Ground Improvement

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Module 01: Introduction

Lecture 04 GI Methods and Classification

Hello, good day to all of you. Once again I welcome you to this lecture in Ground Improvement we are still in introduction module under this we have 2,3 aspect are already discussed and in the previous lecture I have just described that classification of Ground Improvement techniques based on certain function or something by different people over the time and that I have already shown.

And, and once again the way we are classifying different the Ground Improvement technique one by one we have discussed a few of them and I will just cover that and after doing that, will try to discuss about the wide number, wide variety of options and wide numbers of Ground Improvement methods, but how to select between the so many available between the so many Ground Improvement techniques are available from there.

Which one will be the best for a particular site? How to adopt? Of course, in the interaction itself I will not be able to tell the entire thing only a few example I can give you and based on which we can conclude this introduction.

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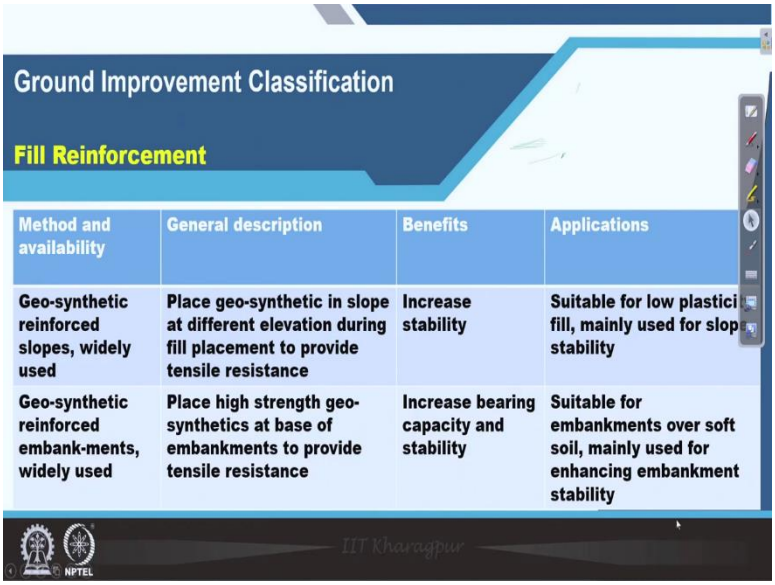

And so, let me come to the first slide today and you can see here. Once again, there are number of classification what we are doing we have mentioned and I have started with excavation and replacement method which is very the simplest one and of course, sometimes it is useful, sometimes it may not be useful, but as far as the method is concerned it is the simplest one because we can remove some of the poor soil and then replace by some good soil and then we can construct.

So, like that number of them we have discussed drainage then dewatering and all then consolidation. Similarly, field reinforcement that is another Ground Improvement technique can be classified and then in that what is the method developed exactly? And under this and how much are used in the practice that is given in the first column, second column is there actually briefly at the description of the method and if we do this what benefit we will getting out of it, that is given in the third column and applications that will which, where actually going to apply that can be that is listed in the last one.

So, here you can see geosynthetic reinforced slope and this is obviously widely used. Geosynthetic placed in slope at different elevation during field placement to provide tensile resistance. So, I can just make you something like if it is a slope like this and anyway suppose this is the slope and it will go at a time we will not go suppose a first layer will be somewhere here and then you put it in reinforcement layer and then it will be dumping soil and then these reinforcement will be rolled over this and then again compacted and reinforcement will put there.

So, this way how it will help we will discuss later on in length that when the soil will try to slide and then this reinforcement that frictional resistance between then this reinforcement also tendency will have movement this direction. But because of the development of friction between the soil and the reinforcement in this zone this will not be able to move.

So, this is a way actually to be used. Now, you can see that that is the one method that means you over the when it will be what embankment is made at different elevation we can lay the geosynthetic or other reinforcement and then cover with sand or good soil and compacted and then you go up to the level required and then there will be some mechanism will happen and that will actually help to stabilise the slope.

And this is a benefit to increase the stability actually when you use the slope the main benefit out of it is increases the stability. Where you can apply you can see the suitable for low plastics soil fill, mainly used for slow stability. So, this is the one then there will be another

under field reinforcement that geosynthetic reinforced embankments and that is also very widely used.

