Ground Improvement
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Lecture – 14
Deep Dynamic Compaction

Hello everyone let me once again invite you all to this ground improvement class. And we are in the third module deep dynamic compaction. And under these various aspects we have mentioned. Now, in addition to that there are certain issues that design one aspect and then second aspect is construction and also there will be third aspect is that quality control and quality assurance. So, these are the things we will be discussing today. So, let me take the first slide.

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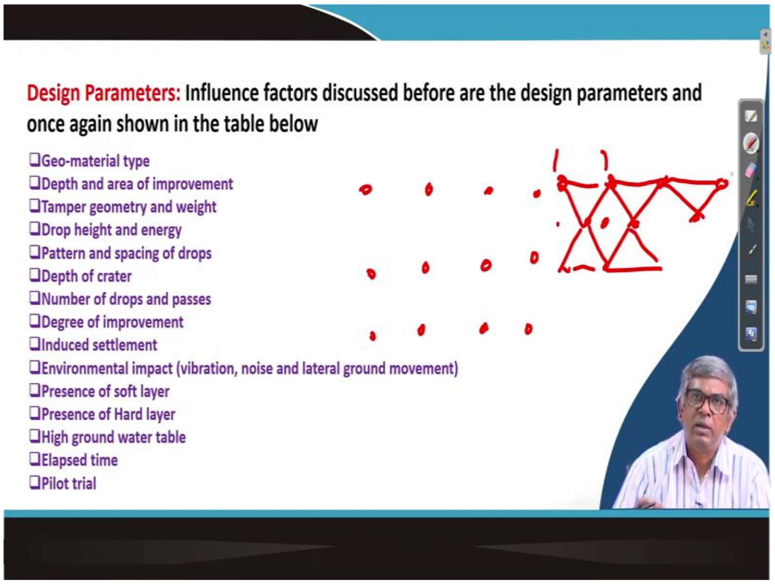

So, first of all we need to know that these are the things I have discussed once again I brought here to summarize once again. The design parameters first you have to find out and the design parameters are what actually influenced parameters discussed before these are the actual design parameter for deep dynamic compaction. And these things we have shown already, you can see that number of them we have mentioned that geo-material type and geo-material type means exactly what it means?

That we have defined that pervious material, semi pervious material with less than PI less than 8. Semi pervious with greater than a PI greater than 8 and their applicability also will be different.

And similarly, depth and area of improvement and how you will find out that you will once you get the geotechnical profile. And then based on that, you will be able to find out which depth what type of soil is there and based on that if you find that poor soil is present up to suppose a 6 meter that means, your depth of improvement will be 6meter.

That is the way actually you have to fast at the beginning you have to decide what is the depth of improvement required? Theoretically you can calculate but by applying energy and all, but at the beginning, we have to do reverse that according to your depth of improvement required we can decide the energy drop height and raw temperature etc. So, that is the second aspect then tamper geometry and weight again based on that, if it is a very deep densification is required maybe you need heavier tamper.

And if it is required lesser depth, then you were required lighter tamper at that tamper we will have typical geometry either circular or square and either of that can be chosen depending upon your availability and situation. Then draw height and energy at a particular that height, energy depends on height and weight and most of the time the contractors will have a particular type of tamper. And then accordingly use based on your depth of improvement you can find out how much energy you want to put and accordingly you can find out.

And pattern spacing of drops that already you have mentioned the two different types of patterns will be there one is square pattern and another is triangular pattern. And again, phase one phase two, all those things are there, which we have discussed before. So, pattern and spacing of droves means a how, that means that we have discussed like this pattern means it is either this way. If it is this way, then it is a square pattern.

And sometimes we do like this like this, like this and then it will do like this and this is not the one. You do here, then do here then, do here. So, these are the triangles are forming. So, because of that it is called triangular pattern. And again, we can do here we can do here like that you can do. And subsequent layer maybe we may drop here, here and accordingly you can plan so different layer.

