Ground Improvement
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Lecture No. 22
Design Parameters and Procedure

Hi everyone, once again let me continue with a ground improvement on module Vibro-compaction. Already we have done two-three lectures on it and in the last lecture I was discussing about various design aspects and I will just continue with this and including construction procedure also, I will be including in this lecture and let me take to the slide.

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The design parameter and procedure this is every topic, this will be there we know various aspect. Finally, while designing, first of all you have to identify the design parameters and then after identifying the design parameter, then how will you design there is a procedure. Then after the designing the thing then how to construct in the field what you will do and then after construction again how to monitor or how to evaluate the performance there is a another that is called quality control and assurance.

These are the things; we will proceed I have already two-three parts already completed. Now, I am doing the identifying the parameters already I have discussed where it is suitable etcetera etc. A scatter array I have mentioned now, I will be giving you the list that what are the parameters which is to be identified before executions of vibro-compaction.

In this you can see that whatever maybe the ground improvement most important aspect is the identifying the problematic geomaterial, you can see that first of all the geomaterial type to be identified. And then we have mentioned right from beginning that vibro-compaction is suitable for granular material and this granular material can also have maximum up to 20-25 percent fine though with up to 10 percent is comfortable, but if it is up to 25 percent can be managed, but up to 25 percent can be acceptable, but preferable is 10 percent.

And again, out of that 10 percent the clay content should not be to more than 2 to 3 percent. That is the thing we have discussed. So, that first of all you have to identify that, the type of geomaterial, then how much is the find content in it, and the percent of clay particles. If it is more than, suppose 2 percent 3 percent is about 5 percent or 8 percent, then this vibro-compaction will not be suitable.

This is the first thing for any ground improvement activity, we have to identify the geomaterial type, what is a problem, how to solve all those things depending on that your method will be chosen. The next thing is thickness and depth of problematic geomaterial. We have seen so far, we have discussed so many methods and we have seen that deep dynamic compaction can go up to 10meter, rapid impact compaction can go up to 5-6meters.

Different technique can improve up to different depths. Here while discussing at the beginning, we have mentioned that vibro-compaction can be used to densify by the soil up to 40meter depth. Because of that, so depth of ground, problematic geometries are also important parameter. If it is up to 2 to 3 meters, problematic soil is there then vibro-compaction should not be used. That is the, that is a point I want to mention.

Then depth of groundwater table, many other ground improvement techniques we have discussed before. We have seen that ground water level, if it is close to the ground, then is not suitable. Here, the vibro-compaction is better if it is saturated less soil. Ground water level is not a problem. That is what you have to identify the if there is a depth of, ground water is close to the ground and the type of material is granular then obviously, this vibro-compaction will be better method.

That means geomaterial type content, find content percent of clay particles etcetera one is that thickness and depth of problematic geometry that is also very important, depth of groundwater table that is also quite important. Now, while doing all designing, we have seen that initial void ratio is also an important part. Initial void ratio or relative density of geomaterial to be obtained.

If you know the relative density, you can find out any initial void ratio or you can directly find out the initial void from there, we can find out the either way, either of these two to be determined. Then, another important while discussing we have seen that to find out the subsidence and depending on the type of work, what is the degree of improvement is required. Accordingly, here to fix the targeted void ratio that is what targeted void ratio or relative density that is also your parameter to be identified depending upon your project type.

Pattern and spacing of compaction point. There are different types of patterns are available was triangular is their square is there. Which will be suitable that can be anything can be chosen of course, and spacing of course, we have shown before that when it is a bearing capacity requirement is less than spacing can be wider, when bearing capacity is high required, then closer spacing will be required, then otherwise there are other methods are to find out the spacing.

Pattern and spacing to be identified based on your bearing coverage requirement. And then, area of improvement how much area you need to improve if it is small void then some method is used, the large void then some other method to be used. Because of that, whether vibro-compaction to be used or not to decide, you need to find out how much area is involved, where you have to do improvement. These are all important points are important parameters to be identified. In addition to that few more parameters are there.