Similarly, already whatever I same thing only and the placed high strength geosynthetic at base of the embankments to provide tensile resistance similar way only. It is here actually the slope on here it is embankment and this is the only difference and increase bearing capacity and stability both and suitable for embankments over soft soil. Mainly used for enhancing embankment stability.

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So, this is actually you can see here when it is a slope and when it is making embankment. So, these are the two examples are shown already here and which I have tried to sketch and you can see that these are the different level of reinforcement has provided different level and then this slope is provided. So, when you provided these, then automatically it will not be able to slide like this.

Because when you tried to slide then entire material along with reinforcement will go. But when reinforcement will try to pull this direction, then it will get a pull this direction. So, that way it will be stabilised. Similarly here actually when it will be high embankment is made you can see here one level of reinforcement is there and then wrapped inside put then second level wrapped inside, third is wrapped inside like that. So, what that embankment is made. So, this is again for the stability and at the bottom it is there then it is for improving bearing capacity.

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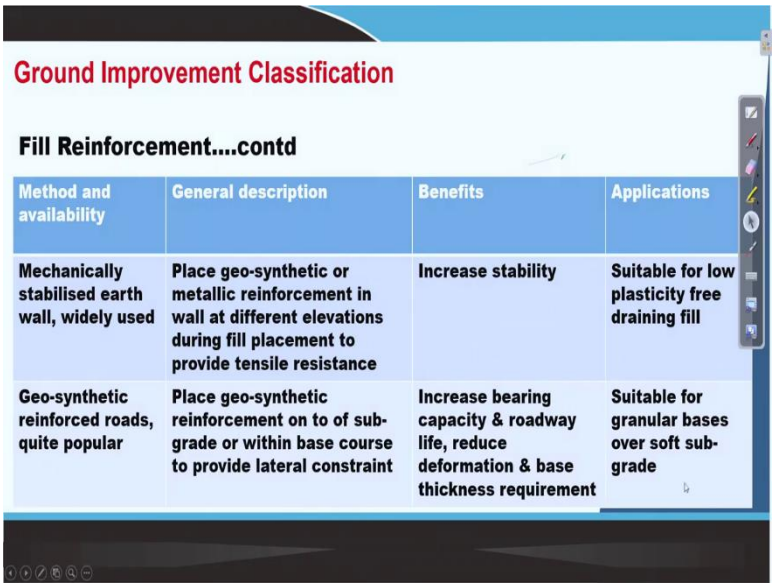

And fill reinforcement again continuation then mechanically stabilised Earth wall this is very widely used. When you will travel around and when you will particularly when you will flyover and we will be seeing then the approach portion of the flyover you will see that some decorated wall like you see that wall actually reinforced Earth wall.

So, conventional wall actually you make a concrete wall which is generally expensive, instead of that if you use reinforce Earth wall where wall will not be there whatever we see that is called facing element. Then, all facing elements will be connected to each other and finally, it is connected to a reinforcement which is inside the embankment.

So, that is the mechanical show it is very popular nowadays almost everywhere it is used and place geosynthetic or metallic reinforcement in wall Earth different elevation during field placement to provide tensile resistance. Similar principle only and here also increasing stability that is the purpose and then suitable for low plastic free draining fill. That is also regard that low plastic means it will require seal to sand if you use clays while it will not be useful.

Then geosynthetic reinforced road that is also quite popular. In this geosynthetic reinforcement is placed on an on top of the subgrade actually it will be the typo error it will be top of subgrade or within base course to provide lateral restraint constant and here actually the objective or doing so is increased bearing capacity and roadway life, reduce deformation and base thickness requirements.

So, these are the purpose actually the objective why we use this and suitable for granular basis over soft subgrade. So, that means if you have something like this is it is a soft, soft soil

is here, ok? And then if I embankment then what will happen it will try to sink like this. And if you make a very strong reinforcement and then granular if you put sub base then it will not easily penetrate inside and it will be giving you a better support. So, this way let us go to the next one.

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And you can see these are the some examples are shown here RE wall is like this, you can see that these are all actually in one piece whatever you seen this is that this is actually a facing element and you can see quite thin and ultimately if you make 8 to10 metre height wall they are holding entire thing. How it is holding? From here actually in other side there will be reinforcement and it will be laid over the soil.

