Ground Improvement
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Lecture 12
Deep Dynamic Compaction (Contd.)

Hi good morning. Let me continue with Deep Dynamic Compaction. And in the first lecture, I have mentioned various concept of the dynamic compaction, then the area of application and advantages, disadvantage and also various other aspects we have discussed. Now, I have mentioned that it has some design steps, before doing that maybe one or two slides I will be using before going to that design step.

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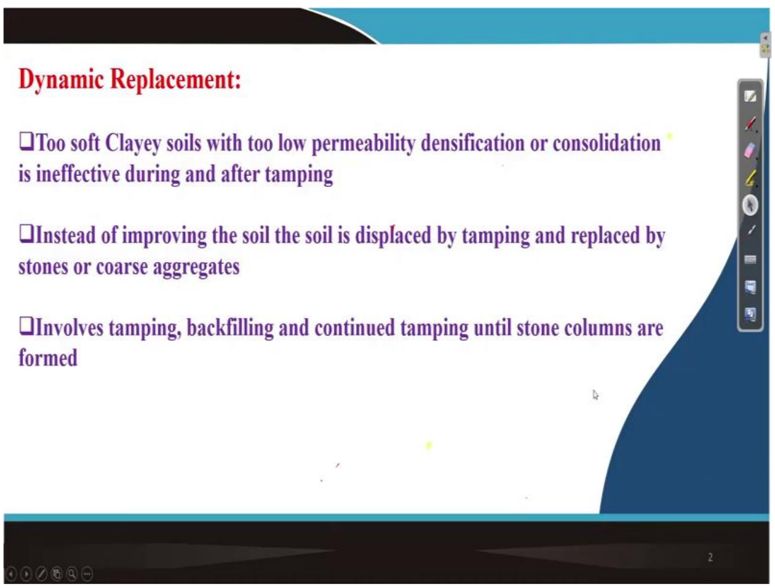

Let me see the first one that dynamic replacement. So, dynamic densification we have mentioned and dynamic consolidation I have discussed in the previous lecture and now dynamic replacement. So, these are also some, I will discuss in the later but when we are, by dropping weight three types of things can happen, one is dynamic densification that means, when unsaturated soil immediately we are getting.

Dynamic compaction means, we have to provide certain amount of vertical drains and all, and then if you apply dynamic compaction then it will be, densification will happen by the process of dynamic consolidation that I have discussed. And then dynamic replaced when if the soil is very soft, then those cases actually instead of densification soil can be displaced by falling weight and that displaced volume can be now filled up with good soil and compaction.

That is nothing but dynamic replacement. These are actually, this can be done in any depth also. So, if you suppose want to do improvement at a 5meter depth, then you have to reach by some means up to 5meter and then fill it with good soil and compact then that will be nothing but replacement. There are different names also there based on different ways. This is dynamic known as replacement.

Here actually, what is the concept of dynamic replacement, too soft clayey soils with too low permeability densification or consolidation are ineffective during and after tamping. That means by applying the load if the soil is too soft and permeability is too low, even by providing vertical drains, this dynamic consolidation was not with dynamic densification is not possible.

In that case, what you can do instead of improving the soil, the soil is displaced the insitu soil instead of improving that itself by weight we are displacing and once the soil is displaced by tamping and that area again can be replaced by stones or coarse aggregate or some good soil and then involves then after doing that again going to be in loose condition still it is not sufficient or good.

That involves tamping, backfilling and continued tamping until stone columns are formed. So, this is actually schematically shown in the next slide. Let us see.

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You can see here that, in this by the crane this weight is lifted and drops and then this, this soil is displace or some punching is happening. And this, when this punching happening and this punching area, you can see this much depth and when you do further then you are getting this much depth and close to that when required depth reach, reached then close to that you have to dump the stone or some aggregates.

And then this can be poured here and then again, you can apply the load and densify, so like that it will, column like things will be formed. And if I do number of them side by side, that this area, entire area will be improved. So, this is the way your dynamic replacement, that is the new name. We will in similar to that there will be different, the vibroflotation other things are there, so that I will be discussing later on.