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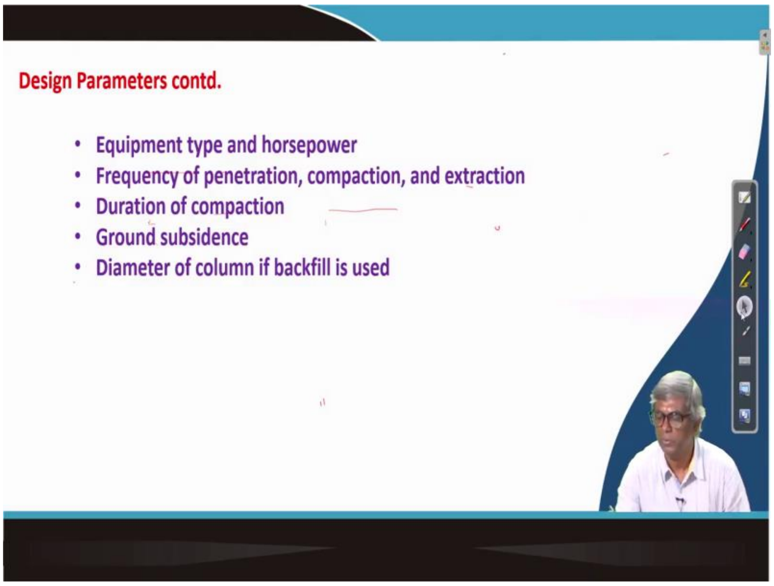

You can see here that equipment time and horsepower. Different equipment can have different performance. If you want to go deeper or if you want to compact heavier, then accordingly you can have different equipment. If you have what type of equipment you have or a particular contractor that also to be noted, otherwise design depends on that. Then frequency of penetration, compaction and extraction. We have mentioned that frequency can play a big role that during penetration, some frequency extraction, there will be some frequency.

Then, during vibration, some other frequency and all those things. Frequency to be identified what frequency exactly needed, that can be identified based on trial test also, and duration of compaction which we will discuss later on how much generally after reaching to a desired place or location you have to vibrate, how long. Generally 30 seconds, around 30 seconds so that we will discuss later on should that also to be identified beforehand.

Then ground subsidence, how much you will be allowing, how much that can be calculated, or how much based on your initial void ratio, target void ratio, all those things or how much you can permit. That can be also one of the parameters can be, diameter of column if backfill is used, so that so D_c as I have mentioned, some of the equation D_c is coming.

So, if you want to backfill what should be the diameter, so backfill diameter, so that is also important. These are the different parameters, which has to be considered before going to in the execution site. After identifying this, you have to do the design or you have to follow certain procedures. Let me come to the, go to the next slide.

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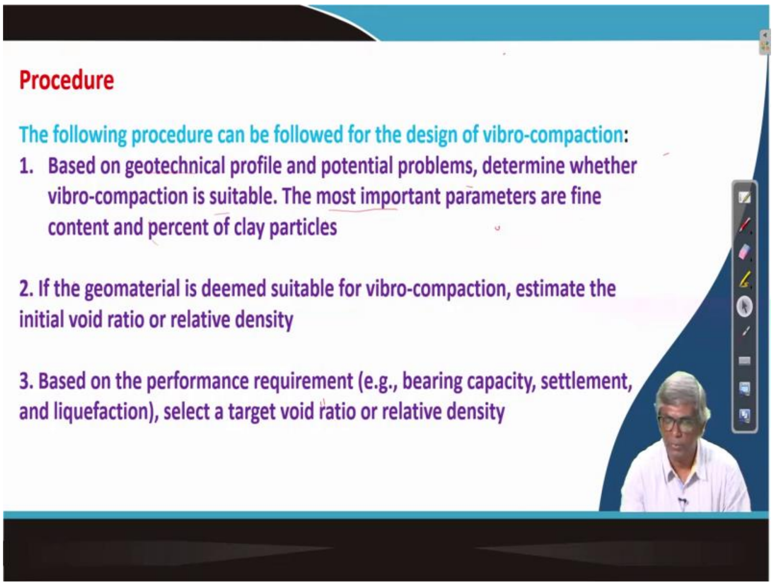

And now, we will go to a procedure what how will follow after you have collected some of the information based on geotechnical investigation, some of the information is based on experience, some of the issues you have got, received from the client what is the requirement etcetera, some of the information collected from contractors that like what is the machine they have and what their different situation based on that we have identified the parameter.

Now, after collecting all those, how will you proceed, so that procedure is like this, that is based on geotechnical profile and potential problem that means, so if you do geotechnical investigation, then you will be able to find out whether problematic geomaterial is there or not, if it is problematic geometry is there up to what depth, this to be obtained. You have to first look at geotechnical profile and potential problems.

