Ground Improvement

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Lecture 11

Deep Dynamic Compaction

Let us continue with the topic, perhaps I have completed 2 modules, 1 module was general introduction and, and in that we have shown that there are a large number of ground improvement techniques are there. It is a method to select and how to apply and what is the condition all we are discussing one by one.

And I have taken the first one that is shallow densification, shallow densification by the name itself it is quite obvious that it cannot be compacted when the thickness of the layer is desired very thick. So, thickness of the improvement is required more then there are different techniques to be applied. In the shallow densification, we can observe what the typical area of application, is mostly parking areas, then some storage places, then there is some ground from the cricket field and all, or even in the embankment and the road and embankment.

Basically, road and embankment though it can be of 8 to 10meter high. Sometime or even 4 to 5meter highs or even more. But there actually you can compact it in layers. And by that shallow densification concept can we use there itself, so there is no issue. Then these are different areas of application and I have shown one or two problems and then how to use this shallow densification concept in calculation also.

Next one is that when the problematic soil is up to a great depth, suppose is a saturated soft soil or loose sand it is there up to 8 to 10 meter or even more, in that case shallow densification method is not suitable. So, for that, again, they are going to be deep dynamic, deep compaction again there are a number of methods for saturated soil there are some effective methods, for non, for loose sand or seal that is another, some other effective methods.

So, now we will discuss one method that is called deep dynamic compaction where by the name itself you can quite obvious, the effect will be quite deep and it will be suitable for a particular type of soil. And those things one by one we will try to take where to be, what is the concept behind and what are, what the area to be applied is, where not to be applied, and what are the design steps. That means, when you do this dynamic compaction, then that entire dynamic compaction you have to design, that means you will show that one later on.

Design means actually a particular weight will be lifted and allowed to fall on the ground and that will be helping to compact the ground. So there, if a large area to be compacted, then what should be the spacing, then what should be the weight of the drop, what is the height of the drop, then what is the number of passes, that means at one place how many drops to be placed all those things are design aspects. So, we will discuss one by one.

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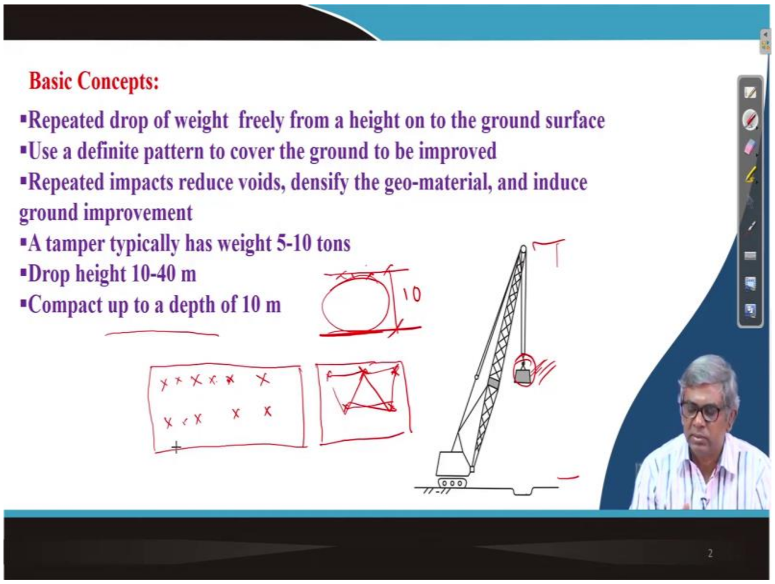

Let me take the first slide, that it is the basic concepts. As I have mentioned that, repeated drop of weight freely from a height onto the ground surface. You can see here that, you can see this is the weight and this is the ground and it is lifted this much height and then through this crane and then finally allowed to fall on this ground.

When it falls as we can see, this depression happens in the soil or subsidence happen and it here little heaving will be there may be at the site, but the soil will be compacted below and surrounding up to some area actually. So, this is the basic concept, though looks very simple, but there are a lot of things to be kept in mind when you apply this technique. Second thing is use it then use a, use a definite pattern to cover the ground to be improved.

This definite pattern means actually you can, I just show you that pattern mean suppose this is the area to be improved, then you can drop somewhere here, you can drop somewhere here, you can drop somewhere here, you can drop somewhere here, somewhere here, somewhere here, somewhere here like this, this is called square pattern.