When because of the soil pressure the element will get pushed this side and when it will pull this side then automatically reinforcement also pulled outward. When it happens then the reinforcement will try to come out in from the soil then there will be friction between the soil and reinforcement will develop that will hold the things in place. So, that has to be designed, how wide how thickness how long all those things that to divert or to keep this reinforcement in place.

So, that is the aspect of course, we will discuss later on. Similarly, this is also at the you can see the if it is this is soft soil and over that there is a geosynthetic mat is placed then soil mat like this, if you do that, then entire thing will be very strong, base will be quite strong and if the base is strong then requirement for the top layer will be reduced. So, that is the objective whatever we have shown.

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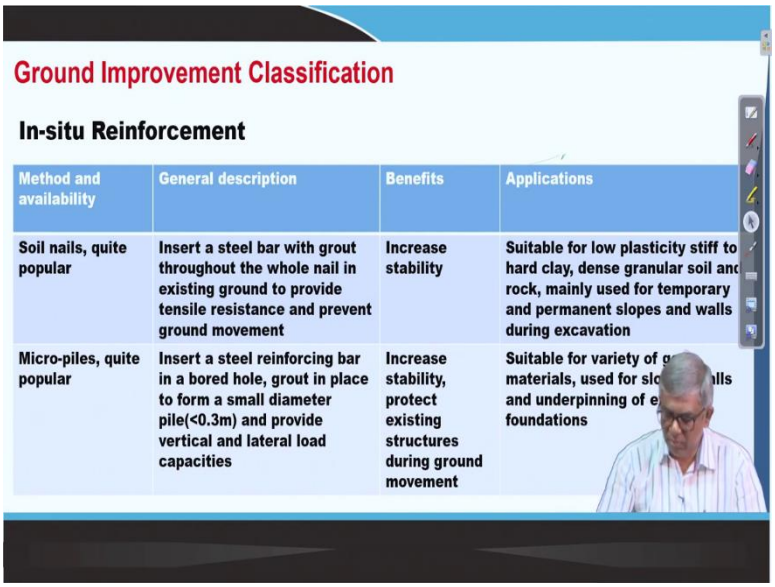

Then in-situ reinforcement, in-situ reinforcement means actually there are the under this sector soil nails. Soil nails means what? Suppose a particular site, so, hilly areas somewhere you want to make a road and you have to cut the hill and if we want to make the hill and to provide a particular road, then you have to make a huge slope and if you make a huge slope then some time it will be very expensive.

So, instead of that, making quite steep slope, but to improve the stability we can nail the soil, it is not by the name nail it is not really like nail, but it is a steel rod to be penetrated inside the soil and number of them and it has to be designed, how, what is the spacing? And what is the length? And all those thing, what is the inclination? All those things to be designed and if you place those nails inside the soil and quite steep slope we can make.

So, that is the purpose of soil nailing. The description is given here, insert a steel bar with grout throughout the whole nail in existing ground to provide tensile resistance and prevent ground movement and here also the objective to use soil nail is increase stability and application of course suitable for low plastic stiff to hard clay, dense granular soil and rock, mainly used for temporary and permanent slopes and walls during excavation.

So, though it is used during temporary excavation, but sometimes permanent work also it is used. Then micro-piles this is also quite popular, they are actually insert a steel reinforcing bar in a borehole, grout in place to form a small diameter pile. Generally less than 0.3 metre and provide vertical and lateral load capacity. That is why if there is if you find a particular site, the soft soil then small diameter or by number of them we can penetrate inside the soil and then grouted and that can give you a good support.

Here, the purpose or objective of this micro-piles in the site is increase stability, protect existing structure during ground movement. We will discuss again later. To discuss this part micro- pile, if at all can take you know our scores, then we will discuss in length.

Whatever methods we have discussed so far, all of them will not be able to take but some of them which are widely used and particular difficult soils those things will be elaborately discussed later on. Coming to suitability, actually the application area is suitable for a variety of geomaterials used for slopes walls and underpinning of existing foundations.