Whether it is soft soil or the granular loose soil. Depending on that you have to choose different techniques and determine whether vibro-compaction is suitable or not. When you are talking about vibro-compaction, you see the geotechnical profile and based on that you assess what could be the potential problem. And if suppose a saturated Cohesionless soil is there and lose, then and it will be extended after a quiet depth, significant depth then, obviously vibro-compaction is suitable.

And if you find that another site where it is saturated, and at the same time the find content is maybe 30-40 percent or even more and in that case vibro-compaction is not at all suitable that will be treated by some other method which will be discussed later on like a pre consultation or something. We will discuss later on.

That means, that is the thing that first day, first of all look at the geotechnical investigation based on that you identify the problematic material geometry and then what is the potential problem, whether it is settlement problem, whether it is a liquefaction problem or something else accordingly you have to choose the ground improvement technique. here if you find that cohesionless soil is there, what a table also quite close to the ground surface, then obviously vibro-compaction can be a method and to be used.

The most important parameters are fine contents percent of clay particles. If you find the Cohesionless soil by a large but there also as you have mentioned again and again fine contents should not be more than 25 percent that is that to be checked, and again clay content cannot be to more than 2-3 percent that also to check. So, these two after checking all those things they normally incur to take decision that vibro-compaction can be a method, can be adopted for a particular site.

Second one is the, if the geomaterial is deemed suitable for vibro-compaction, estimate the initial void ratio or relative density. So, for the site investor we have got collected a lot of things and you find initial assessment that is cohesionless soil, it is a fine content is within limit, clay content also within limit and we are about to adopt vibro-compaction. In that case, what you have to do you have to estimate what is the void ratio, initial void ratio or relative density that to be estimated.

And then based on the performance requirement like bearing capacity or settlement or liquefaction, select a target void ratio or relative density. As we have mentioned that, depending upon our problem, you can have different density requirement can be there. So, based on that you have to set, so you get the initial validation from the field condition. Now, you have to, you have chosen the vibro-compaction but how much compaction is needed.

That is, you have to fix the target that suppose void ratio is point 8 or point 9 or 1 or 9 5 something to be target to be fixed. That is based on of course, your performance criteria like bearing capacity, settlement, or liquefaction, whether you are using a liquefaction resistant, whether you do you are using these one to reduce the settlement, whether you are using this one to improve the bearing capacity based on that you can target the relative density or initial void ratio. Let me go to the next slide.

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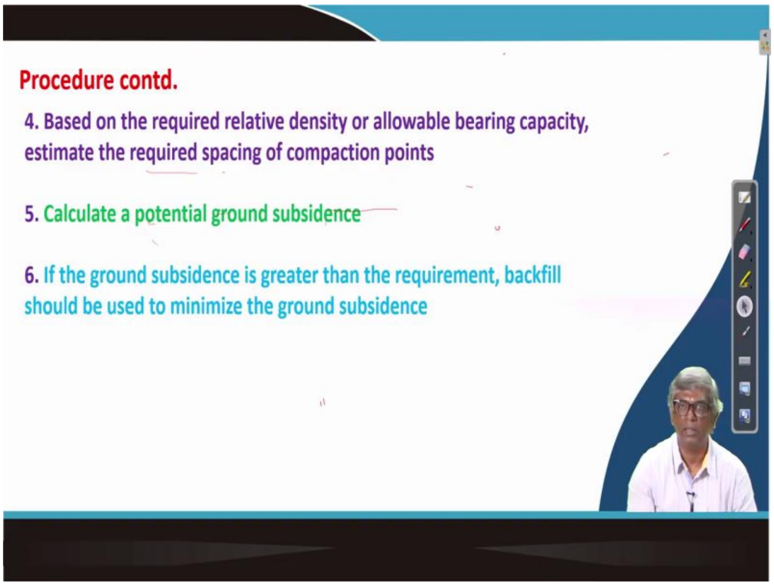

Next step will be based on the required relative density or allowable bearing capacity, estimate the required spacing of compaction point. So, that the estimate the spacing of compaction point there are different methods we have discussed that can be used from the bearing capacity point of view there is a method and then there is another method we have discussed that you have, your depending upon soil is classified as three groups A B C.