But this is actually the, the pattern and spacing, the spacing again, is standard actually 1.5 meter to 3 meter some time the spacing some time depending upon diameter or size of the tamper, we can decide spacing, those are the things we have discussed before. Next is depth of crater that is also important too, there is a standard crater calculation method if it is more than that actually that is some time lifting will be difficult.

Because of that, you have to decide that what should be the carter depth number of drops and passes that is again how much energy we can give by one drop based on that if energy requirement is more than one phase may not be sufficient. Then we can go for second pass some time each pass again the single drop may not be enough, then we can give multiple drops in a single pass. So, like those things to be all our design parameters, we have to decide beforehand before going to the construction site.

Degree of improvement, how much improvement we are doing that also need to know induced settlement that means, after so, much of dynamic compaction then what is the amount of settlement how to get that there are method and there is a limit we can find out. And that should be the also some parameters, then environmental impact as I have mentioned before also that vibration noise, then lateral ground movement and all those things are to be kept in mind.

Then presence of soft layer if there is a soft layer is present then standing the equipment will be difficult. That maybe the unfavorable for the construction. That point also you have to keep in mind. The presence of hard layer, if it is in between some layer or hard layer is there and compaction will not reach to the bottom weaken layer that also you have to take care and keep in mind while going to the construction, high groundwater generally not suitable.

If it is high groundwater table that should be noted. And if they it has to de-water water to lower the groundwater table, then elapsed time as I have told that when is a free trading soil. Then compaction can be achieved immediately after the impact whereas, if it is a not so, free draining soil then the regaining is the densification will take some time actually have to give some time.

So, that also to be considered as a parameter then pilot trial also you have to do. Because all those term designs are there that is good, but this design while doing design you may miss certain parameters or certain aspects. And because of that your design may not be perfect. Whether the design is going to work or not before going to the main construction, you may do a pilot trial and see how the performance is compared to the design. So, that is things you have to consider while doing construction, construction, deep dynamic compaction.

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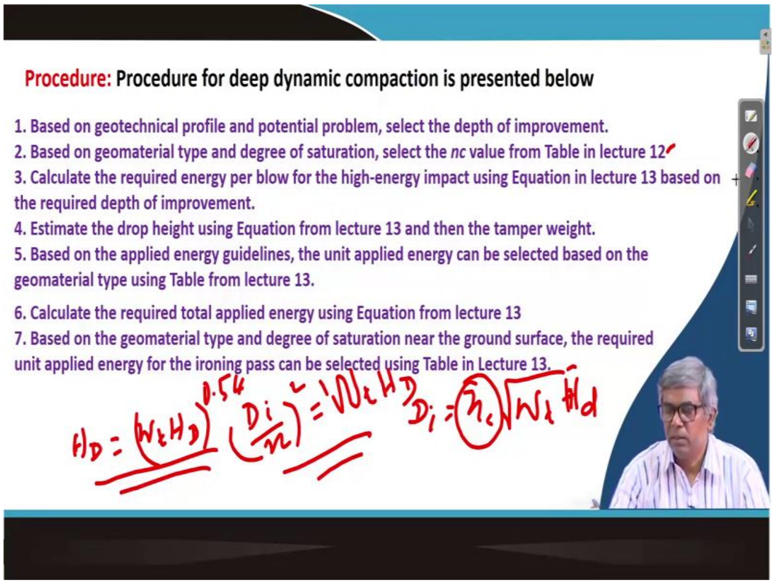

So, let me go to the next slide that is procedure how we will proceed that in the design you can see here that based on the, geotechnical profile and potential problem. Select the depth of improvement already you have mentioned that geotechnical investigation is first of all is required. And from the geotechnical investigation we can find out what is the stratification and what is their strength and quality and based on that we can find out the depth of improvement.

$$H_D = \left(W_t H_D\right)^{1.54}$$

$$\left(\frac{D_i}{n}\right)^2 = W_t H_D$$

$$D_i = n_c \sqrt{W_t H_D}$$

Then based on geomaterial type and degree of saturation select the n_c value. There is a table we have given that we have the equation D_i equal to n_c under root wt dt. I think that is depth of fall wt and then another parameter is drop, drop height. So, this is Hd height of drop. So, this thing so, this n_c is a constant it depends on material that is given in the tabular form, that can be referred which I have already represented in lecture twelve.

