Ground Improvement
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Lecture No. 24
Deep Replacement

Hi everyone, once again let me invite you or welcome you to this ground improvement class. And in the previous lecture I have just completed vibro-compaction. And vibro-compaction is a deep compaction method or deep ground improvement method. There are many deep ground improvement methods of vibro-compaction is one of them and I have taken in detail about the vibro-compaction method, design, quality control, and monitoring construction, and with numerical problem everything I have done.

And there are again and a number of deep densification method is there and one method is named deep replacement, deep replacement that means, if the soil is poor at some depth also can be densified by replacement method. And when vibro-compaction is used, there also we can use without backfill and sometimes we can use with backfill also, if I consider vibro-compaction with backfill then the method is quite similar to deep replacement.

Because of that, I thought that along with this module, I take a few lectures of deep replacement and this deep replacement is basic concept is that you have to reach to the desired depth where the soil is not good and then you have to replace them with a good quality soil or some geomaterial compacted and then that can be used as a foundation. That is deep replacement that is why I have taken.

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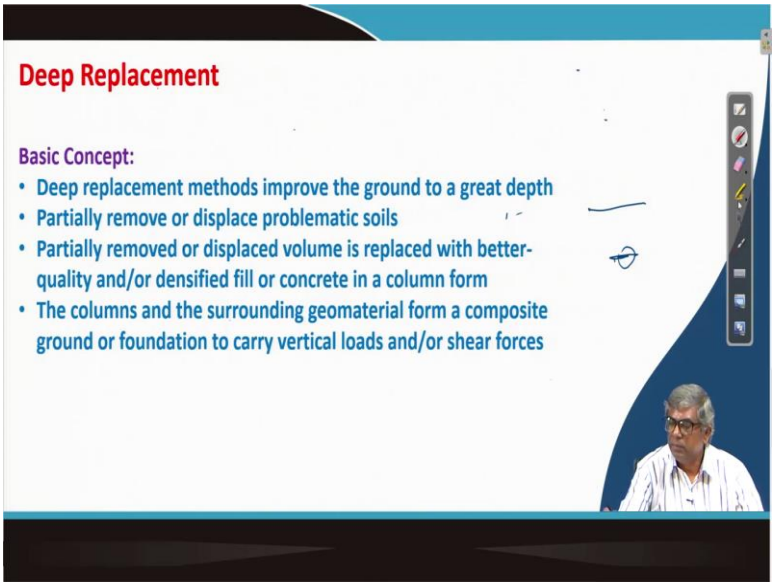

Let me start with the first slide that your deep replacement. Here basic concept is you can see here deep replacement methods improve the ground to a great depth that is of course vibro-compaction also same thing, it can go up to 40 meter, which we have discussed before. These deep replacement methods also involve ground to a depth and great depth.

And here partially remove or replace a displace problematic soil. Suppose at a particular depth soil is there, which is poor either partially to be removed by some means, or it could it could be displaced. You have to create a vacuum and displacing the problematic soil and that way also by and then after creating and then replaced by good soil and compact that you also it can be done.

And partially removed or displaced vacuum is replaced, that is first, this is first point is it is an in depth compaction. Second thing point is basic concept is that the soil, problematic soil either partially removed or partially displaced not fully. And then partially removed or displace volume that means, after if you remove or displace then that volume created that is to be replaced with better quality or densified fill or concrete in a column form.

The deep replacement will like when is a vibro-compaction also when you backfilling those, there also form like column. Here, or if you do not use then there will not be the uniformly compacted, but here, it is a requirement that it is a column like of things will be formed after end of this compaction.

And then with the column sand column or concrete column or stone column along with the surrounding soil it will be a composite foundation will form, that is the difference from there and the columns and the surrounding so that is what last point is that the columns and the surrounding geometrical form a composite ground or foundation to carry vertical loads or and or sheer force. This is the basic concept of deep replacement. Let me go to the next slide.