And then related density from there, if you know that related density of particular type of soil, then we can get the range of tributary area can be adopted and from there again based on your grid pattern, you can relate them and you can find out the spacing. So, this is next target, or next to the job will be to estimate the spacing of the compaction point.

And then calculate the potential ground subsidence that is again by some method, initial void ratio, final void ratio, or depth of improvement and all those things I know then I can find out the subsidence that there are equations we have given already, that can be used and estimate the settlement.

And all after that all those things if the ground subsidence is greater than the requirement. So, we have, our every site will have some requirement that to how what is the amount of subsidence permissible, if the subsidence is too much then in that case backfill to be used to minimize the ground subsidence. That is the steps to be followed in this design and construction process. Let me go to the next slide.

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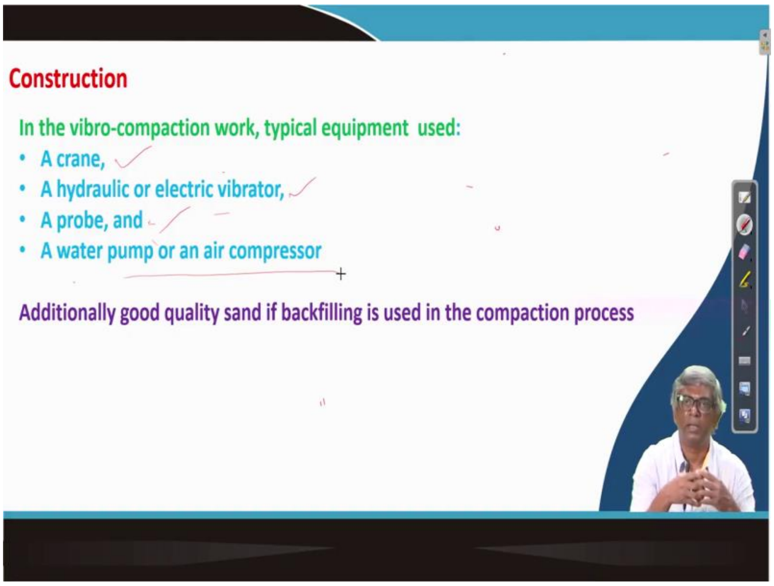

Now, we are in the construction and this construction again when you do the construction, again number of points to be kept in mind. In the vibro-compaction work the typical equipment there are different compaction technique different equipment's are used. When it is a shallow compaction, there is a major equipment is roller, when it is a deep dynamic compaction there is a tamper and there is a crane, and one is the rapid impact compaction there is a commercial exhibitor and there is a vibrator where there will be hammer and there will be and there is a footplate.

And similar to this when you use vibro-compaction in the vibro-compaction measure equipment's, which we used are your there will be a crane is the most important part and then is a hydraulic or electric vibrator which will be and then there is a probe and there is a water pump or air compressor because the crane will be used to hold the entire assembly and then that will be by the motor and that which will be the probe to be driven inside the ground and up to a depth where improvement is required.

After driving the depth, while driving again you need water jet and air jet and because of that our water pump or air compressor either of these two is required and then by that using that you when you are reaching to the desired location, then that probe you have to apply vibration and you have to keep up to some time to compact the densify the surrounding soil. So, that is the thing.

Main equipment here a crane, what is the function of the crane holding entire assembly then hydraulic or elected vibrator to vibrate those probes and a probe that is more main equipment to densify the soil. And water pump and the air compressor to accelerate or to help the compaction or to penetrate the probe or sometime extract the probe this water jet is required. So, these are the major equipment which are used in the vibro-compaction.

Next thing is and another important thing which we manage generally that is our equipment, but additionally good quality of backfilling is used in the compaction process. There are many ways as we have discussed before, when there is a subsidence is too much, we generally use material or sometime we need to make a good foundation or sometime whatever side that is we are compressing laterally and at the same time by compressing laterally we are generating or creating some hollow space or vacuum and that vacuum can be compacted with some good soil.

With purpose some good material can be used and additionally, that is additional, that is not equipment, but that is part of the accessories in the vibro-compaction. Let me continue.