Since it is similar to deep dynamic compaction, just mentioning here that dynamic densification, then dynamic consolidation, and then dynamic replacement. So, three things I am just mentioning at a place, but again similar to this topic in detail we will discuss later on. So, let us go to next slide.

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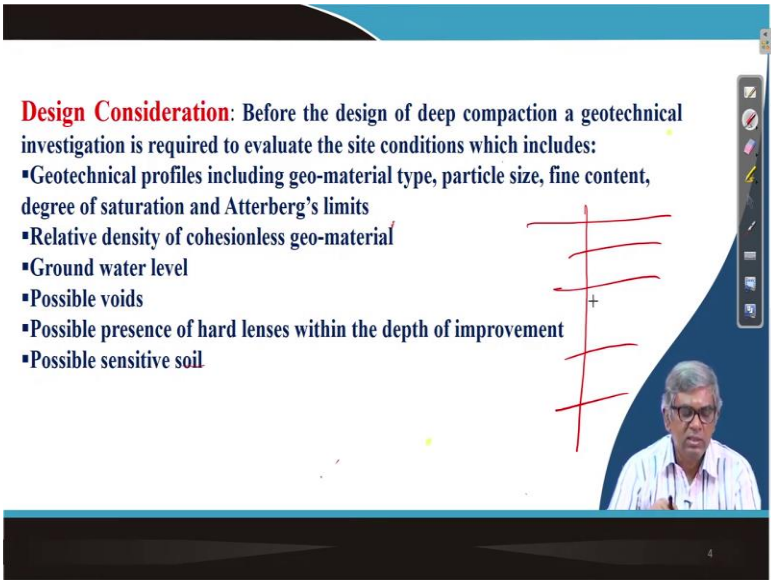

Coming to the design consideration, what to be designed. Before the design of deep compaction, a geotechnical investigation very much necessary because what type of soil, what is the groundwater location etc. important, otherwise whether it is suitable or not you have to know first. So, before designed, deep geotechnical investigation is required to evaluate a number of things what are those, so geotechnical profile including geo material type, particle size, fine content, degree of saturation and Atterberg limits.

Suppose a particular site, soil what depth, how it is actually, what are the different layers presents and what is their properties, that means grain size and other things, what particular size and fine contents, then degree of saturation, then Atterberg limits because we have seen before that to make effective, what are the requirements it is discussed before. So, those things actually whether meeting or not that to all you have to see, then only you have to decide whether we will apply deep dynamic compaction or not.

Then, relative density of cohesionless geo material, when the cohesion, if the soil is cohesionless, if it is not cohesionless if it is some other type of material sealed and mix up fine, then we can do this, but when cohesionless soil you do need to find out relative density because the relative density is a measure of, of the compactness of the soil. If the relative density you find above 80percent then, no need.

If you find relative density is 40 or 45 or 50 then you can improve it by dynamic compaction. That groundwater level as you have mentioned that if ground water level is very close then dynamic compaction is very inequity you have to lower the water level, so that information to be collected. Possible voids. So, if there are any voids in between, larger voids there anywhere nearby that to be determined.

Possible presence of hard lenses within the depth of improvement if there is a rock in between and below and after the rock, above the rock is lose soil, but if it is in between rock or similar type of strong material, then deep dynamic compaction may not reach up to the, loose soil was actually required. That to be determined and possible sensitive soil. So, if there is a sensitive soil of course, this will not work that already we have mentioned. So, these are the information first to be determined, collected by geotechnical investigation.