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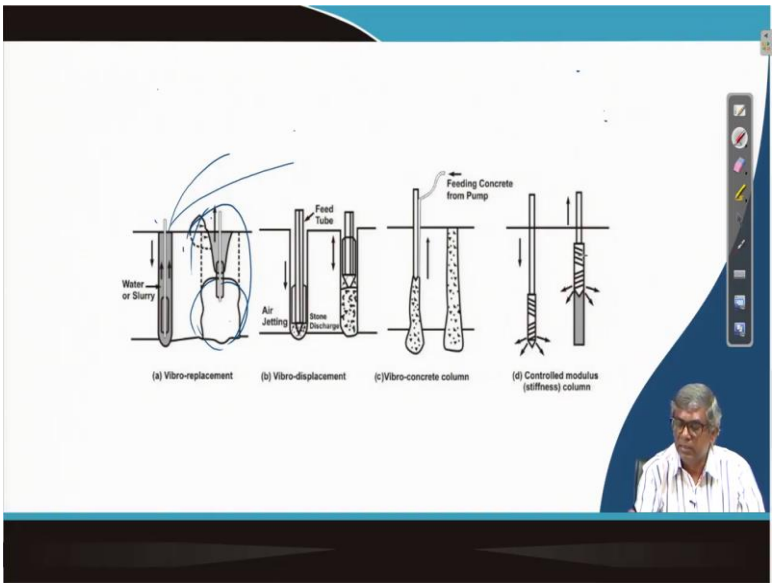

Here the all, concept the different ways that partial displacement or partial removal possible. Similarly, replacement also different ways it can be done. Depending on that there are different names and there are different technologies available. I will show or explained one by one this picture, you can see this one here you can see by vibro-replacement by water slurry.

We can go up to the depth and you supply water and create water slurry, in the form of water slurry it can come out from here and taken away and then there will be a borehole like things will be created and then you can fill it by some material and compact and then go up to the surface then you will get, you will see that there was improved zone up to this.

If I go up to the surface this is improved zone. Now, here you can see by air jet, by applying air jet again you can create volume and from the some of creating the vacuum and also some by some mechanism through a pipe we can pour sand also there or some other materials stone discharge as a stone or some other material can be discharged here and then you can compact and go up to this then there is a vibro-displacement.

And then here again vibro-concrete column you can see, whatever we are creating here at the same time we are feeding concrete and then go up to the surface, then this will be concrete column like things will be created, this is a vibro-concrete column. And then controlled modulus column, stiffness module. Here we can go up to depth and then we can inject that your grout, different grout it can be cement, it can be grout material, it can be some other chemical.

And by doing that, and if you go up to surface then you can see that we can have like things will be prepared. This is called controlled modulus column. Similar to this we have some more, let me go to the next slide.

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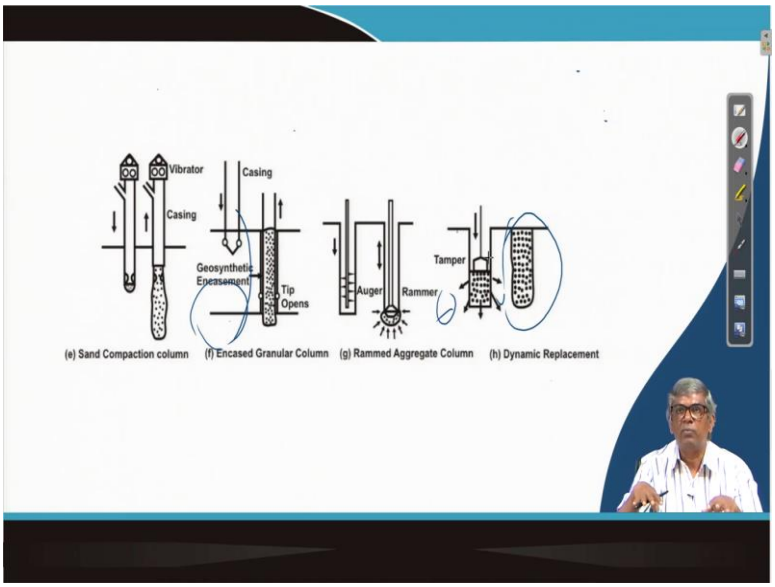

Here you can see there is one sand compaction column. Here what we do, we can casing can be inserted within the ground, when you do that, then will be surrounding soil will be compacted. And through the casing sand will be pulled and that casing again will be extracted up and down and pushed downward like that number of times if you do that, then by that way a sand will be getting densified and will come up to the surface then it will get a sand column like of things will be formed.