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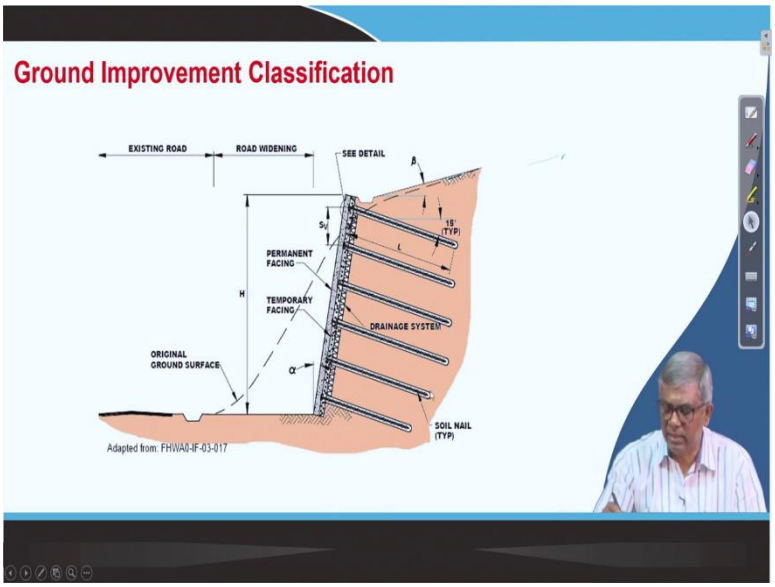

And these are you can see this is the example of soil nailing. You can observe this is it can be soil or it can be rock and whatever it maybe and if it is if you want to natural stability, suppose it was the slope, the naturally it will stable like this. But suddenly if I want to cut and widen this road here, then we can protect this wall by providing this sort of nail. So, this is called soil nailing.

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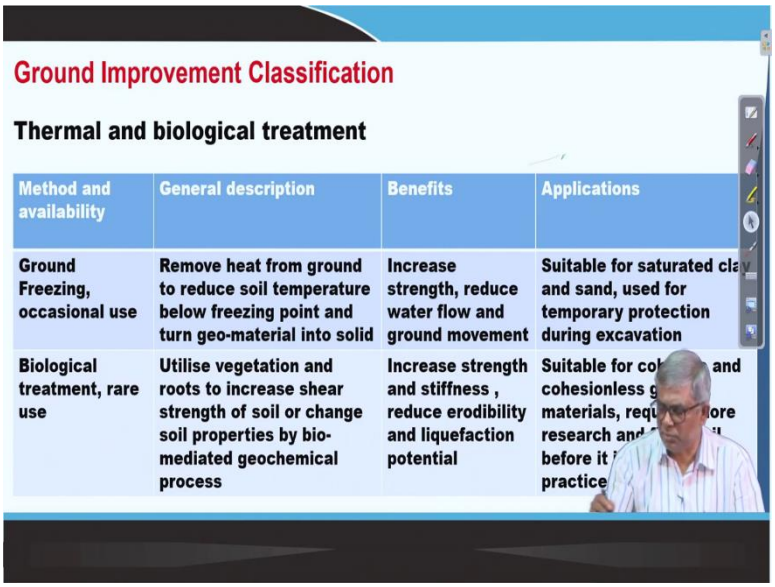

Then there are other methods are there thermal and biological treatment. So, grind, ground freezing is one biological treatment that is actually very rare use of course, in our country particularly at ground freezing, some places it is used, what is the description of ground freezing? It remove heat from ground to reduce soil temperature below freezing point and turn geo material into solid and that way it will help to excavate and any other excavation or something or some activity can be easily done.

And the benefits is to increase the strength reduce water flow and ground movement and suitable for saturated clay and sand use for temporary protection during excavation as I have mentioned, that if you solidify entire soil and water then the water movement will be stopped and as a result you can easily excavate and biological treatment utilise vegetation and roots. Actually, in the slope in fact sometimes you will see that we put the grass why because to protect the slope.

Similarly, for long big trees also who can make that root also can help to protect the erosion. So, like that utilise vegetation and roots to increase shear strength of soil or change soil property by bio-meditated geochemical processes and it increases strength and stiffness reduced the erodibility and liquefaction potential and where we can use? Suitable for cohesive and cohesionless geomaterials, requires more research and field trial before it is adopted in practice.