Calculate the required energy per blow to energy per blow can be obtained from here actually you can see that Di divided by n_c whole square will be w_t H_d. So, that is the energy requirement plus per blow. So, that can be calculated then estimate that drop height using equation from lecture thirteen and then the tamper weight. So, that is actually we have an H_d equal to w_t H_d to our point 54. There is an equation empirical equation the drop height and energy, height of drop and weight.

And they have some unwitting energy that is some relationship and based on that relationship there is a graphical form which is available someone mentioned in the empirical form. And this the empirical form of equation and from this equation one can find out what is the drop in height is required. Then based on the applied energy guidance, the unit applied energy can be selected. So, different material what is the unit applied energy level that can be taken from the table there is a range is given we can either sometime you if it is a soil also that we extreme.

And the both extreme will be there, if it is if you find more soil with lower side then you can adopt lower value. If you find a more soil will be the stronger side then you can take the higher value or if you do not have much information, you can take the average value. So, table can be I will show the table again once again. But the table to be referred for finding out the unit energy and then calculate the required total applied energy using tuition from lecture thirteen.

That is also total energy requirement that also can be calculated. Then based on the geometrical type and degree of saturation near the ground surface, the required unit for the ironing pass. So, both deep dynamic compactions actually will have generally surface around 1 to 1.5meter depth will be disturb. And that to be compacted separately by conventional method that is called ironing pass.

That also again can be selected and some value that unity applied energy for that. And then based on the depth of ironing pass from their energy requirement for that require, required you can find out. And then total energy minus that will get the energy requirement by the heavy dynamic method. So, these are the steps of listing one these are all discussed ones. So, before going to the following problem I am just discussing these steps.

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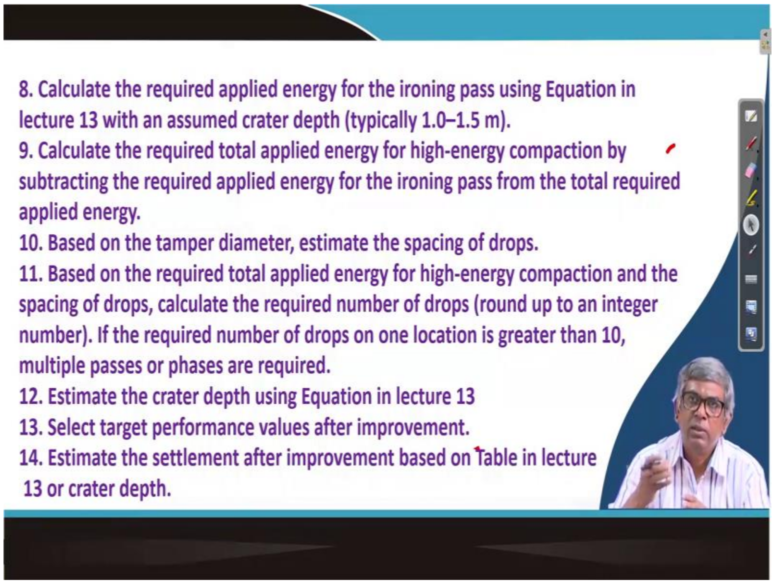

So, next one is that calculate required applied energy for the ironing pass using equation already I have mentioned. Then calculate the required total applied energy for high energy impact. So, ironing pass total energy have calculated by one equation. Then ironing pass we have calculated and energy requirement then total minus ironing pass that will be equal to energy requirement from the high heavy dynamic impact from that is deep dynamic compact that went by tamping.

So, and based on that tamper diameter estimate the spacing of drops that is also there is a guidelines you can find out. Then based on the required total applied energy for high energy compaction you can determine how many drops required. And again, if you find that if one phase does and each one phase itself, there is 20 drops are coming that is not good, that is better to do in a number of phases, particularly when the soil is not free draining, then number of phases actually it is better.

