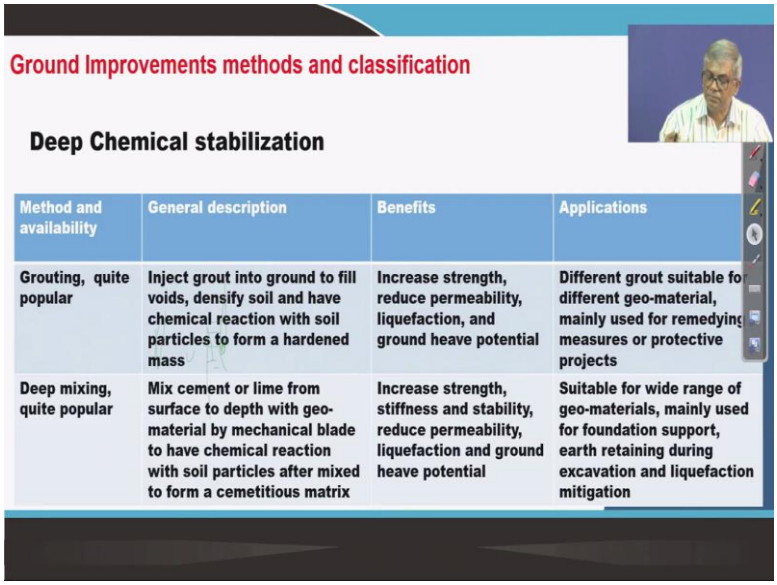

Then next one is the Deep Chemical Stabilization you can see here the deep. Deep means quite deep, actually different methods again use the deep chemical compaction stabilization here actually grouting is there and then there is deep mixing, two methods are there when it is the grouting it is quite common popular already I have mentioned and how it works actually inject grout into ground to fill voids.

Then densify soil and have chemical reaction with soil particles to form a hardened mass. So, we can actually take some needle and through this needle it will be penetrated particular depth and then with the pressure, some chemical to be injected inside the soil and those soil and injection of grout material can enter into the pores of the grains. And then sometime if it is a there are depending upon chemical type and soil type, sometimes it may have reaction also and by that it can form a different and more stable stronger material and that way the soil will be improved.

So, that is one method and what is the benefit? Again we can get same thing increase steepness, reduce permeability, liquefaction and ground heave potential and where you can use? You can use it different grounds suitable for different geo-materials, actually different grout suitable for different, the grout again it can be cement, it can be some other material, so, we will discuss that different types of grouts are there.

So, for depending on what type of soil you can use different grout and mainly used for remedying measures or protective projects. Remedial measures that means, already we are

observing that there is an existing building, it is undergoing some stress or some distress. So, you want to reverse some remedial measure for that actually, we use this type of grouting technique. So, you inject from the side and reach to the bottom and push the grout material and that grout material finally, helps to improve the overall stability of the structure.

Then there is a Deep Mixing it is also quite popular, how it works, mix cement or lime from surface to a depth with the geo-material by mechanical blade to have a chemical reaction with soil particles after mixed to form a cementitious material mixed metrics. So, this is actually through blade from the surface to up to depth, it will be mixed actually. And by this process, sometimes it will have chemical reaction and finally you will have a better material.

And how it is benefit, almost similar any ground improvement technique we required higher strength and lesser permeability or all those things similar to that here also by deep mixing also we get benefit increased strength, stiffness and stability, reduced permeability and liquefaction potential and ground heave potential also, where it can be used? It is suitable for a wide range of geo- materials mainly used for foundation support, the earth retaining, retaining during excavation and liquefaction mitigation. So, these are the different areas where you can use Deep Mixing.

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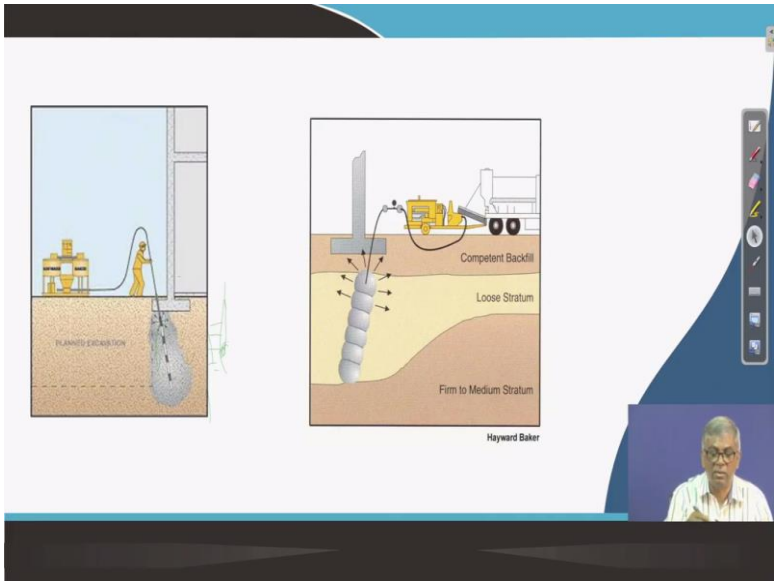

And you can see the grouting how it works, as I have told you that if this is the existing building below that there was some activity going on here. Also this building foundation below that

actually this grouting is to remove, repaired or improve or make the stable or improve the stability of this foundation.

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So, with this actually we have described different methods of Ground Improvement technique in general, we have not mentioned any calculation we have not shown any calculation anything in generally we have done and I am not making any conclusion because we are in a still introduction module and we are doing same thing and then maybe one more or two lecture. I will be taking, where out of these so many methods available in the ground improvements methods available, which method to be chosen and how to be chosen what are the basis.

So, those things I will discuss in maybe another one or two lecture and then I will go one by one ground improvement technique in detail with the calculation that if I want to do roller compaction, then sometime I have to bring material from somewhere and I have to make an embankment there are some calculation. So, I will do there suppose somewhere I have to do deep dynamic compaction.

So, there actually you have to take what is the weight to be lifted and what height has to be fallen, then how frequent how many drops some calculations are there. So, those things in detail will be done afterwards. So, of course, in the introduction Module two more required, where I will discuss the basis by which out of so many available methods, depending over materials and

site condition, how we will choose a particular method we will discuss and complete the introduction. With this I will stop here. Thank you.