So, not much design is available. Generally, when we use the grass and all we know that if you lay a particular type of grass because of the root and soil cannot erode so easily. So, we can do is to lay it you will see that sometime some sort of geotextile will be sprayed over the

slope and through that grass seeds will be sprayed and if you water it then through that seed grass will grow.

And when it will be grow significantly then entire thing will be becoming green and it will be covered and it roots also will go deeper and that way it will protect the slope. So, these are all of course not much design available right now, but this is the one commonly used.

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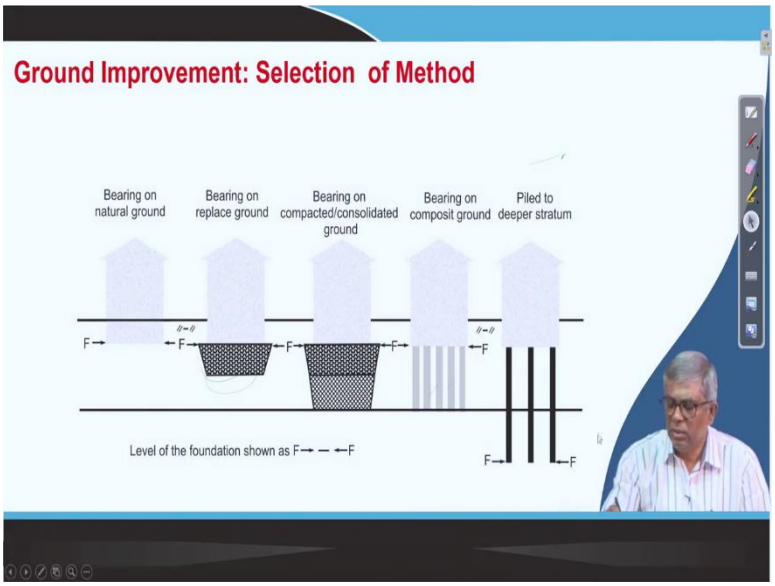

And now, as I have mentioned there are so many types of Ground Improvement techniques here. We will be talking about that selection and you can see that if you have a building which is not visible here, actually let me try to draw suppose if this is a building, ok? And then if the soil this area is not so good one such choice is that you can replace this much portion, and if you find that it is sufficient, then we can build this.

The another option is that your same building maybe is there, but analysis shows that you have to replace up to this you can do replacement like this, this is another choice. So, you have to do analysis and you have to arrive at the solution, suppose if it does not work, then this is suppose another situation the building is like that.

So, this replacing also will not do something like stone column or similar type of thing which I have told already that type of thing can be done and then building can be constructed if all those things whatever I have mentioned if it does not work, then sometime we can have the pile foundation you can see that these are the piles, it is penetrated through those poor soil and it has gone to the good soil here.

And then finally, we are constructing the building. So, this is the way actually how to do first step as it is soil you do bearing capacity analysis and then see whether it is suitable or not. If it is not suitable, then try to think that whether I can excavate and replace some portion it will work or not do some analysis if it does not work, then again you can have more replacement and then you can make this if suppose this is the this is a soft soil.

Either you can compact and consolidate and then it this is replacement and this is actually may be consolidate the layer and then if it is sufficient then you can construct the building. Similarly, if this method also does not work then we can make sand column or stone column and then you can build here. If all those things does not work. Then you can go for pile foundation, pile can be 30, 40 metre long or it can go to up to that strong layers.

And in the weak layer also it can have some frictional resistance, it can have bearing resistance here and altogether it can have significantly strong, where we can build the structure. So, this is the way actually we can select one after one we can try for one and then if it does not work go for next like that you can get the solution final solution. So, this is one example. And then next.