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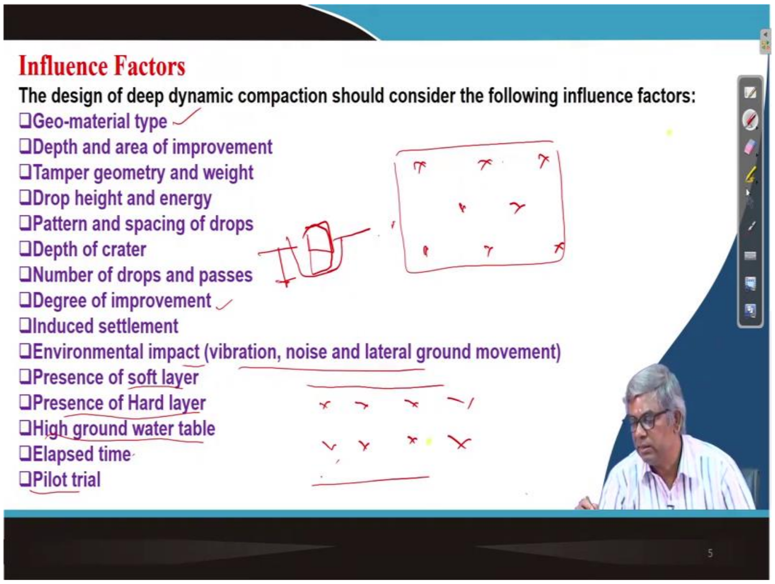

Next thing is influencing factors. What are they, when you do what are the parameters actually can influence your deep dynamic compaction, you can see a number of them so geo-material type? We know that silt is loose sand as you know good for dynamic compaction. So, geological type is one of the most important influencing parameters. Depth of area and area of improvement.

If the large area, then all it is economic that you have to think and depth when the depth is required about 8 to, more than 2, 3meters or even up to 10, 12 meters then actually deep dynamic compaction is suitable you know.

So, depth an area of improvement is another influencing area, the tamper geometry and weight, actually how, what type of tamper, weight, how much weight, what is the shape that actually is also influenced the deep dynamic compaction. Then drop height and energy. That is also important because we have mentioned that it is 10, 40meter height. That means, that also effective or influence the dynamic compaction.

A Pattern and spacing that is also important. That also influence, pattern and spacing means as already I have mentioned if this is the area of pattern can be like this, if you do like this, this is called a square pattern and similarly if we do like this, then this is called triangular pattern. So, that also another influencing parameter this can be designed whether you do this way or that way which is the better one that can be designed.

A depth of crater, so that means after falling off weight, how much depth it is going actually. So, ground surface is here. This is called depth of crater actually, so this is the one. And then number of drops and passes. That is also very much influencing parameter because, if you want to go deeper then you have to give a greater number of passes and again a greater number of drops in a single pass also. The degree of improvement, the induce settlement.

Because of these deep dynamic compaction, original ground surface will be lowered. So, that is also another influencing parameter. Environmental impact, vibration, noise, and lateral ground motion all those things also is the influencing parameter because based on that you have to select. Presence of soft layer, if the soft layer, then crane, heavy crane cannot be moved. So, that is another problem that, which, for which you may not be able to select.

Presence of hard layer, if it is there in between then also it will be difficult or you have to take precautions. High groundwater table that is also I have mentioned, that deep dynamic compaction not that effective. Then elapsed time that is also important and pilot trial. So, these are the things initially you have to do the same trial and see the effectiveness and then you have to go for application or particular technique. Let me go to the next slide.

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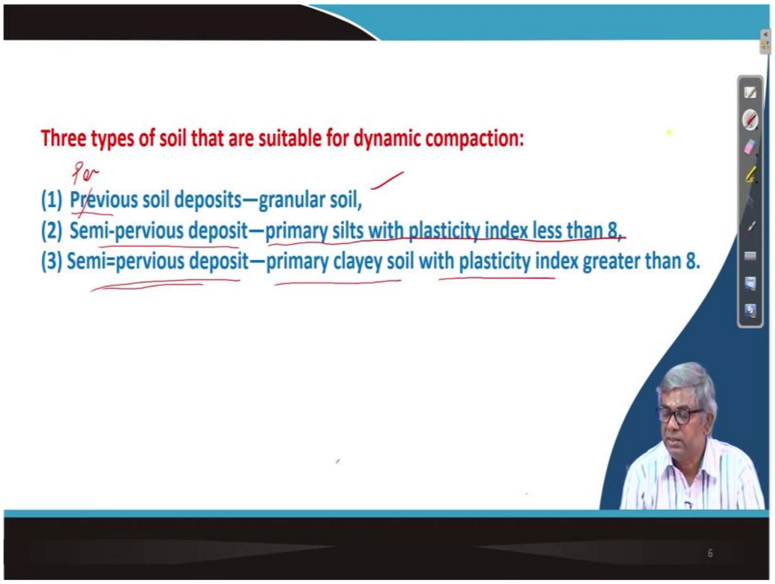