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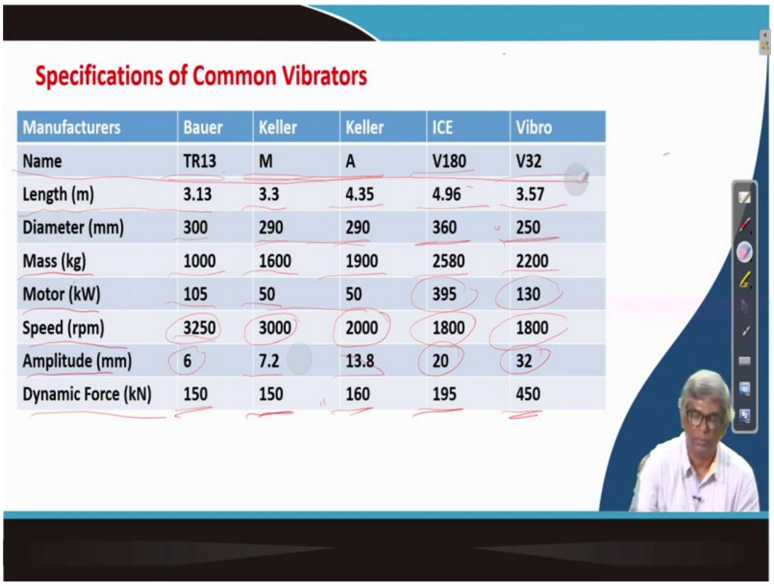

In the construction, we have mentioned that there is a crane required and in that as you can see I am giving you the different companies which they do this vibro-compaction there is a Bauer one company, Keller is one company, ICE one company, Vibro there are another company and they have different types of equipment and that equipment's have specification and you can see here the brand name of Bauer is TR13 there are in fact more than one they have, the killer also have three types, I have M type, A type and there is a S type I have listed here too, ICE has only one type that is V180, Vibro also has more than one I have mentioned only V32, they have another V23.

So, this is brand name of the particular equipment and in that equipment, you can see when it is a Bauer length of the equipment is 3.13 meter, when the Keller equipment 3.3meter, Keller equipment A type that is 4.35meter, ICE 4.96 meter, and Vibro 3.57 meter. And you can see 3 to 4 meter is the average length of the equipment. And diameter is 300 is a probe diameter, 290 for Keller and Keller M type 290 and both are same and they have a different frequency, different and other things will be another S type, changes there you can see here and ICE the diameter is 360, Vibro 250.

And mass of this one 1000 kg and for Keller it is 1600 kg and Keller A type it is 1900 kg, ICE it is 2580 kg, Vibro it is 222 kg. Similarly, motor size by Bauer 105 kilo watt motor, and then Keller motor capacity is 50, both are 50, and ICE they use a motor of 395 kilowatt, and Vibro they use a motor of 130 kilowatt. And it has a speed, when the Bauer more than 3000 3500 RPM, if the Keller, M type 3000 RPM, Keller A type it is 2000 RPM, ICE it is it has 1800 RPM, and Vibro it has again 1800 RPM.

And amplitude for Bauer machine, it has 6millimeter amplitude that means when it vibrates whatever maybe the reduction amplitude means peak to peak 6millimeter, and Keller it is 7.2 still close to that, but Keller A type if it has higher amplitude 13 almost double, Vibro again it is a big amplitude 20millimeter, and Vibro it is 32millimeters, Vibro also have another category they have letter amplitude.

And you can see dynamic force for Bauer machine is 150 kilo Newton. Again, Keller also 150 kilo Newton Keller another A type if it is 160 kilo Newton, ICE is having 195 kilo Newton, and Vibro has 450 kilo Newton. These are all different specification of the machine. So, you can choose your particular machine accordingly you have to choose spacing and operation accordingly you have to do. This will influence some of the design also. Now, design construction procedure. Let me see the few other steps.

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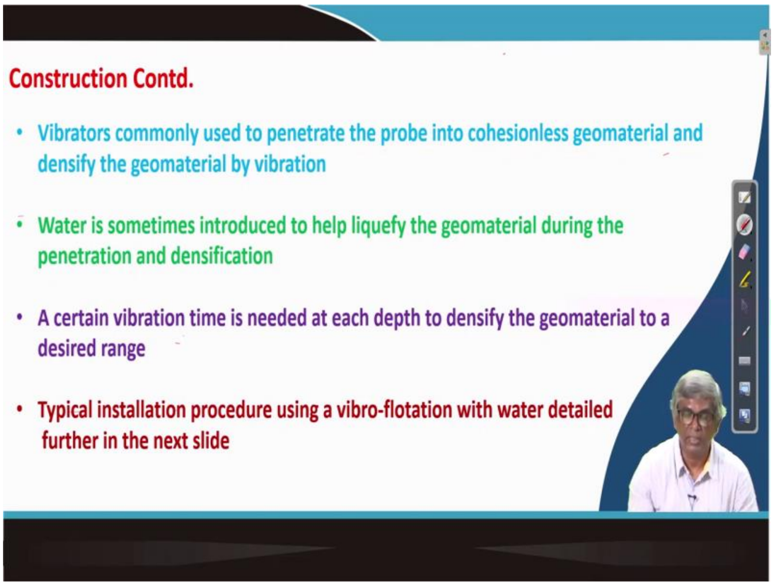