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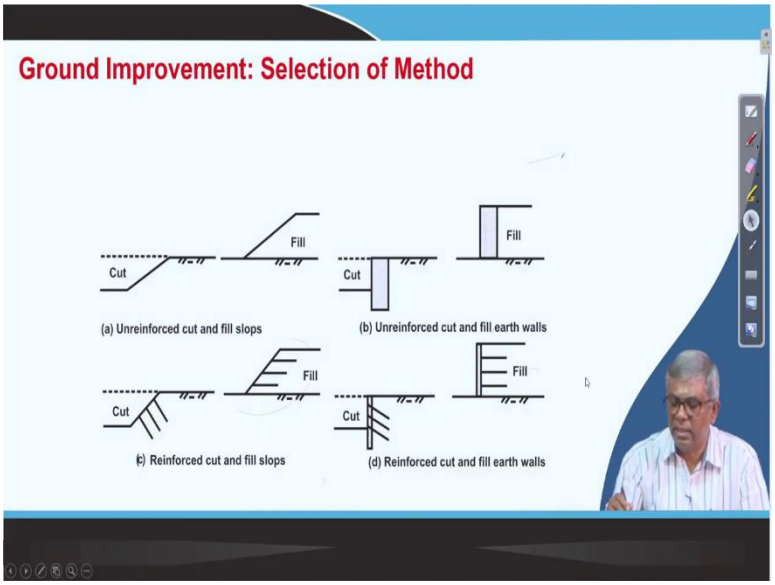

Suppose this is the one you can see here. You have some options then you have to cut or you can fill, that is your job either that side you have to cut or you have to fill it and in that actually you can see if you do not use anything then your slope will be mild. You can see here mile slope here also quite mild slope, but if you want to make vertical that in that case, what you have to do whatever method we have discussed like you can make a wall and then sheet pile wall you can make it and then excavate here.

Similarly, if it is a fill then you can construct a retaining wall and then fill should this is the way you can do this is one type of solution and then another type of solution suppose you are cutting like this and then if a provides nail here, then you can make comparatively steeper slope, ok? So, this is soil application of soil nailing and then you have to see which one is useful both economy and feasibility in the service.

So, this is the one and similarly if it is a fill also while filling there also you can provide a reinforced layer one after another and then go up to the, the top desired level and this is the way also you can adopt. Suppose if you want to make a wall again then you can see simple wall if you make then it becomes very heavy concrete work you have to do.

But you want to make the thin like a sheet pile or similar type of thing, then what you can see in addition to the wall you can anchor it through that nail actually similar to the nail you can provide here and by which the stability can be improved here. Now, again, you can see here if it is again that fill if you want to make and if you do not want to make the gravity or cantilever retaining wall.

If you want to make the wall thin wall like as you have mentioned RE wall. So, this is type of RE wall actually. These are all these are all actually facing element and in the facing element, the reinforcement is connected and laid inside the field. And this way actually, we can, it will be stable, how it will be stable? Because the weight of this soil this will have tendency to movement this direction wanted to try to move and this reinforcement also try to come out when you will try to come out then friction will develop in this direction.

So, that friction will keep these retaining wall in position or with minimum deformation which is permitted. So, these are actually different choice you can, when you want to make a cut or fill either you can just freely cut or freely make embankment then your slope will be quite mild. But if you want to make vertical then you have to you have a choice of making wall either here concrete wall, here concrete wall and then excavate you excavate or similarly if you want to modify the slope by some means, suppose you nail here or you use reinforcement here, then this can be also done with different slope.

Similarly, instead of heavy concrete structure, if you want to make thin one like retaining that facing element, then you can have in addition to the facing element you can use this type of anchor and also it is this anchoring effect with the nails that also can be designed and if you use this a quite thin structure providing thin size you can cut quite deep here.

Similarly, here also that our RE wall can be connected with reinforcement, and it can be make stable without any heavy structure here. So, like this, this these are all different choice available to you. This is about actually geometrical modification or using some inclusion in the soil you can do better construction or economic construction. And in addition to that there are actually a situation where you have to choose the method depending upon soil type. Now, I will come to that point and you can see here.