And see, the three types of soil that are suitable for dynamic compaction and you can see they are listed, it is a pervious soil deposit, granular soil generally. Semi pervious deposit, primarily silt with plasticity index less than 8, this is another type. And semi pervious, semi pervious deposit, semi pervious that is primarily clay soil with plasticity index greater than 8. The three different types of soil, that deep dynamic compaction can be applied. And this is, how this will be classified. I will show in the next slide.

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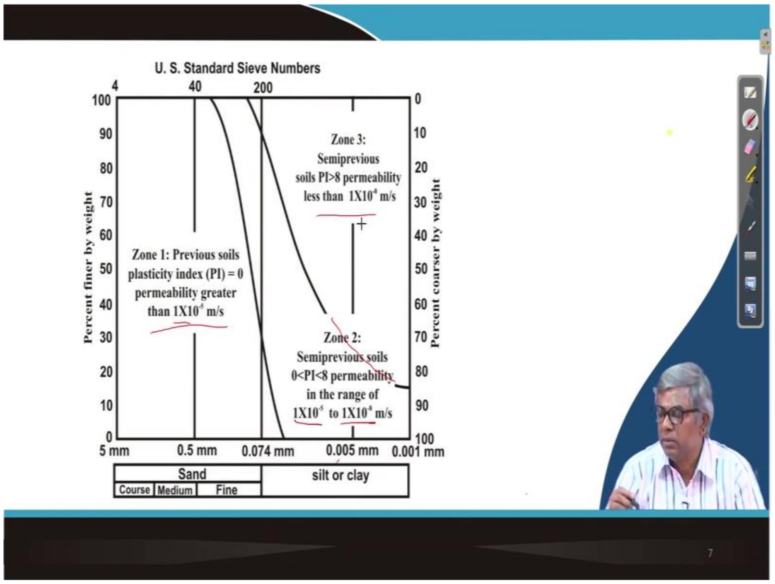

You can see here, this is the grain size distribution curve and this is the three zones are, if you are grain size distribution curve falling, falls in this zone that means it is pervious soil plasticity index 0 and permeability greater than 10 to the power minus 5 meter per second. And between these and these, this is, so this is zone 2, here if this is semi pervious soil and plasticity index between 0 and 8.

And permeability range actually 10 to the minus 5 to 10 to the power minus 8. So, 10 to the this is the range actually 10 to the, meter per second is the part that is semi pervious. And then zone 3 that means, if this soil grains falls in this zone, so this is actually plasticity index greater than 8 and permeability is less than 10 to the power minus 8 meter per second. So, this is the 3 zone.

When you get soil, you have to draw the plasticity, gain size distortion curve in this chart itself. And you can see the location and based on that you can decide the soil whether it is pervious or semi pervious or you can say semi pervious 3. Zone 1 pervious soil, semi pervious soil with plasticity index less than 8 and another is semi pervious soil with plasticity index greater than 8. So, these are the three zones and accordingly you have to select or you have to design, your dynamic compaction.

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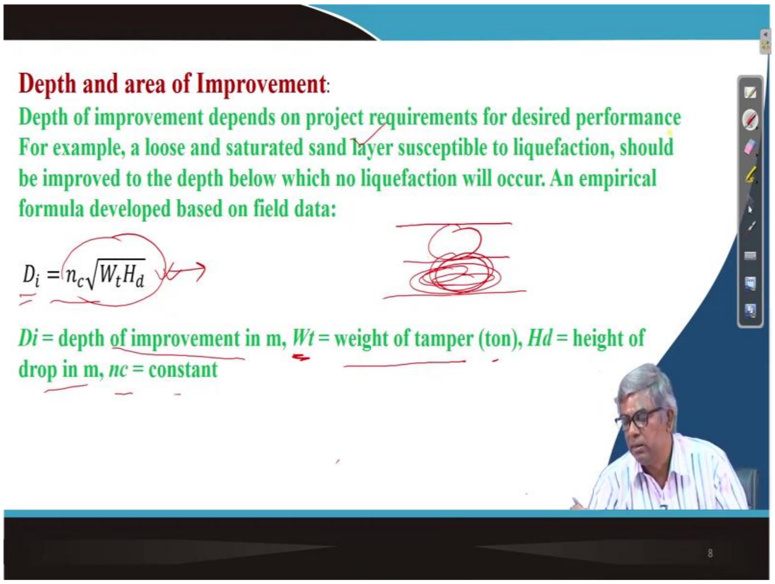