Instead of doing this I may do something else like this suppose, one here, then one here, then one here, then one here like this. In this way what we are forming, we are forming three angles. So, this is called three angular patterns, this is three angular pattern. So, like that, a definite pattern to cover the ground to be improved, that means this is the area, I can cover like this, in between there may be drops etc., that we design this is by a large, the second step.

A repeated impacts reduce voids, densify the geo material and induce ground improvement. So, as I have shown here that because of this drop, what happens that the soil getting compacted means, soil grain is forced to come closer and when it happens, then void ratio will be reduced. And if the void ratio reduced, then of the soil then what will have that result actually ground improvement or, or soil improvement.

That is the purpose for which we use that ground to be or soil to be or geo material to be densified. And once you densify then several advantages we will get, will be more, settlement will be less, and its permeability will also be reduced. So, all sorts of benefit will get. Then a tamper typically has a weight of 5 to 10 tons, so this is called tamper actually.

So, this will be lifted and depending upon your soil type or where to be ground will be applied and technique will be applied, depending on that this weight will be selected, it can have between 5 to 10tons and drop height range between 10 to 40meters. This height, it can be between 10 to 40meters. And, and compact up to a depth of 10meters.

So, what I have said that in the shallow densification it cannot go beyond 1 or 2meter, of course in layers, you can do more, but when you compact in the embankment, we do 30-40centimeter layer. And so, that is the range actually maximum 1 meter can be compacted by roller but here actually up to 10 meters. Suppose this is the ground surface and if you do by this dynamic deep compaction then, up to this, this is a 10meter up to this much depth will be densified.

So, of course, for making effective up to 10meter you have to design this, you have to allow, you have to use number of drops at the same place, we may have to have in between drops, like that so many things to design. If you want shallow then you may do, require less, but if you want to make deeper then you have to do more number of drops, more heights, more weights, all those things are there.

So those things we will be discussing slowly one after one. Next part, let me go to the next slide. Then when you go to the next slide, give me one second let me see.

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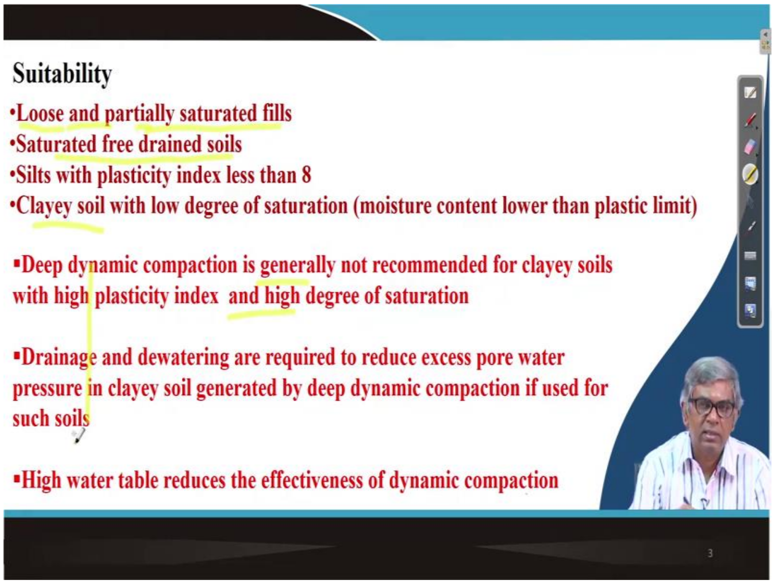

And you can see suitability; suitability means actually, you can see that where actually we can, we can use this deep dynamic compaction effectively. The most important is that loose sand and partially saturated fills, loose, loose and partially saturated fields and then saturated free drained soils. So, this is another important thing.

Such, if it is saturated actually generally not suitable, the loose and partially saturated most effective area, but if it is saturated then in that case it should be free draining, that mean permeability should be high in then only this will be effective. And silts with plasticity index less than 8. So, silty soil also can be used, but there actually you have to determine one parameter that is plasticity index and that value should be less than 8, if it is greater than 8 again it will not be that effective.

And clayey soils with low degree of saturation, that means the clay soil when you want to compact, so degree of saturation, moisture content lower than plastic limit that is the requirement actually in a particular site soil the, degree of saturation or moisture content should be lower than the plastic limit. That is the requirement, then only clayey soil also can be compacted.