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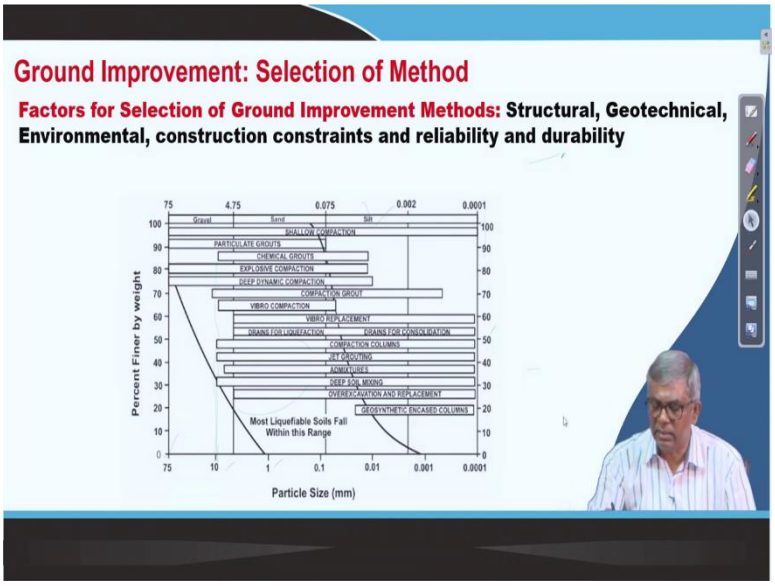

Next slide you can here, that when we have several factors actually the factors include structural factors then, what type of structure you will make? Geotechnical factors, environmental factors, construction constrain and reliability and durability. So, many factors will be there, all those things to be examined, and in addition to that, what you have to see, you have to see the soil and when you see the soil.

And you can observe in this chart, this chart is showing actually you can see I will show you that this side actually grain size from this side to this is actually this is 0.001 the grain size this is 0.01 this is 0.1, 1, 10, 75 millimetre, these are all millimetre. 75 millimetre to 0.001. So, this is the range or even smaller than that particles out there and if you plot in the similar plot, which we do gain size distortion, and then accordingly you can see here that different methods are mentioned.

You can see here shallow compaction; shallow compaction can be done for any soil actually you can use roller and compact. So, that is why you can see from this end to this end, any soil actually can use shallow compaction. Similarly, particulate grouts when the soil particles is 70 millimetre to 0.1 millimetre, then we can use particular grout. So, in the particulate form

grout can be pump in so that those grout material will go inside the larger particles and make solid one.

So, that is one. Suppose chemical grouts will be used you can see here, suppose size is 10 millimetre to here actually 0.1 millimetre, the 10 millimetre to 0.1 millimetre then then you can use chemical grout then explosive compaction can be used, you can see from 75 millimetre size to you can see here maybe around 0.01 millimetre size. If the site contains this type of material, then you can use explosion to compact the site.

Similarly, deep dynamic compaction can be used you can see from 75 millimetre diameter particle soil material to you can see up to 0.01 size particles. In the same way, compaction grout can be used you can see 10 millimetre size to 0.001 millimetre size then you can use compaction grout. Then similarly vibro compaction range is mentioned here, then vibro replacement there is a range is given from here to here.

Similarly, drains for liquefaction, drains for consolidation. So, again these are the range is given from you can see approximately from 5 to any size some fine particles that vibro replacement or vertical drains can use used. Then compaction column that is again from this to this range. So, like this is actually a chart available.

Now, you can plot your grain sizes distribution, suppose your grain size distribution curve comes somewhere here grain size distribution curve come somewhere here, then you can see there are a number of methods actually can use, but these methods actually may not be that suitable it is the boundary. So, you can adopt this method because it can go wide range.

Similarly, you can use this method like that. So, this is the chart actually applicability of different methods for different size of particle of soil and then if you have a soil at a particular site, you will do the grain size distribution and then plot it and see the position then accordingly you choose which one is most suitable. There may be again so many methods will be available to you and again material availability, construction equipment availability, then the other availability based on that you have to choose the best one.

There may be more than one method may be suitable based on size, but again you have to adopt the most suitable one considering many other factors. So, this is actually can be used as a design guideline chart.

