Earthquake Geotechnical Engineering

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Lecture 54

Ground Improvement Techniques: Types of GIT

I welcome you again for this NPTEL course on earthquake geotechnical engineering. And we are at lecture number 54, which is related to ground improvement techniques. We are at the chapter number 1 of this technique, which is on the types of ground improvement techniques. And this is the third lecture on this topic, the first chapter, this chapter number 1 will be over, which is on types of ground improvement techniques. And what we are going to cover in this third lecture today, that grouting and mixing techniques. In the grouting techniques, which we are going to discuss permeation grouting and intrusion grouting.

While in mixing techniques soil mixing and jet grouting will be considered. Finally, drainage techniques will also be discussed. So, all these two grouting and mixing techniques and drainage techniques are part of the ground improvement techniques. Before I go ahead, let me acknowledge that most of the information taken in this lecture is from the Kramer's book.

So, coming to grouting and mixing techniques, the engineering characteristics of many soil deposits can be improved by injecting or mixing simultaneous materials into the soil. So, here you either you can inject inside the soil, or you can mix inside the soil. These materials both strengthen the contacts between soil grains and fill the void space between the grains. Grouting techniques involve the injection of such materials into the voids of the soil, so that the particle structure of the majority of the soil remains intact. So, when you say in case of grouting techniques, you do not disturb the particle structure of the original soil.

You just injecting inside that, but without disturbing the particle structure of the soil which was in the before grouting. But in case of mixing technique, you introduce simultaneous materials by physically mixing that material with the soil that come therefore, the completely disturbing the particle structure of the soil. So, this is the basic difference between grouting and mixing. In grouting, you are not disturbing the particle structure of the soil, but in case of mixing, because you are mixing physically, so it gets disturbed. The mixing can be accomplished mechanically or hydraulically.

So, you can use some mixture, or it could not be done. Grouting and mixing techniques tend to be expensive but can often be accomplished with minimal settlement or vibration. As a result, grouting and mixing techniques can often be used in situations where the other soil improvement techniques cannot be used. For example, permeation grouting involves the injection of low viscosity liquid grout into the voids of the soil without disturbing the soil structure. So, when we use permeation grouting, then you are injecting a liquid, low viscosity liquid grout, grout is of low viscosity.

So, it can be like a fluid, it can be injected and when it is you are injecting, then you are not disturbing the soil, the basic soil structure. The particulate grouts, what is particulate grouts in is used? In this case, you can have aqueous suspension of cement, fly ash, fly ash is a waste material, bentonite, microfine cement or some combination thereof can be used as a grout. Or chemical grouts, for example, silica and lignin gels or phenolic and air-fry residence may be used. The suitability of different types of grouts for different soil conditions is most strongly influenced by the grain size of the soil. Here is one of the example is here, which is similar to compaction grouting.

Like what you have in like this case, pump, pressure gauge, grout penetration that is your soil escalator that is penetrated inside this and you have this is for permeation grouting process. What is done here that you pump from the top through this stem and wherever you have the loose size there, then you have grout penetrator, soil escalator is formed. It is similar to what we discussed in case of compaction grouting. Continue with that virtually any type of grout even relatively viscous cement grouts can be used in soil with large voids such as gravels and core sands. Normally, you have the large voids inside the gravels and core sands.

Chemical grouts generally exhibit lower viscosity than particulate grouts and can therefore be used in fine sands. The presence of fine can significantly reduce the effectiveness of permeation grouting. If the fines are present, then they can reduce the effectiveness of this grouting system. Permission grouting produces soil improvement by two primary mechanisms. The grout tends to strengthen the contacts between individual soil grains, thereby producing a soil skeleton that is stronger and stiffer than that of the un-grouted soil.

The grout packs up space in the voids between the soil particles, reducing the tendency for densification or let us say the tendency, the generation of excess pore water pressure generation will be reduced upon cyclic loading. So, first of all, it will strengthen the contact between individual soil particles and it will also fill the voids as a result the generation of excess pore pressure will be reduced that means chances of liquefaction will reduce. Now, we come to the second types of grouting that is called intrusion grouting. The last one was permission grouting, and this is in case of intrusion grouting. In the process of intrusion grouting, fluid grout is injected under pressure to cause control fractioning of the soil because the grout is not intended to flow through the small voids between soil particles.

Relatively viscous cement grouts can be used. So, this is intrusion grout. So, in this case, other system is quite similar what we have used for permission grouting except the bottom part. In case of bottom part because you are using the stronger grout compared to the last one, the grout can produce fissures inside the soil that it could not you know it can have kind of a cracks where it is injected. When it develops the cracks inside the soil, then what happens these cracks can be filled up with the grout and when you filled up these cracks with the grout, then you can have better ground improvement.

After allowing the initially placed grout to cure repeated intrusion grouting fractures the soil along different planes. Eventually a three dimensional network of intersecting grout lenses can be formed. Some densification of the soil may occur, but the primary mechanism of improvement results from the increased stiffness and strength of the soil mass due to the hardened lenses of grout. So, this was all about grouting, where we have discussed two types of grouting. One was permission grouting; another was intrusion grouting.

Now, we are talk about mixing of the soil. So, first let us talk soil mixing and then we will see the jet grouting or jet mixing. Thus, mixing describes a specific technique in which cementing material is mechanically mixed into the soil using a hollow stem auger on pedal arrangements. So, when you do the mixing in that case you are discussing, you are disturbing the original or the particulate structures of the soils. So, it will get disturbed, it is not the remains original, and it will get disturbed.