Then there is other area where actually if you want to use what are the difficulties it is mentioned you can see, deep dynamic compaction is generally not recommended for clayey soil with high plasticity index and high degree of saturation, this is the requirement is mentioned obviously, this is the condition generally not recommended, if it is recommended then a lot of other precautions to be taken that we will discuss maybe later on.

Drainage and dewatering are required to reduce excess pore water pressure, if you want to saturate fine grain soil and if you want to use this, then obviously you have to do either some ways actually dewatering to be done, that water level to be reduced lower. And otherwise, the saturated fine grain soil if you suddenly apply load, then excess pore water pressure will develop that pore water pressure actually will not allow to soil then come closer. So, you then automatically will not be effective.

And height water table reduces the effectiveness of dynamic compaction. Obviously, that if the water table is very close to the sharp edge where actually, then that area actually deep dynamic compaction that the method we to have shown will not be effective, mainly because why, because that, that pore pressure development and that pore pressure actually when developed then it will push the soil particles away not allow to come closer.

But in this technique by applying certain energy, you are forcing the particles to come closer, but if it is a saturated fine-grained soil, this will not happen. As a result, this will not be affected. That is why these are the point mention because these are the difficulties if you want other than this soil, these are the difficulties that is why it is highlighted. Next slide will go.

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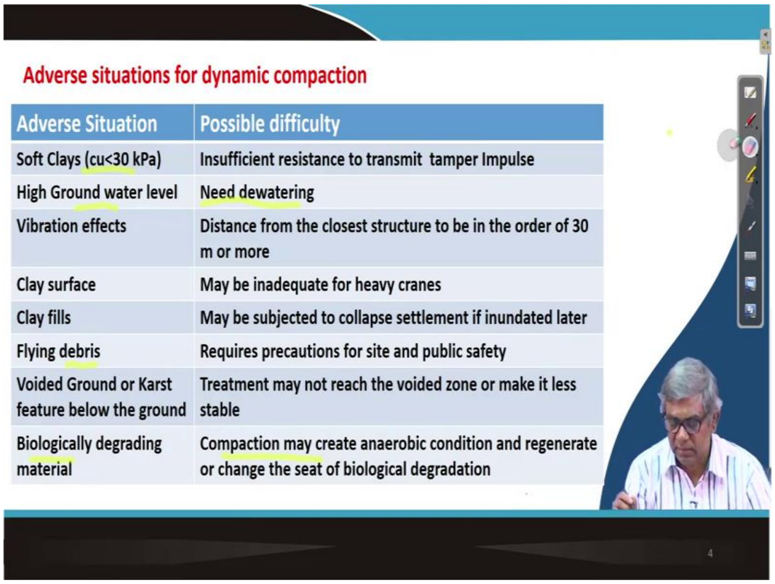

You can see here that the adverse situation for dynamic compaction where actually we cannot use dynamic compaction, deep dynamic compaction and if we use what are the difficulties. Actually, you can see that adverse situation is soft clays, where actually your Cu value that where under shear strength is less than 10, 30 that soil will be treated as soft soil.

And that soil actually, if we use then what are the difficulty, insufficient resistant, resistance to transmit tamper impulse. So, that means, when a tamper weight falls on these, then it will just sink, from impulse transmitting that will not happen properly. Insufficient resistance to transmit temper impulse, so that is what it will be just splitting some time instead of compacting.

Then high groundwater table that is another condition we have mentioned previously, high groundwater table even if you are under this condition, then obviously if you want to use deep dynamic compaction it will not be effective and if you want to make effective then you need some time dewatering. So that will add some cost and of course, other difficulties, if it is not permitted, if it is not desired then this of course not suitable.

Then vibration effect, another thing is deep dynamic compaction it creates a lot of vibration. And as a result, everywhere you cannot use this. And there is a distance from the closest structure to be in the order of 30 meter or more that means, if the, if there is a structure somewhere here, at least you have to have deep dynamic compaction 30 meter at least their way, even more will be better, because otherwise, because of this vibration and all the building can be damaged and people also may not feel comfortable all sorts of thing can happen.

Then clay surface if it is there maybe inadequate for heavy cranes. If there is a very soft clay surface is there and if you want to compact and then that heavy crane will not be able to stand there, then all the activity cannot be done. Then there is a clay fills, may be subjected to collapse settlement if inundated later.