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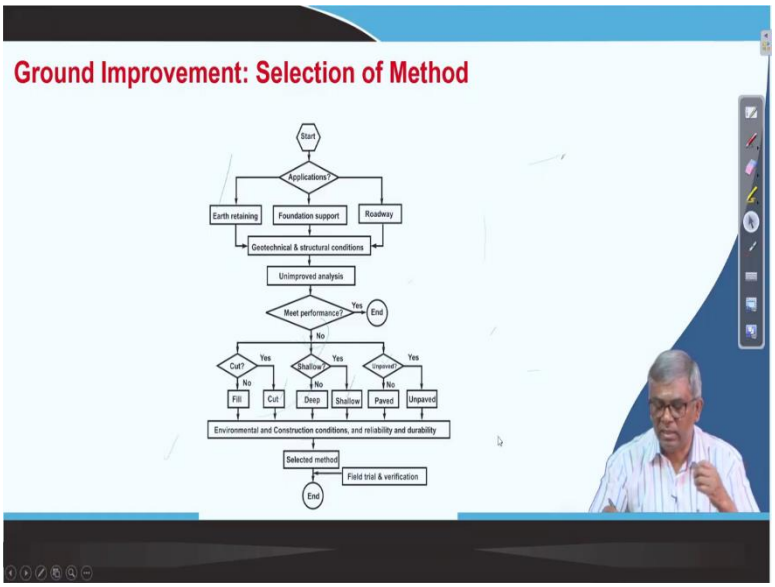

So, next let me go to the next slide that is the last slide. So, that means when you are at a site and when you are you have a project and you have to execute the job then first thing to observe is a starting point you are here and then you have to the what type of application and then it can be Earth retaining or it can be roadway or it can be foundation. And then what you have to do?

You have to do geotechnical and structural condition you have to see and then in unimproved condition, whether they are suitable or not that to be judged. If it is fine that it is meeting the performance you just do analysis whether it is meeting the performance, this is a question mark. If yes then that is the end that means that soil you do design accordingly and if the answer become no, then you can see whether you can cut if it is go for cut and if no then go for fill.

Similarly, here whether it is shallow foundation? If it is yes go for shallow foundation if no go for deep foundation. Similarly, if it is a road it is unpaved road if it is yes then you go for unpaved and if it is answer is no then you go for paved. So, like that, so, many options you are getting and then finally apply environmental and construction condition, reliability and everything and then select the method and do some field trial and verification and then the project will be ended.

So, you have to go flowchart like this you can end somewhere in between it always will not come here it may be ended here, but if you check number of things, and then proceed at the end here like this. So, this is the way actually you have to select the Ground Improvement technique and finally, to execute a particular project. Then by enlarge, this is the introduction module is completed. But we have one more session, as I have mentioned in the beginning

that replacement is a comparatively easier method. So, I will take that part within introduction itself.

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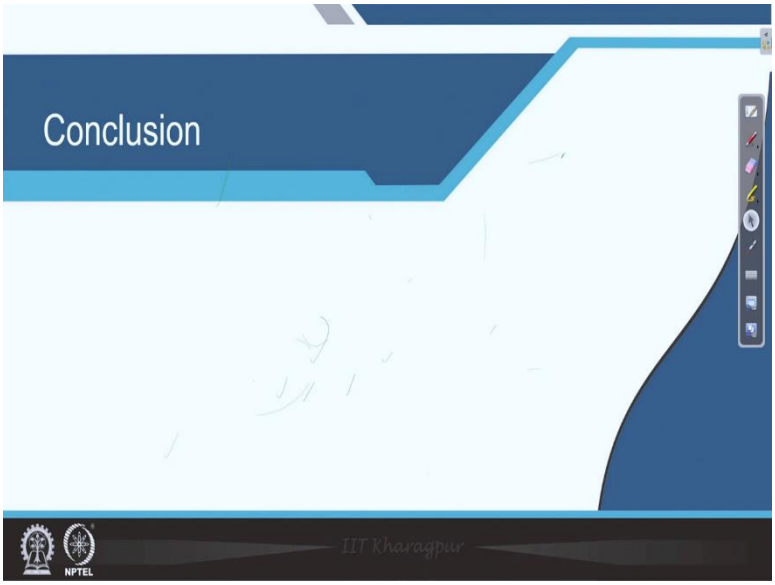

In next lecture, I will try to include the replacement method of Ground Improvement. Here, what to conclude actually? I have given the importance of soil in civil engineering construction, one important point I have highlighted is different ways of classification.

And then finally, you may have a good number of options, when soil is poor particular side you may have a number of options, but ultimately how to adopt a particular method, how to select a particular method, you have to do some analysis, and consider some factors external, internal availability, all those things and then select particular methods.

So, this is the way I just conclude the introduction. And in the upcoming lecture, I will try to take your excavation and replacement method of Ground Improvement that is the starting of Ground Improvement techniques. With this, I will close this session. Thank you.