And so, if you decide to do that, decide to do in two or three phases, the total energy requirement is known then one phase how much energy required just divided by two or three then once you know that energy then how many drops required you can calculate. Then estimate the crater depth using any equation that is an equation based on that you can find out select the target performance value after improvement. How hot is the target improvement value means, generally after deep dynamic compaction and we will do some field tests.

Those will test either SPT or CPT or some other test and we know that how much SPT to be achieved that to be fixed. And then after compaction you have to check and that that is achieved. And then estimate the settlement after improvement based on the table in a lecture thirteen already, I have mentioned and crater depth. So, those things based on greater depth you can find estimate the settlement that also to be checked. So, these are by and large, the steps in the design.

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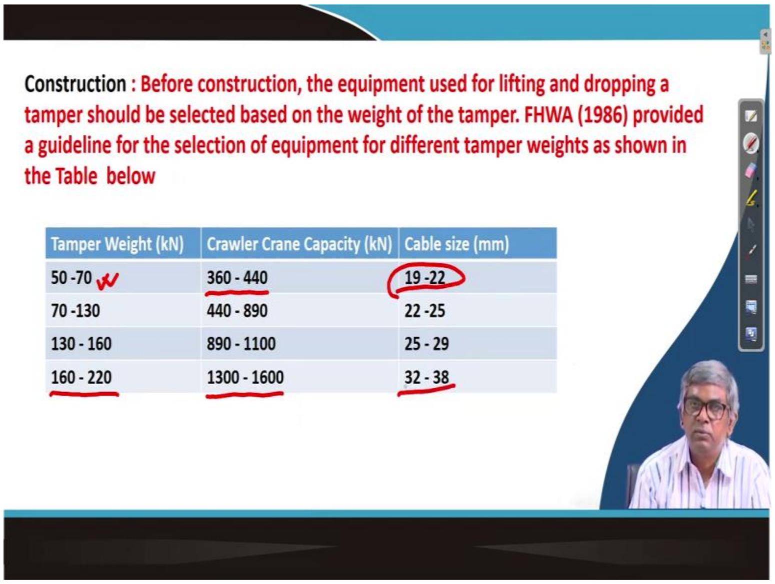

Now, let me discuss sorry, before going to the construction actually we had to select some equipment also. And these are the equipment actually if they based on temperature weight, you can see the tamper weight is given here 50 to 70 kilo Newton; it is actually a little different union so far, we are talking in tons. So, 50 to 70 means it is a 5 to 7 turn actually 5 to 7 tons if it is a tamper weight then your cranes capacity should be of 360 to 440 kilo newton and cable size should be 19 to 22 millimeters.

These are also guideline. You have to before construction you have to select the proper equipment, if it is actually 16 to 22 tons of tamper that means 160 to 220kilo newton size of tamper in that case you require 1300 to 1600 kilo newton on capacity crane and you require the cable 32 to 38millimeter size. These are actually another guideline to be kept in mind and you have to select before going to the construction site.

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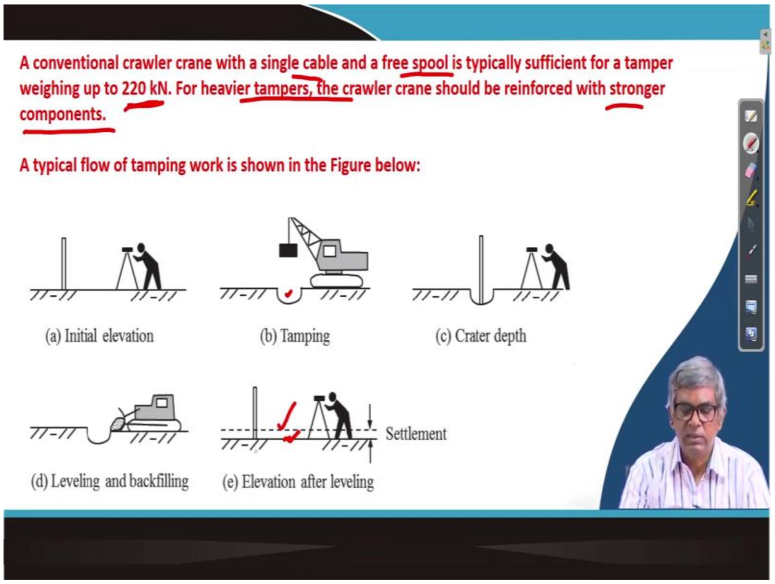