That is compaction pile sometimes it will be known, also it is known as sand compaction column, then there is an encased granular column you can see this is a casing, it can be again inserted and then afterwards some granular materials can be fit here, fade here and compacted. That way in case the granular column like your stone column or similar type of things can be formed.

And this is rammed aggregate column and you can see by, you can say auger by reverse auger, when you go then soil also come out and then when it will be a whole like of things will be created and then we can put concrete and again you can compact and then rammed it, and then if you come up to the surface then there will be again concrete column like of things will be formed.

And with the surrounding soil, it will be formed a composite foundation type of things. And dynamic displacement, that means if there is soft soil, we can keep some we can make a character and then we can put some sand and then the applying impact we can force those sand in the deeper area. When you do that, this soil around this will be displaced and we will get densified also and at the same time we are pushing sand and densifying, so it will be a compacted sand column like of things will be created.

There are a number of ways this can be, everywhere you can see that the either removing the soil totally or displacing the soil you are creating a vacuum. There we are backfilling by some other material and from the bottom, we can go up to the top or ground surface like that the continuous column like of thing we can create and that will together with the surrounding soil and a number of them is there surrounding places then all of them together can form a strong foundation. These are all by and large different methods, what were the basic concept we have mentioned with respect to basic concept, there are different technologies can be used and they are explained through these two figures.

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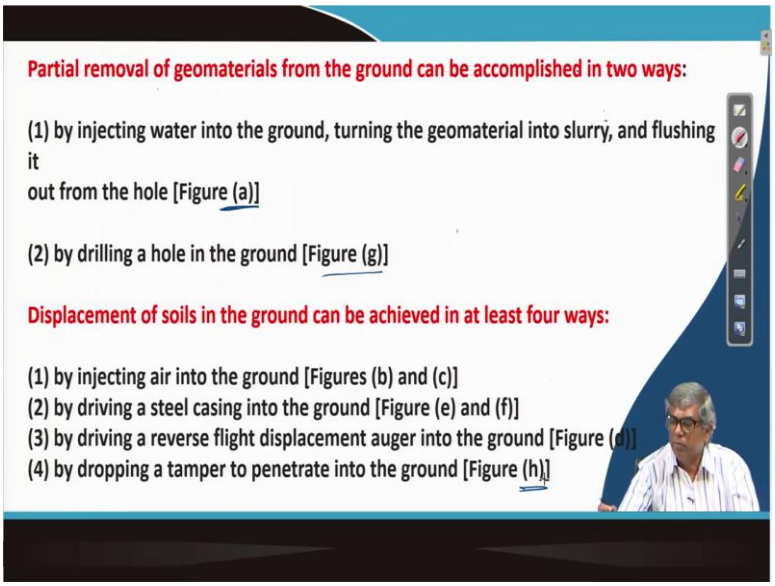

Let me, so partial removal I have already explained but once again, I have also listed here you can see partial removal of geomaterials from the ground can be accomplished in two ways. Soil first of all, suppose 8meter depth soil is there you have to remove you cannot excavate it just by like an excavator and collect soil. You have to that big opening you have to create. Lot of cost will be involved that is not the way.

How to remove that soil, that is by injecting water into the ground and turning the geomaterial into slurry and flushing it out from the hole. That is the way to do it. That I have

shown one figure that is figure, first figure number a, first figure and figure a indicates that. And by drilling a hole in the ground, by drilling a hole by some means, like auger or some other means, you can drill a hole and then that is figure g whatever I have shown, if I go back then you can find out the corresponding figure, I can go back of course, it is not going anyway, we will leave it.

All indicated there also a b c d e f g h they are accordingly. How you, by slurry form we remove that is corresponding to figure a and by auger or by drilling we do that is figure g and this is removal or partial removal of the geomaterials and also, we can do partial displacement. Partial displacement of the geomaterial can be made or can be achieved by different ways and you can see here by injecting air into the ground. And then vacuum created and then simultaneously you pour something and then compact.

So, that is figure b and c, whatever I have already shown. By driving steel casing into the ground, already we are sand column and all we have mentioned that the figure e and f and that is in geosynthetic encased column that is e f, so e and f. And by driving a reverse flight displacement auger into the ground that is another, so that is d, the reverse flight displacement auger can be used to displace the soil.