In case of soil mixing rigs may have single augers, if you have single augers then the in the case of single augers may be ranging from 0.45 to 4 meter in diameter or gangs of 2 to 8 augers can be used usually about 1 meter in diameter. As the mixing augers are advanced into the soil grout is pumped through their stems and injected into the soil at their tips. So, here you have soil mixing, triple auger soil mixing, rig improving liquefiable soils. So, what you have in this case, here you have a three auger rig, you can see that three 22 meters are coming, and they are going, three rigs are going down.

So, three triple auger and then you have grout based plant is shown at right, this is grout based plant, where the grout is prepared. The grout is thoroughly mixed with the soil by the auger flights and mixing pedals. After the design depth has been reached the augers are withdrawn while the mixing process continues. The soil mixing process leaves behind a uniform of constant width column of soil sediment. By overlapping the column before the grout cures, walls and cellular structures can be constructed below the ground surface.

Soil mixing can be used in virtually in any type of inorganic soil. So, the mixing can be done in any types of soil. Now, the second type of mixing is called jet grouting. In case of jet grouting the soil is mixed with cement grout injected horizontally under high pressure in a previously drilled borehole soils. The injection nozzle is rotated to allow the grout to be placed in all directions.

Air and water may also be injected to add in the mixing process. Jet grouting begins at the bottom of the borehole and proceeds to the top leaving behind a relatively uniform column of mixed soils. So, it is similar to what we have discussed. Here in jet grouting what is done, you have a stem and it get rotate and it is lift. Basically, you have jet column so ultimately this part is left out grout jet with this because this is rotated and lifted.

And this is jet grouting process which is by like by Hausmann in 1990. This arrangement pump pressure gas rotate, and this is quite similar. But the bottom part where grout jet is used is different than so this was about mixed jet grouting. By overlapping the columns before the grout cures, wall cells can be constructed below the ground surface. The diameter of jet grouted column depends on the soil conditions and the manner in which the jet grouting is performed.

Column diameters are generally greater in coarse grain soils than in case of fine grain soils. By varying the air, water and ground pressures and the rates of rotation lifting of the grout tubes, a jet grouting operator can control the effective dimensions of the column. The diameters which range from 0.4 to 0.5 meter in clayey silt or 0.9 to 1 meter in case of sandy gravel can be expected using a single jet system. Diameters of 0.8 to 1 meter in clayey silt and 2 to 4 meter in sandy can be expected with a triple jet that means when you have more than 3 jets and, in the jet, you have air, water and grout system. So, the jet will consist of air, water and ground system. Jet grouting can be performed in any type of inorganic soil to depths which is limited only by the range of the drilling equipment.

So, this was about mixing and grouting techniques. So, grouting and mixing techniques. Now, the last part of the ground improvement techniques which is drainage techniques we are going to discuss in the drainage techniques in the next few slides. In case of drainage techniques unacceptable movements of slopes, embankments, retaining structures and foundations can frequently be eliminated by lowering the groundwater table prior to earthquake shaking. A number of dewatering techniques have been developed and proven useful in engineering practice.

The processes for the design of dewatering systems are well established and it is widely used. These standard techniques may be used to increase the stiffness and strength of soil deposit for mitigation of seismic as well as non-seismic hazards. So, there are number of techniques. Basically what happens in case of soil many of the issue are related to pore pressure. And even for clayey soils where the liquefaction is not an issue, if you remove the water or pore water pressure then automatically strength will increase.

So, if you want to increase the strength and stiffness of the soil then one of the thing that if you pump out the water using some drainage techniques that is better and half of the problem is already solved. But of course, this drainage or pumping out the water may not always be possible, that is. The built up of excess pore pressure during earthquake shaking can be suppressed using drainage techniques although drainage alone is rarely relied upon for the mitigation of liquefaction hazard. So, when we talk about liquefaction hazard it is not only the drainage which need to be taken care, but the built up of excess pore pressure during earthquake shaking can be suppressed. The installation of soil column stone columns for example, introducing columns of freely draining gravels into a liquefied soil deposit through mixing of the gravel and the native soil during installation may reduce the permeability of the stone columns.

So, when the permeability of the stone columns is reduced what will happen? Because if you have the higher permeability then you have the better drainage and the chances of pore pressure generation automatically get reduced because when in the higher permeability drainage systems works better that means the water may be easily drained out. So, dissipation is faster. The earthquake induced excess pore pressure may be repeatedly dissipated by horizontal flow pore water into the stone columns. So, the excess pore pressure may be drained out, it is easily dissipated particularly when the permeability is large. The rate of excess pore pressure dissipation depends on the diameter and spacing of the stone columns and on the permeability and compressibility of the surrounding soil.

For example, Seed and Booker in 1976 and 77 develop the process for selecting the sizes and spacing of gravel drains or stone columns. So, this gravel drains is very important issue and these are used for the dissipation of pore pressure and like a peripheral drains or vertical drains are also there. So, these drains are used for the dissipation of pore pressure. The use of gravel drains for separation of excess pore pressure requires careful attention to drain permeability and filtration behavior of the drain soil boundary. So, these are drainage techniques like in fact, in the drainage techniques one of the drains which is properly used is vertical drains, they are simply called vertical drains and vertical drains are used for mitigation of reliquefication.

And then we will also discuss one types of drain particularly one of the research mitigation of leak refraction. Then we are going to talk about what we call the PVD, where one of the lectures in the we are going to talk the perforated vertical drains, particularly for mitigation of reliquefication we are going to discuss. So, these drainage techniques are quite popular, particularly vertical drains and one of the things PVD we will discuss like this. With this we completed all the techniques for ground improvement and in the next lecture what we are going to discuss is related to its verification part and then we will talk about geosynthetics also. So, with this I thank you very much for your kind attention. Thank you.