So, that is another thing. Flying debris, this is another most disturbing things actually when deep dynamic compaction is done and then on developed area generally do a lot of debris and all will be there when heavy weights will fall. And those a lot of devotees will be created and if there is a wind those debris will be flowing and going around the places and that sometime create a lot of problems. So, requires precautions for site and public safety that is for, that flying debris then voided ground or karst.

So, if there is a voided ground then treatment may not reach the voided the zone or make it less effective or less stable. Because of that, this is also not a, this is also adverse situation. And biologically degrading material that is another area adverse situation where this is not suitable, because compaction may create anaerobic condition and regeneration or change the seat of biological degradation. So, this is another situation where you cannot, if you want to do deep dynamic compaction, there is a difficulty. So, let me go to the next slide.

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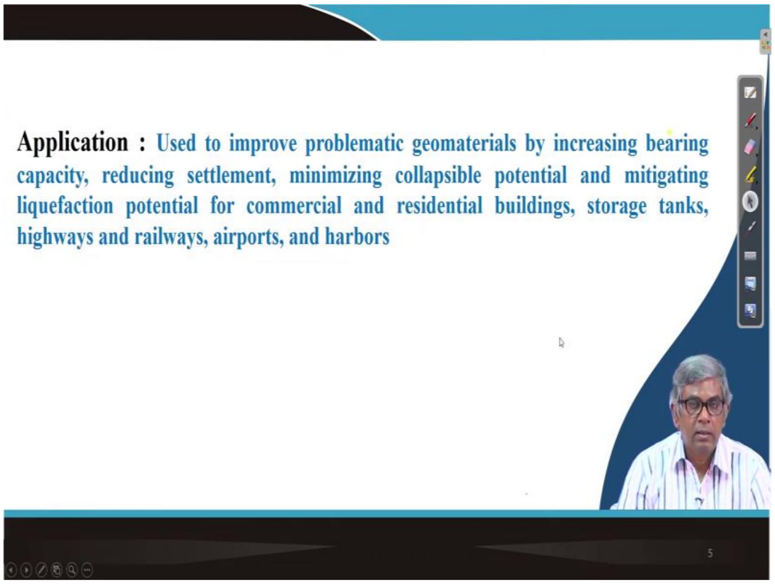

The application, typical application that went in since we know that technique now, where actually, where actually you can apply this type of where and why. Then it used to improve problematic geomaterials by increasing bearing capacity that is the objective everywhere for ground improvement technique almost. The increasing bearing capacity, reducing settlement, minimizing collapsible potential and mitigating liquefaction potential for the, for commercial and residential buildings, the storage tanks, highways and railways, the airports and harbors.

This is the thing actually that means, increasing bearing capacity reduce settlement and some areas actually, where actually we are going to construct building or an infrastructure those infrastructures should not be susceptible to liquefaction. So, if that type of soil were actually you find that liquefy, liquefaction potential is high. That area can be densified by this deep dynamic compaction. Let me go to next slide.

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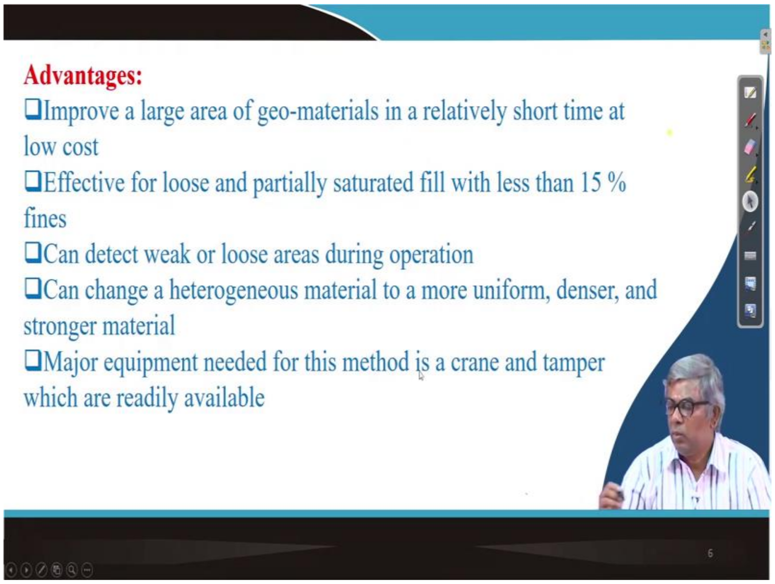

What are the advantages? You can see that when we have discussed about shallow densification with respect to these, what is the advantage of this method. It improves a large area of geo materials in a relatively short time at low cost that is the most important, very quickly it can be done. And first of all, its depth of improvement is quite high and very quickly and large area can be covered.