Here construction, vibrators commonly used to penetrate the probe into cohesionless geomaterial and densify the geomaterial by vibration. This is right from the concept, we have mentioned that a vibrator is used to penetrate the probe and after penetrating a particular then again further vibration, we densify the geometry.

This is the construction main mechanism and water is sometimes induced to help liquefy geomaterial that means, you put water and in the geomaterial with force, then the surrounding soil will be liquefy, then if that happened, then it is probably easy to penetrate. That is to penetration and densification will be easier.

And a certain vibration time is needed at each depth to densify the geomaterial to a desired range. So, depending upon what type of, what target value required. After reaching to a target depth, the probe to be vibrated over a particular time, that is these are all the basic concept in the construction and a typical installation procedure using a vibro-floatation with water detailed further in the next slide. I will be showing in the next slide.

This is major concept that means, by vibration you penetrate the probe and then further reaching to the location vibrate to densify the surrounding soil, water to use to liquefy the soil, so that it will penetration will be easier. And then after reaching to that particular again you produce the vibration over a particular time to densify the soil. This is the major steps and further detailed steps I will be showing in the next few slides, one or two.

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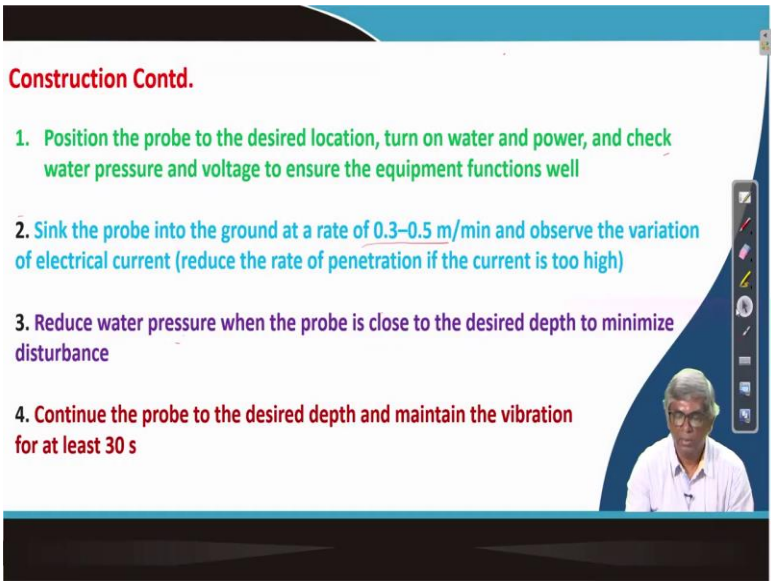

First of all when you construction for even deep dynamic compaction or even your rapid vibration compaction, what you do you find out the spacing and then after finding out the spacing you reach to the desired location and then you give the desired number of drops when it is a deep dynamic compaction and what is a rapid impact compaction, they are you give the number of blows.

Here also you have to design the spacing and you have to mark perhaps there and then after marking, so you have to position the probe. Whatever predetermined location you go and you have to position the probe as a desired location, turn on water and power both you have to put on and then check water pressure and voltage to ensure the equipment function well, then you how to run under that initially over from time and to see the stability and because it when it will be at a particular halfway if it is does not, if does not function then your entire initiative will be spoiled.

Initially you have to turn and see the all-monitoring system and then seeing the probe into the ground at a rate of 0.3-0.5 meters per minute. This is if you want to do our slower or higher speed sometimes performance may affect. Because of that it is a standardized 0.3 to 0.5 meter per minute rate you have to penetrate. And absorb the variation of electrical current.

When you are penetrating, you have to see how the load taken in the, so reduce the rate of penetration if the current is too high. When you are probing, the it will be load will be more and you will find too much, then accordingly little adjustment in the probe movement can be done, that is the operational stage that to be monitored.