And by dropping a tamper to penetrate into the ground. That one last one h, whatever I have shown. That figure h that indicates the displacement. There are four displacement methods, not four, four to six displacement method and two removal method. There is total 8 figures are there. That is the way whatever I have explained also while showing the figure, the same thing I mentioned here, how we can do it.

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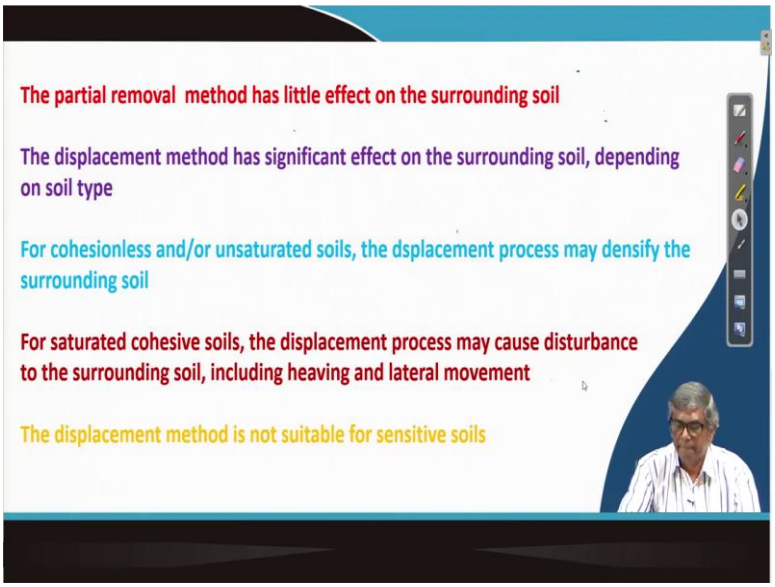

And you can see here that partial removal method has little effect on the surrounding soil. if I do compaction, improve the ground by partial removal method that means, I make a slurry or air jet if I put, create vacuum, removed the soil then what happens? It is only since equal volume of material is coming out, it is not affecting the surrounding, soil surrounding soil mostly it will be intact.

And whereas, the displacement method has significant effect on the surrounding soil, displacement how different ways you are displacing, is it not? So, suppose a casing you are driving when you are driving then you are displacing the surrounding soil. So, that is what the displacement method has a significant effect on the surrounding soil, it is getting compacted automatically and then further you are putting a good quality of soil in the hole created and as a result you are creating a large diameter your improved ground.

And then here for cohesionless less or unsaturated soil, the displacement process may densify the surrounding soil. The cohesionless soil are unsaturated soil, the displacement process may densify the surrounding soil whereas, in saturated, though I have mentioned the displacement method generally densify the surrounding soil, it has significant effect, what?

If it is cohesionless or unsaturated soil, then they can densify the surrounding soil whereas, if it is a saturated cohesive soil the displacement process may cause disturbance to the surrounding soil, including heaving and lateral movement. Instead of densifying, it will heave, it will, if I go try to display it like this, it will have spread like this and move side ward. So, that will not be densified.

And displacement method is not suitable for sensitive clay soils. That is also important, because strength will be significantly altered and because of that, it is not at all used this one because the displacement it has significant effect or disturb the soil, surrounding soil. This disturbance in the form of reduction of strength and all. Because of that this sensitive soil generally the displacement method is not used.

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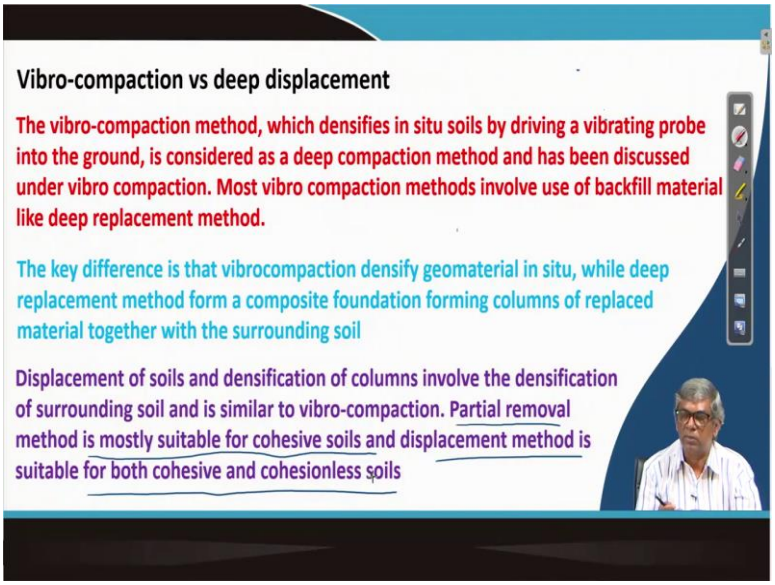