Next part actually so, this is actually the first some statement is mentioned is conventional crawler crane with a single cable and a free spool is typically sufficient for a tamper weight of 220, 220 kilo tons means it is 22 ton. That means it is a single cable and free spool typically sufficient for this much sites. For heavier tampers the crawler cranes should be reinforced with stronger components these are all warning or sort of you can say the commendation that up to single this is crawler crane can we use up to this much.

But if it is more than that, we know that it is generally 5 to 40 ton it is possible, but in that table only 20 ton is given, but sometimes it can use more in that case actually heavier tamper the crawler crane should be reinforced with stronger components some other accessories etc. to be used. So, these are actually then, then a typical flow of tamping work is shown in the field figure below that means what it is actually how we will progress?

Initially you have to buy some leveling work you have to mark the elevation of the ground and then you have to by using tamping you have to compact the soil and then it will happen like this. And then again you can take the reading price from the leveling instrument and from there you can find out the crater depth.

Or after removing the tamper, we can also hide the determine the height from there also you can find out tamper crater depth otherwise also you can again take the leveling and from their elevation difference, you can find out the crater depth and then once you happen, they are like this. So, then what do you have to do by using a bulldozer or other equipment either you have to level the entire area or sometime some backfilling is required that have to be done and then it has to be again filled and then by ironing pass to be done.

And then after that, again once again you have to take the elevation of the final finished surface and suppose this was the original ground surface. And now after compaction and after the ironing pass the ground level rest here, then you take the elevation of these and elevation of this difference of these two elevations will give you the settlement or subsidence of the ground because of these deep dynamic compactions. This is actually schematically shown the same thing I will explain step by step is in the form of step in the next slide.

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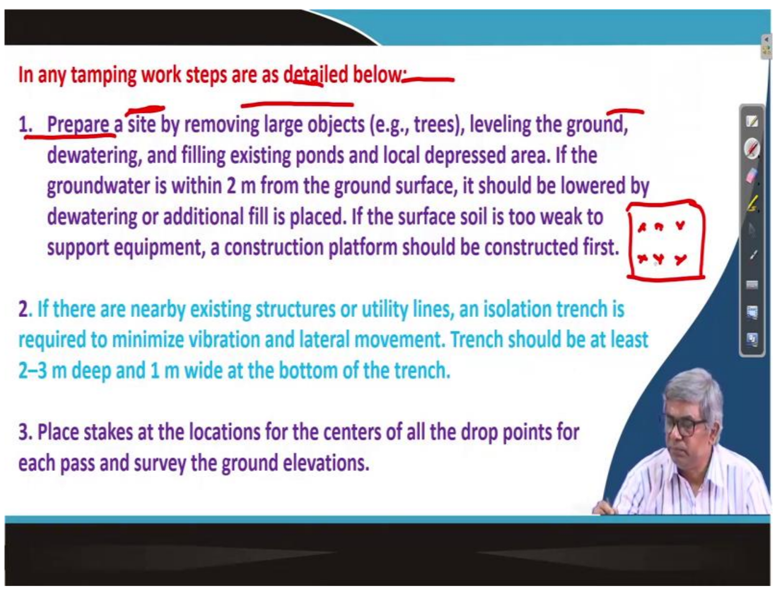

You can see here that those steps are one second is mentioned you can see the prepare side by removing large objects. So, if there are there are various trees there may be some called previous construction material, debris, all sorts of things maybe they are at this original site. You have to prefer site by removing large object like trees, leveling the ground, and then dewatering and filling existing ponds and local depression area.