This is the biggest advantage of these deep dynamic compaction. Next one is the effective for loose and partially saturated fill with less than 15percent fines. So, this is very effective, sometime loose soil densification by other methods whatever we have discussed before is not so easy. And can detect weak or lose areas during operation.

When you do deep dynamic compaction, if cannot resist that weight when it falls from the height then obviously you will realize that there is something wrong, those things can be detected easily. And can change a heterogeneous material to a more uniform, society is heterogeneity suppose the field, and then by applying this type of dynamic compaction we can make a more homogeneous material to more uniform denser and stronger material finally.

And major equipment needed for this method is a crane and a temper, which are readily available with most of the contractor. These not much sophisticated on crane and one heavyweight these things are not required. Because of that, these are the most advantageous in some application or you can say that compared to shallow foundation, shallow densification these are the few advantages, but it is not only advantages it also some cases it is disadvantage also let me see what are the disadvantages it has.

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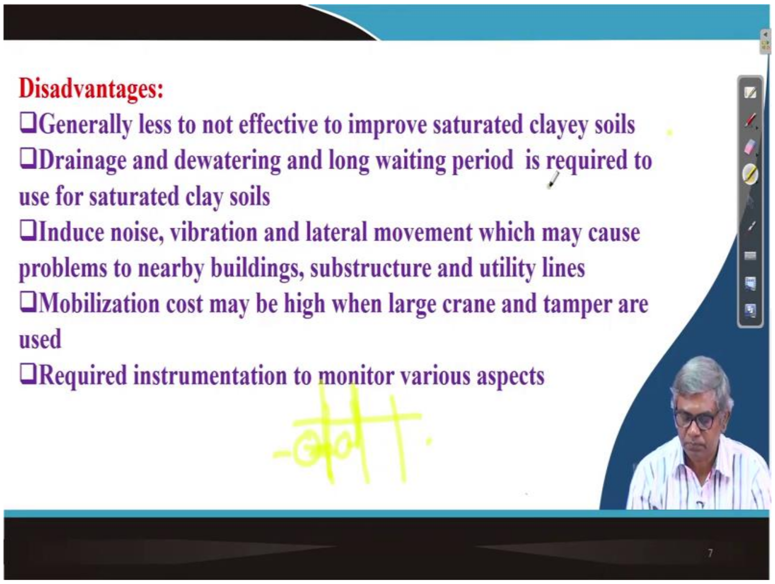

You can see number of disadvantages will be there, generally less to not effective to improve saturated clay soil. This is most important, saturated soil if you want to improve then we have to make some arrangements actually, otherwise just falling weight it will not help to improve the soil. Drainage and the watering and long waiting period are required to use for saturated clay soil.

That means diligent dewatering means what actually sometime we have to, that we will be discussing later on what is the drainage method of dewatering, drainage method of densification et cetera. How drainage helps to accelerate the consolidation or densification would discuss that later on. For the time being I have just mentioned, if there is a soil here, and if you make number of vertical drains, and then, so this vertical range can be prepared based on sand or there is a new material available called prefabricated vertical drains these can be there.

And now, if I apply impact, then because of these the water in this area can move instead of vertical and this direction it can move laterally and it can reach to this drain and through this it can come out. Similarly, from here it can come out either this direction or this direction comes out and this direction. Because of these advantages, it is actually drainage and dewatering, if you do this, then only fine grain soil will be effective otherwise it will not.

And next is the induce noise, that is again biggest disadvantage is the locality if we want to do this type of work that will have noise, vibration that is also ground will be, people also feel, building will also we vibrate, lateral movement, which may cause problems to nearby buildings substructure and utility lines. So, because of these operations, these are the damage sometimes can happen because of this vibration.

Of course, discomfort also is another, also part that sometimes can be avoided, but damage cannot be avoided. Then mobilization cost may be high when large crane and temper are used. So, this is again, another issue, when actually undeveloped area when you want to develop by this method, there may not be any access, proper access etc. then heavy crane to transfer that area, maybe mobilization cost, maybe the variable will be high.