Now, vibro-compaction verses deep displacement we have mentioned they are similar that you can see the vibro-compaction method which densifies in situ soil by driving a vibrating probe into the ground and is considered as a deep method and also, we have discussed already. And most vibro-compaction method though vibro-compaction is, vibro-compaction can be done without backfilling and if you do not do backfilling, then of course, there will be settlement. So, because of that most of the vibro-compaction is done with backfilling.

So, because of that, they are nothing but a replacement, the deep replacement. That is what is a conclusion want to do. So, when the vibro-compaction is used with backfill, they are almost similar to or can be treated as also deep replacement. What is the main difference between vibro-compaction and that is vibro-compaction densify the geometry in situ while deep reflection method form a composite.

Vibro-compaction by compaction you will compact surrounding soil and if the too much of settlement takes place, then we are supplying or backfilling material and then compacting the entire in situ soils, whereas in replacement method, we are making a hole creating a hole by some means, and then we are column like of things we are forming and that column with surrounding soil making a composite foundation, that is the main difference.

And displacement of soils and densifications of columns involve densification of surrounding soil and is similar to vibro-compaction, already I have mentioned before. And partial removal method is mostly suitable for cohesive soil, so partial. Why it is because crazy soil can be through water injection can be made a mud type of things that can be taken out easily.

So, because of that, partial removal method is mostly suitable cohesive soil and displacement method is suitable for both cohesive and cohesionless soil. Displacement of course, by force you can displace, by auger also you can displace, cohesive soil also. That means partial removal is only possible or more suitable for cohesive soil only whereas displacement can be adopted both cohesive soil and cohesionless soil also.

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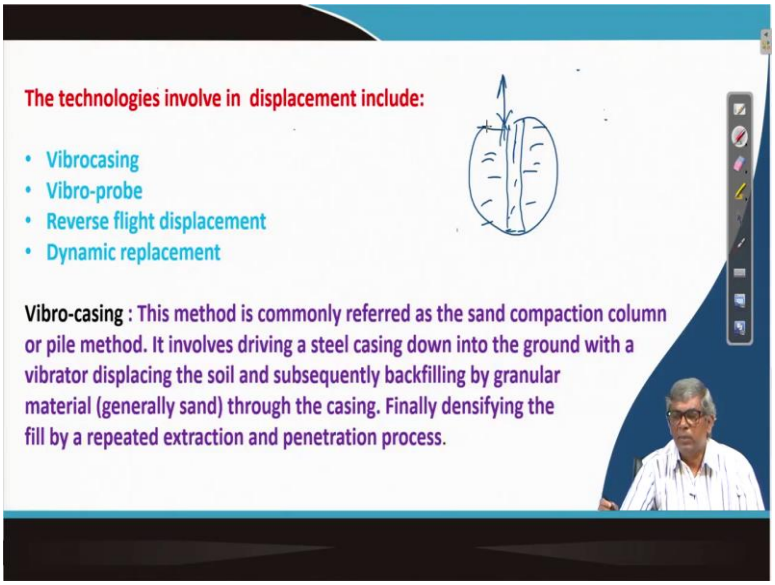

And technologies involving displacement include. So, augments we need. Suppose you want to displace and create a vacuum. How to create the displacement, how to displace? There are a number of ways which already are shown. But that can be by and large, can we classify in these categories vibro-casing, one, vibro-probe, then reverse flight displacement, and dynamic replacement.