All those things you have to do before going to the begin the live dynamic compaction. If the groundwater is within 2 meters from the ground surface, it should be lowered by dewatering or additional field is to be placed. And if the surface soil is too weak to support the equipment, a cost action platform a platform should be constructed. The construction platform means from one on that the crane or other equipment will move.

The second step will be if there are nearby existing structure or utility lines and isolation trench are required. As I have mentioned that sometimes these because of this vibration and noise people maybe people may object you have to keep as much low level of vibration as possible. So, for that if there is a thing then you have to have the construction area you know the boundary all around boundary you can make a trench the trench will have certain dimension that two to three meters deep at least and a top width would be one meter.

That was if you keep if you do that, then sometime the vibration will be isolated that means it will not go outside or if it goes it will go very minimum. So, that is the second step to be done for the locality, the displays the states at their location for the centers of all the drop points that means you have planned at the site.

So, you have located some drop points, we have to mark it properly so that while dropping exactly you can drop there itself then only it will be satisfactory. Otherwise, if you randomly if you do then some places will be more compacted some place will be under-compacted.

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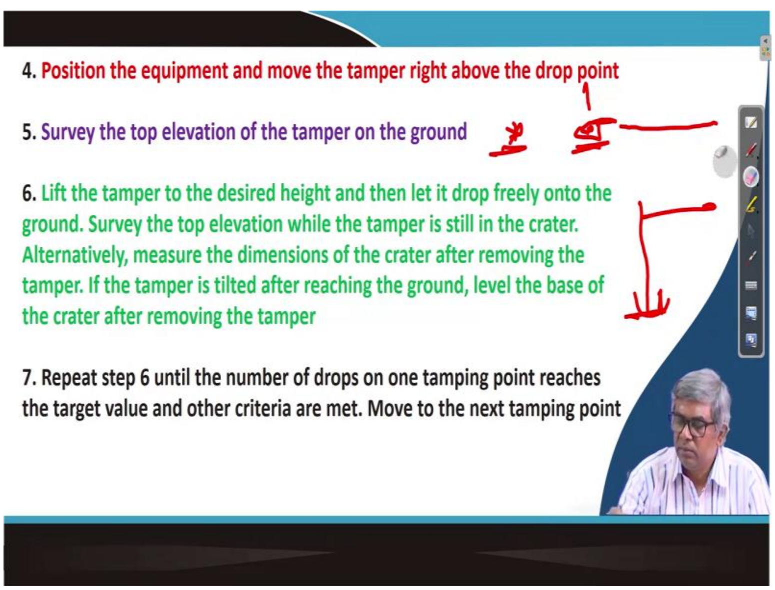

Let me go to the next one and same continue that position the equipment and move the tamper right above the drop point. So, that means, if you have the drop points here, you come there and put the weight exactly above that and then follow this that that is the procedure then survey the top evolution of the tamper on the ground. As I have shown in the schematic diagram, the top elevation you can find out and the dimension and from there you can find out how much elevation actually are it has gone in the below the ground.

That leave the tamper to the desert height and then let it drop freely onto the ground serve the top elevation while the temporary steel in the crater alternatively measures the dimension of the crater after removing the tamper. That also while showing the schematic diagram, I have mentioned that elevation can we directly you can find out illusion can be taken and from subtracting the elevation of the ground we can find out that one or if after removing we can determine the depth.

The repeat the step six until the number of drops and the tamping point reaches the target value that means in a particular point suppose there are five drops is required then unit unless it is completed you do not move. So, suppose this is the point next point is here. Once you complete all five drops, then you go to this point. Repeat step six until number of drops this is okay.