And required instrumentation to monitor various aspects that is of course so for some time at some cost. So, these are the disadvantages. Let me go to the next slide.

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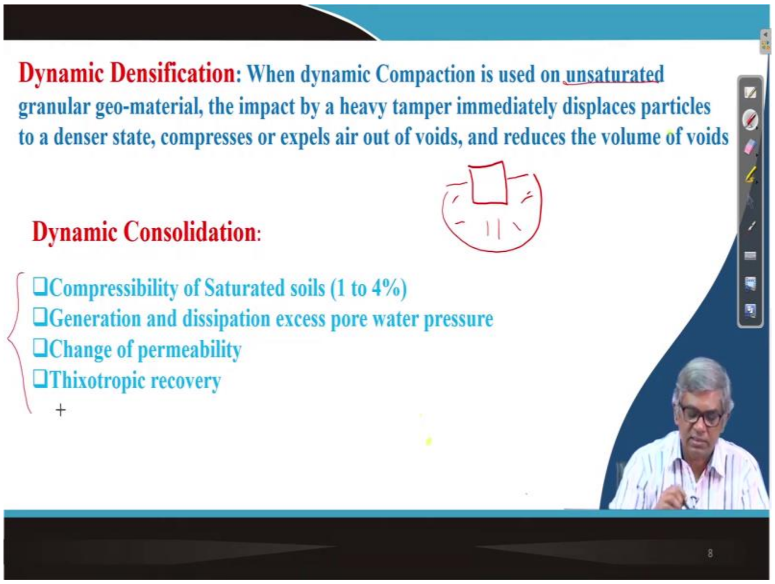

So, dynamic densification again can be of different types, when dynamic compaction is used on unsaturated granular geo material, the impact by heavy temper immediately displaces the particles to a denser state, compresses or expels air out of voids, and reduces the volume of voids. So that means, I will just show that is heavyweight, for this heavyweight fall on the ground, so it will happen. Surrounding soil actually, so this march it is penetrated this much, that means that much volume will be reduced in this, when it is, how it will be reduced only by sending the particles closure or exploiting the air within the voids.

So that is the way actually it can densified. At this will happen, if the soil is unsaturated this happened almost immediate, because weight drops immediately below that, the weight actually soil be compressed. So, this is the immediate effect. But if you have other type of soil then the mechanism will be different. So, because of that we can classify this 1 in 4categories that when it is particular saturated soil then dynamic consolidation and it will have different stages.

Compressibility of saturated soil that means, immediately after loading because of this compressibility of saturated soil 1 to 4 percent actually can be reduced. And then generation and dissipation of excess pore water pressure. When weight falls it develops pore pressure and then it dissipates by this way actually again settlements continue.

The change of permeability happens because of these with time. And thixotropioc topics recovery showed dynamic consolidation if you do, that means in the saturated soil it will be dynamic compaction, dynamic densification and unsaturated when it is saturated clay then it will be dynamic consolidation and in these have 4 stages. Let me explain one by one those stages let me go to next slide.

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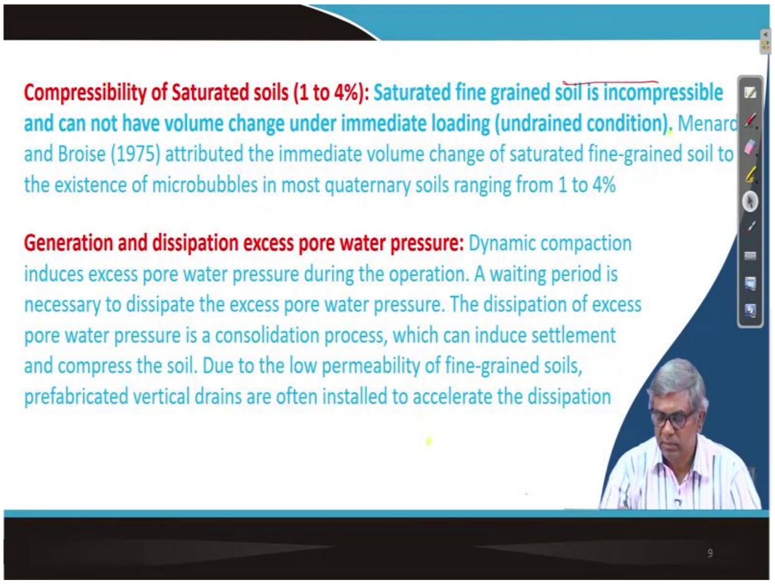

Compensability of saturated soil 1 to 4percent as I have mentioned, saturated fine grain soil is incompressible and cannot have volume change under immediate loading undrained condition. And so, Menard and Broise actually 1975 activated the immediate volume change of saturate fine grain soil to the existence of my micro bubbles in most quaternary soils ranging from and 1 to 4percent.