What is what vibro-casing is what, so I have explained once again I repeat in this method commonly referred as the sand compaction column pile method, column or pile, compaction pile or sand pile method. generally by a steel tube, if I keep the bottom closed and pushed inside, then soil will be automatically compacted, surrounding soil will be compacted because, whatever volume is displacing, that will be compacted, equal volume.

And then whatever column or tube or steel tube or steel casing we have driven that also can be filled up with sand, and then again and again you can lift and again you can drive that way that sand also will be compacted. first of all while pushing, you are compacting the surrounding soil and inside the casing again we put soil and then that can be up and down movement by that sand also can be compacted. That is the way the vibro-casing work.

And it involves driving a steel casing down into the ground with a vibrator displacing the soil and subsequently backfilling by granular material, generally sand, through the casing. And finally, densifying the field by repeated extraction and penetration process. So, this is the thing already I have mentioned, vibro-casing that means, you have to push the vibro-casing some depth up to some depth and then sand filling will be there.

While doing this it will be compacted and then sand, this can be moved up and down and then this sand also compacted and that way entire area will be getting densified. This is vibro-casing, next one is vibro-probe.

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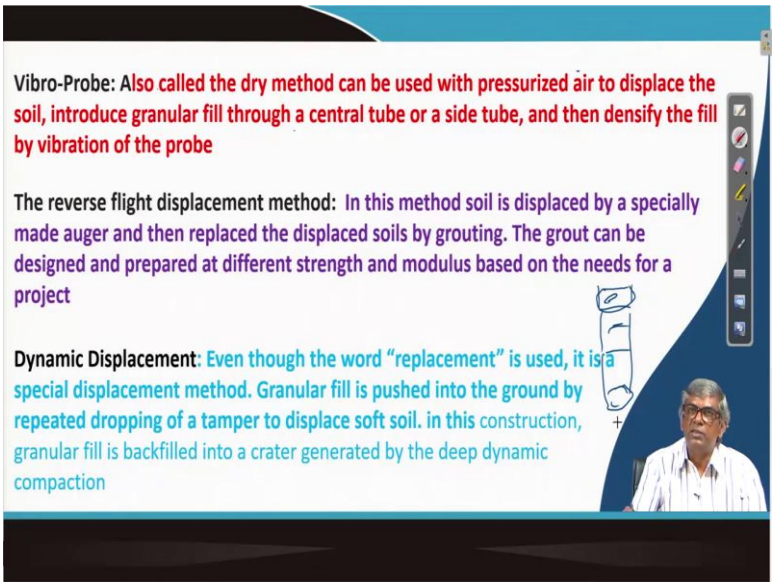

And this is also called the dry method, and can be used with pressurized air with air high pressure air to be used to displace the soil and same time introduce granular fill through the central tube and our side tube and then densify the field by vibrator or of the probe. This is the one while driving the probe you have to have a high pressurized air pressure and through which it will create some vacuum and centrally there may be another tube through which sand can be there and probe and when sand getting filled up it will be lifted and then afterward with that probe creating vibration or can we lift it up and drop by the repeated that way, repeated drop that sand can be compacted.

That is vibro-probe also called dry method. And the reverse flight displacement method. This is again soil displaced by specially made, especially the auger. This is auger and then replace the displaced soil by grouting. So, by augur we are, while we are going down the soil will be coming up and then it creating some vacuum and that vacuum can be filled up by grout and that can be designed and a difference according to strength, whatever strength and modulus is required for a particular site.

Accordingly, that grout can be designed and grout can be injected and then finally it can go up the surface then soil will be densified, or soil may not be densified, that along with that grouted column and surrounding soil they will be considered a composite foundation. Then dynamic displacement here the word replacement is used here. Here, it is a spatial displacement method. The granular fill is pushed, suppose I will create one crater and fill with sand and this one by some mean we can push up to this.

The sand can come here like that again I can push some out of sand like that you can go up the surface and create a sand column. That is called dynamic displacement. And in this construction, granular fill is backfilled into a crater generated by the deep dynamic compaction.

Already I have mentioned that you have to create a crater and then fill it sand and then by dynamic compaction of push them downward and then, we can do slowly up to the ground surface. That is the one and it is applicable only for soft soil because otherwise it will not be easy to displace the sand column or pushed downward. These are all by a large different technology used to displace soil.