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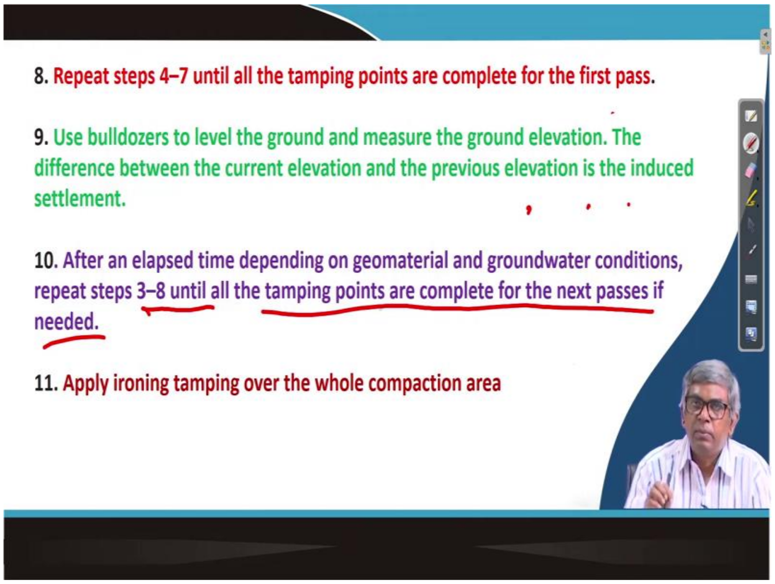

I have already mentioned then repeat step four to seven until the tamping points are complete for the past pass. So, whatever three to seven, whatever that means, you select a point then move to another point and then measure the crater depth all those things, an entire area is covered, then only that one phase is over one pass is over use bulldozer to level then next part is the surface will be disturbed and by using bulldozer again you have to level it and then you can second pass can be continued.

And then after the elapsed time depending on the geomaterial the and groundwater conditioned repeat three to eight the step three to eight until all the tamping points are completed for the next pass if needed. Next pass suppose you need to give five pass the five drops again. You have to give some time of course from first pass to second pass and that act will how to decide depending upon your groundwater table location and material type and degree of saturation.

Considering all those things, you should not do immediate actually you have to decision how after how much time you can do this second pass. So, that when you decided then again, the repeat step three to eight to complete the number of drops there. And then finally, after completion of the second pass again you have to do the ironing pass to give the final finished surface of the compaction.

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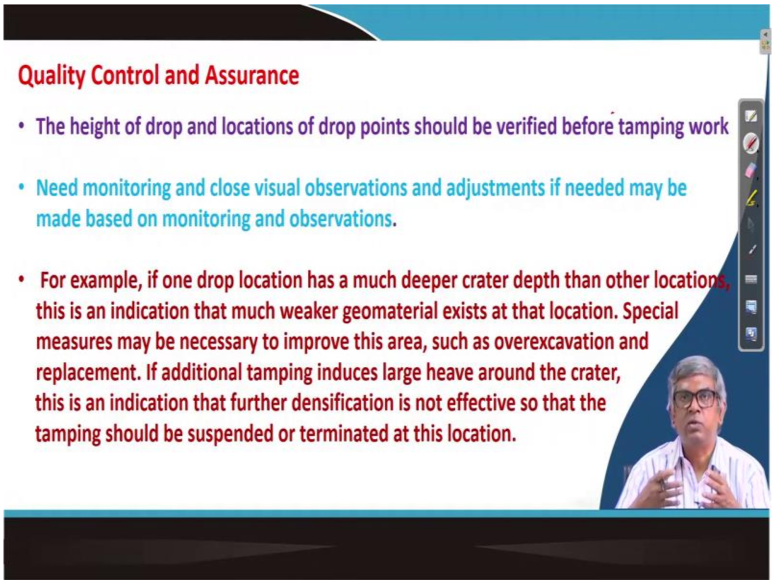

Then quality control and assurance under these what actually you need to do, you can see that when you do certain work, then that you have decided this much height this mass drop weight all those things, so whether it is there or not that to be checked. Height of drop and location of drop points should be verified before tamping work. All those things marking has to be verified and need monitoring and close visual observation and adjustment if needed, maybe it needed may be made based on monitoring.