That is actually the presence of microbubbles and sometime have not removed and that because of that it can be reduced up to 1 to 4 percent. And generation and dissipation of excess pore water pressure that means dynamic consolidation compaction induces excess pore water pressure during the operation. A waiting period is necessary to dissipate the excess pore water pressure.

The dissipation of excess pore water pressure is a consolidation process which can induce settlement and compress the soil. So, this is of course, consolidation you have learned in the soil mechanics the weight is applied on saturated soil pore pressure develops and with time that will dissipate, dissipation means that actually that pore pressure will be reduce and excess load will be transferred from the water to fine grains and that will help to close the, bring the file closer and that helps actually consolation, that is the way actually generation and dissipation of excess pore water by this way actually.

So, due to the low permeability of the fine-grained soils, prefabricated so that is what, if we want to use this saturated soil this dynamic compaction then you have to dissipate the pore pressure, you have to provide some drain vertical drains that is what we have mentioned before also.

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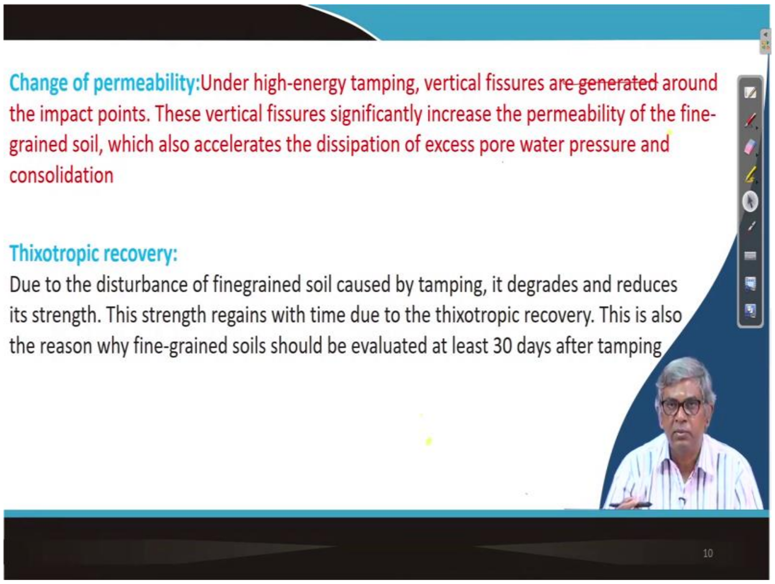

And next part is the change of permeability under high energy tamping, vertical fissures are generated around the impact points. These vertical fissures significantly increase the permeability of the fine grain soil, which also accelerate the dissipation of excess pore water pressure and consolidation. That means, when the weight falls the lot of fissures and cracks in form and through that cracks water also can seep through that will help to dissipation of pore pressure.

And thixotropic recovery actually due to the disturbance of fine grain soil caused by tamping, it degrades and reduces the strength. Immediately because of these impacts, it degrades and reduces strength, but the strength degrades because of thixotropic effects. That is things actually sometimes we can use then they are not, not always, this can be discarded and can be used with some precaution.

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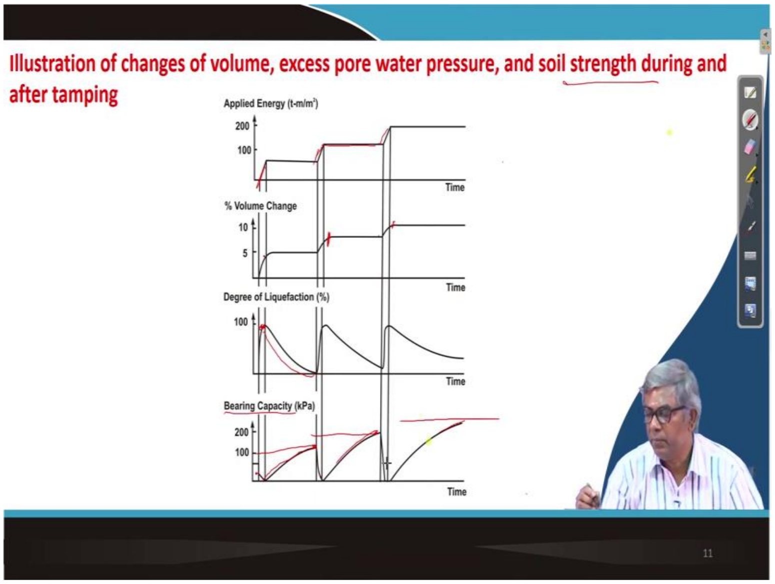