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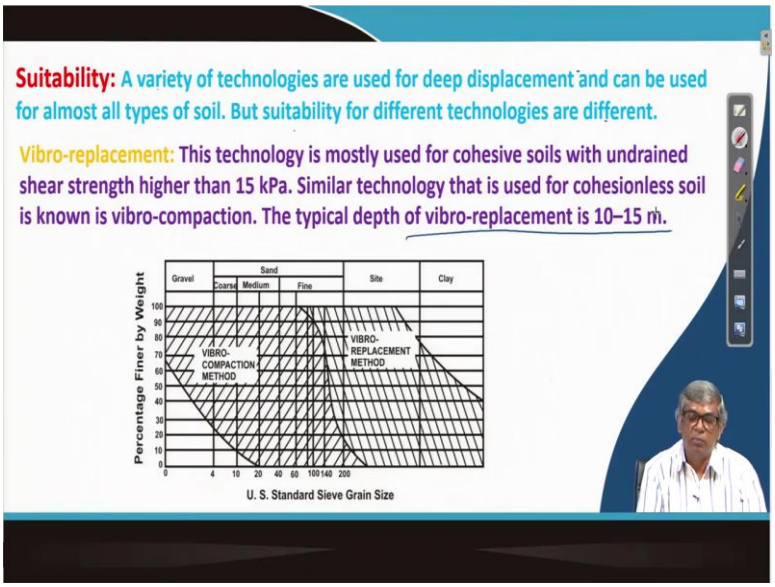

And suitability again displacement method a variety of technologies are used for deep displacement and can be used for almost all types of soils since. Whereas, vibro-compaction only granular soil, silty maximum, some amount of sales but here as we have mentioned the by deep replacement can be used in the both granular soil and cohesive soil.

And of course, suitability for different technologies is different that I will discuss one by one. And by a large one figure is shown here you can see in this there is a zone marked, if this is the zone vibro-compaction, vibro-compaction is nothing but a special type of displacement method, deep replacement. If it is a coarse then a medium ground soil then vibro-compaction method is suitable, and if it is this fine soil and then it will be vibro-replacement is suitable. These are briefly.

Now, vibro-replacement whatever we have mentioned this technology is mostly used for cohesive soil, vibro-replacement with undrained shear strength higher than 15 kPa. And similar technology that is used for cohesionless soil is known as vibro-compaction. And these vibro-compaction technique typically go up to depth 10 to 15 meter we can do by vibro-compaction. And what type of soil, cohesive soil with shear strength greater than 15 kPa, undrained shear strength.

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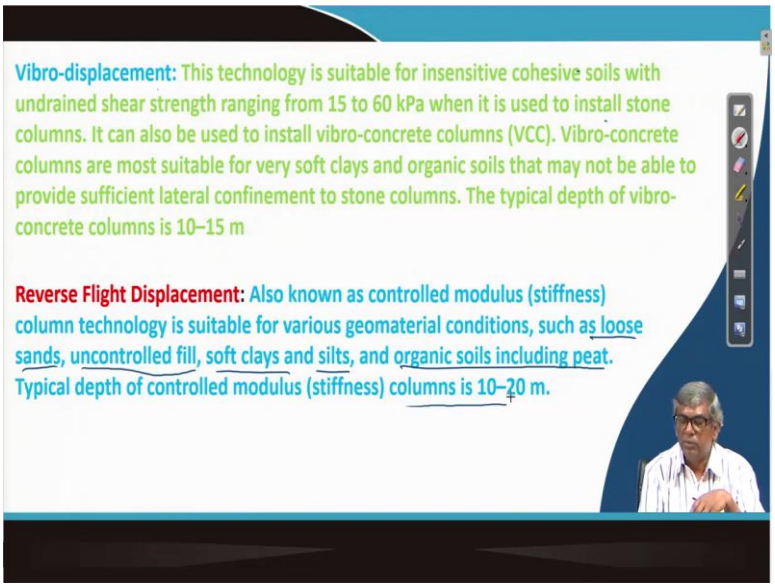

And vibro-displacement here, this technology is suitable for insensitive cohesive soil with undrained shear strength ranging from 15 to 60 kPa and when it is used to install stone column. This vibro-displacement this is the type of soil and this displacement and the replacement is done by stone and sometime concrete can be used also, vibro-concrete can be used. And vibro-concrete columns are most suitable for very soft clays and organic soils that may not be able to provide sufficient wind lateral confinement to stone columns.