Continuous monitoring when you see that there is some difference what we have planned what you have planned and it is maybe not happening according then based on that observation we can take some decision you can modify it. And for example, what type of modification can be done if one drop location has much deeper greater depth, we have estimated some crater depth a particular point you have got much deeper crater depth that means that area particularly having some problems while is not as good as it has filed.

Because of that you have to do is take special attention there. If special measures may be necessary to improve this area such as some over excavation and replacement some sharp soil or too bad soil to be removed and some good soil to be given. And another thing is that if I put additional tamping and if you find that too much of heaving is happening, too much heaving happening means it is not energy is not going downward, note that means the compaction is enough no further compaction is not possible.

Even though it is decided that five drops is required, but out of third drops, you find is happening that means there is some modification is needed in the design. So, after the at that level itself you have to stop.

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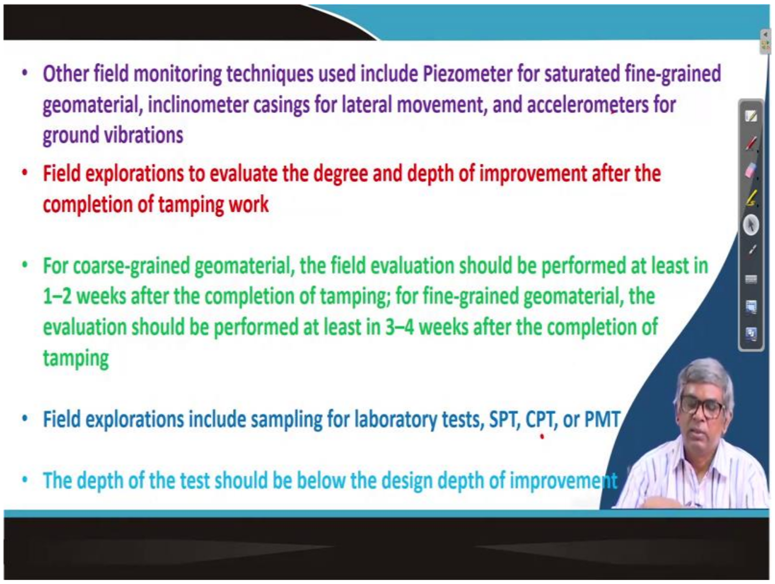

So, next one is other field monitoring techniques used in Piezometers. The field monitoring Piezometer to be used for saturated fine grained geomaterial and inclinometer casings for lateral movement and accelerometer for ground vibration. These are the all-field monitoring equipment depending upon what type of work what type of problem you have visualized based on that if there is a lateral movement is within inclinometer to be used.

If you find there can be a vibration problem then you can use accelerometer to measure the vibration and if you feel that there can be a development of pore water pressure, then you can use Piezometer to monitor those. Those are the things to be see and controlled and then after that field exploration to be done for to evaluate the degree of depth of improvement. How much depth is required and how much depth is done? So, that to be seen.

And then for core skin geomaterial the field evolution should be performed at least one or two weeks after the completion of tamping and for fine grained geomaterial the evaluation should be done three to four weeks after the completion of the tamping. Because, as you have mentioned that that free soil can easily mostly immediately compact getting densifies but when is not that really draining, then with time also it get some amount of subsistence.

And field exploration includes sampling for level test CPT SPT TMT all those things can be done in the field. And what is the value to be achieved that already targeted and you have to see how high that is achieved or not. A depth of tests should be below that desired depth of improvement. And so that means up to what depth you have to do the test. That is at least you have to go below the depth of improvement.

Thank you with this that complete deep dynamic compaction different aspects, what is the design parameter and design steps and then how to construct what are the steps and after construction, what are the things to be monitored or to assure quality and quality and all those things it is covered now. Now, it is almost I have only talked then some I tried to take it one illustrative example in the next lecture, where whatever I have discussed so, far in the four lectures are then that I will try to show the application, how we are applying to them in the design stages of deep dynamic compaction. With this I will close here. Thank you.