And reduce water pressure when the probe is close to the desired depth to minimize disturbance. Then, water jet is used to move only to accelerate the movement of the other probe to our desired when you are reaching to the desired depth you can reduce the water pressure, so that minimize the disturbance.

And then after reaching to the desired location continue to, continue the probe to the desired depth and vibrate, if there is a word missing continue to vibrate the probe that desired depth and maintain a vibration for at least 30 seconds. You have to reaching you have to keep at least 30 seconds. I mentioned previously that the vibrator should be operated up to some time. How much the duration, that is 30 seconds is the requirement, our recommendation generally.

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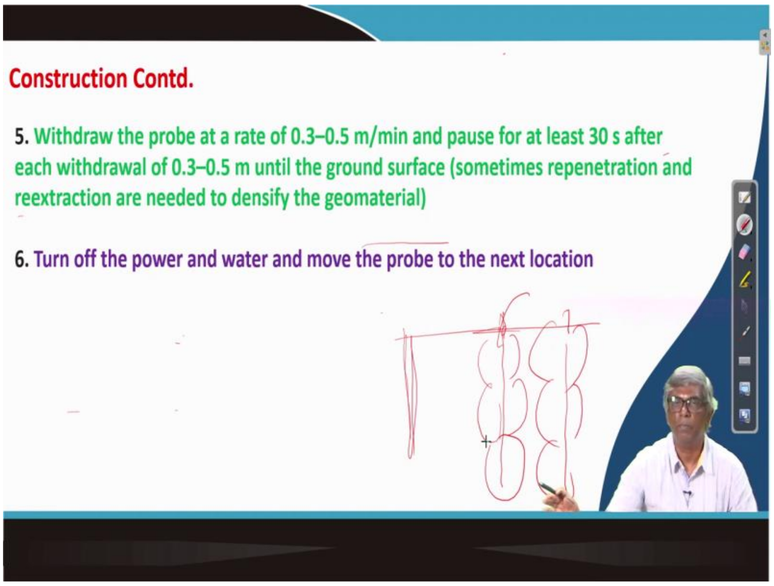

Let me, and then next step is that withdraw the probe at a rate again point 3 to point 5 meter per minute and pause for at least 30 seconds after each withdrawal of point 3 to point 5 until the ground surface. So, what do you have to do that when we have raised to desired depth you have vibrated compacted, then he had to withdraw?

Again, withdraw time again he had to rate will be fixed that is point 3 to point 5 meter per minute and while doing that, again you cannot do continuously. After point 3 to point 5meter again you have to wait for some time 30 seconds, and then slowly you have to do the operation at different level starting from bottom and go up to the ground surface and like that, you can compact from the desired depth up to the ground surface. This is a way to we propagated.

Then finally, this is sometimes re-penetration and re-extraction are needed to densify the geomaterial, that also the required once you have done then again if it is not achieved certain density or whatever required density, then again you can penetrate one second you can do and then again extract that also can be done some time.

And then finally, turn off the power and water and move the probe to the next location This is that means at a particular location when that operation is completed, and then you go to the on the surface go to the next point and again drive the probe to the desired depth, densify the soil here then lift, then densify the soil here then lift, then densify the soil then lift.

Finally, then again go to the next location and these then densify like this, densify like the like that, you have to entire area where the densification is required to be completed. This is the way densification, vibro-compaction operation will be done in the field. And then after doing this of course, we know our initial void ratio, and we know our target void ratio, or relative density.

After completing this, what you have to do, you have to do the quality check and for quality checking first of all while doing this you have to monitor several things whatever I mentioned. At the same time, after completing everything, you have to check the quality how to check the quality again we have to some field test can be done or some sample to be collected to do the laboratory and then you have to see that whether it is satisfactory or not.

And if it is not, then of course, you have to take some additional measure and if it is satisfactory, then you have to move to the new location. This is the way to be completed, the project will be completed. And now by now actually all theoretical aspect, procedure, steps everything I have discussed.

In the class, little more detail I will discuss quality control and assurance in addition to that, whatever theories and all I have discussed to show how you apply or calculate with a numerical example, one or two numerical example I will take, within that I will try to show you the calculation step how we will proceed, and how will reach to the design parameters. So, in next class I will do that. With this today, I will close here. Thank you.