Once stone columns are there and stone column when you are putting and then it has to be laterally stable or if the soft soil, too soft soil is there then stone itself since they are not bonded, they may slowly bulge and they may get into the clay soil. Because of that, when it is a soft soil and organic particularly where they do not have sufficient strength to lateral confinement that soil concrete, vibro-concrete can be used which can stand itself. And vibro-compact displacement method can be used up to 10 to improving up to 10 to 15meter.

And reverse flight displacement method. It is known also known as controlled modulus column technology, it is suitable for a various geomaterial condition and that is such as loose sand, uncontrolled fill, soft clays, silts and organic soil including peat. The reverse flight displacement method, this is the suitability area and a typical depth of controlled modulus column can be made up to 10 to 20 meters.

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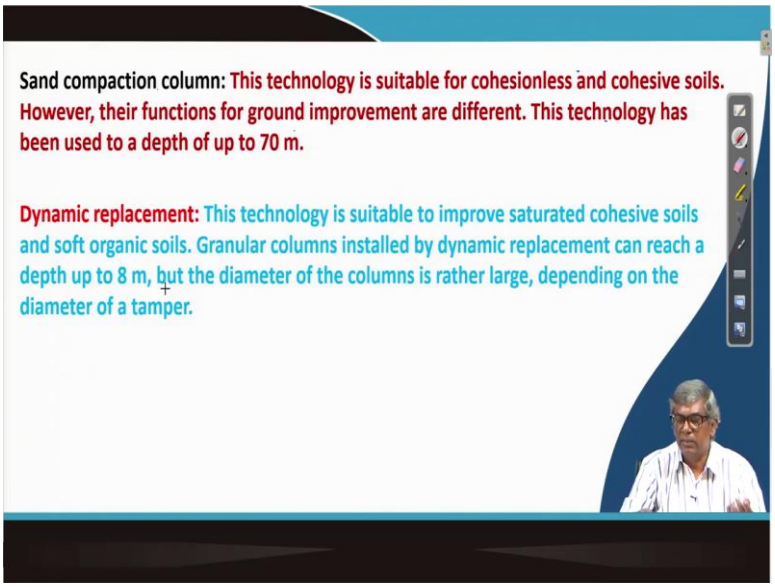

And then sand compaction column. This is suitable for cohesionless and cohesive soil both. Of course, they are function for ground improvement will be different, when it is a clay then it will be again column sand column will be used. And when it is a column then also the compacted laterally and also it will be created. And this technology has been used up to 70meter, this sand compaction column method can be used up to 70 meters.

This is so far highest depth of improvement we have seen by vibro-compaction. But in replacement method here that sand compaction column method can be used up to 70 meter deep. So, that is the highlight. And dynamic replacement and this technology is suitable to improve saturated cohesive soils and soft organic soils already I have mentioned. And granular curve is installed by dynamic displacement and can reach a depth up to 8 meter and but the diameter of column is rather less large depending on the diameter of the tamper.

Dynamic displacement cannot be done much because we have to displace and we have to push the sand it is not so easy by pushing, displacing the soil at some depth, beyond it we do not we cannot do and but its diameter sometimes can vary depending upon what size of tamper we are using. With these are all various points relating to vibro-compaction and deep replacement, what is their difference between the two things what are the differences, what is the technology wise what is the difference, what are different technologies available for vibro-compaction or the deep replacement?

All those things briefly I have mentioned maybe one more lecture I will try to take highlighting some more aspect, some load transfer etcetera, because here in the sand compaction method, once compacted we are considering uniformly soil as entire compacted

ground. Here is a non-uniform, there is a surrounding soil and there is a column, this column and soil together there will be a composite foundation.

There are load transfer mechanism and behaviour will be little different, so that I will maybe briefly I will discuss in one lecture, but detailed design I will not take because there is no end there are so many methods, I have mentioned, everyone will have a different design method. So, then it will take, then I have to take the entire class only on that. I will not do that. I will just highlight one certain feature by one lecture and then I will go to the next topic like several other topics for ground improvement is there, so I will take that. With this, I will close here. Thank you.