And this is actually illustration of changes of volume, excess pore water pressure, and soil strength during and after tamping. You can see here that different things are there when the applied load. Suppose 3 drops I have applied. So, one when applied load is there with time. This is the time within time load is applied actually, within this time load is applied, then this constant, so this much time we have waited, then second drop we have applied.

This is that rise of load and then kept constant, then again third drops off. This is the time over which the load is applied suppose, and then again keep constant See, if this is the 1 then volume change how it happens you can see here that within this during the application of the load, the volume change will be 0 to this much will happen and then when load is idle, this also will be idle.

When second drop also applied then again, this volume change will happen like this, again it will be and actually not the load is applied up to this, but you can see the volume change going immediately little after the application of the load. That is why it is up to this. And similarly, when third load is applied, and then comparatively the volume change will be reduced the order of increase here, order of increase here, order of increase here is different, because first drop will be more, second drop will be less, than third drop will be further lesser.

That is what is happening and you can see they are also it is going beyond the load applied time. And then degree of liquefaction actually again when you apply the suddenly at the, when the load is applied fully that time degree of liquefaction will be to the peak and with time this when you will be waiting that die by that time it will be reduced to almost 0. Then when second drop is applied again degree of liquefaction will be increased and then it will be deduced and then we like that it will happen.

And bearing capacity increase you can see when it will be a load is applied that time it will be 0 if you assume and when the, and then unlimitedly after, when you are applying the load, we are uncovered is less because it is punching and then with up to these it is regaining and then then the within the idle time again regaining further it will be reaching to this value.

When you apply second drop again at this level from this level to it will be reduced to this and again in the idle time it will be regained and it will become this then when third drop will apply again it will happen like this and again increase. like that you can see the past drop it increased to this second drop it has further increase, in the third drop it is further in you like that, it will depending upon your requirement, you can 1, 2, 3, 4drops can be used and to increase the bearing capacity of the soil.

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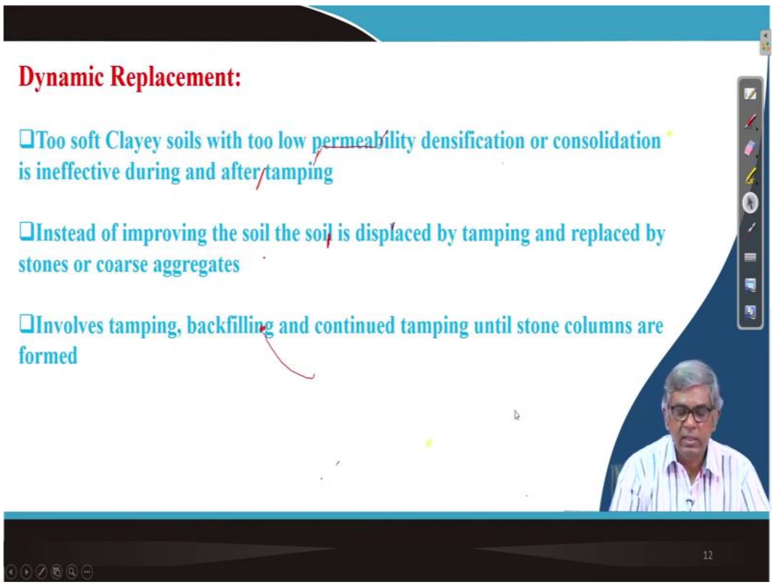

Dynamic replacement I think I will take this one in the next slide. So, with this, I will close this session. And these are the different aspects of the deep dynamic compaction I am discussing. So far, I have not come into the design part of course, I will come to the in the subsequent module subsequent lecture. I will stop here. Thank you.