You can see now; this is real design step we have reached and you can see that depth and area of improvement. First of all, depth of improvement, we have mentioned loosely that after meter deep actually soil can be improved by deep dynamic compaction how much you can do, actually this is the, in the form of the equation it is given you can see the depth of improvement depends on project requirements for desired performance. For example, loose and saturated sand layer susceptible to liquefaction should be improved to the depth below which no liquefaction will occur.

$$D_i = n_c \sqrt{W_t H_d}$$
$$D_i = Depth\ of\ improvment\ in\ m$$
$$W_t = Weight\ of\ tamper(ton)$$
$$H_d = Height\ of\ drop\ in\ m$$
$$n_c = \text{constant}$$

That means, an empirical this is that means, you want to do the soil, liquefiable soil is here suppose, then you have to do that how much depth it is, and you have to design in such a way that it improved this area, this depth or so entire area, so this entire depth.

So, whether it is possible or not to determine there is an empirical formula is given based on the field experience and that equation is depth of improvement is Di is given by equation nc multiplied by under root Wt Hd. And what is Wt, what is the Di, Di is the depth of improvement and that is also in metre and Wt is the weight of a tamper that means, whatever we, the weight is falling, so that is the 1. And that is in ton, and that is important that when you lose this, these are the empirical equation this is dependent on those unit.

So, when you use this equation, everything should be the same unit as it is mentioned then only you will get correctly or otherwise you will not. And Hd is the height of drop that also in meter and nc is a constant recommended based on type of soil. That will so see later on. That means, that way it will be ton. So, 5 to 20, 5 to 40 ton a tamper with can be used that is what we have mentioned.

So, it can be anything in between 10, 15, 20 whatever may be that it has to use in ton and Hd should be in meter and this value whatever 0.5 or 0.6 anything that based on that you calculate and that is the, whatever value comes in meter that it will become the depth of improvement for a particular dynamic, deep dynamic equipment. Let us go to the next slide.

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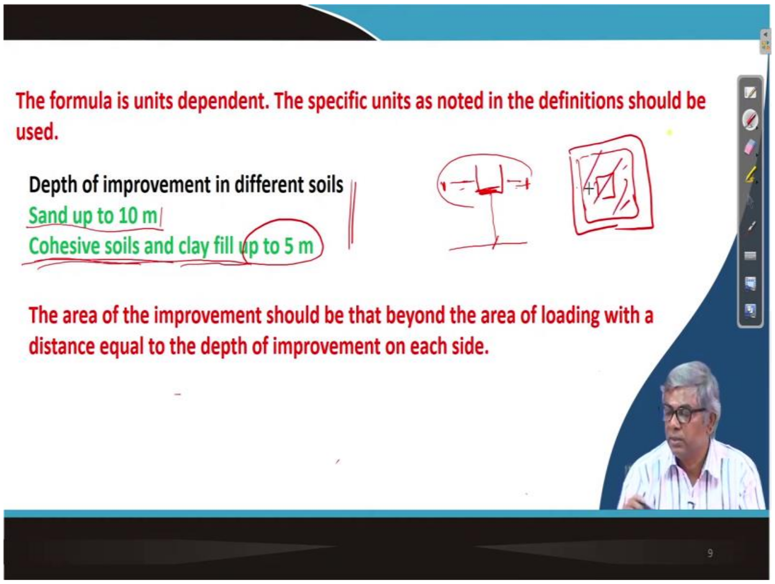

And as I have mentioned already the formula is unit dependent. The specific units as noted in the definition should be used. And typically, if you know the type of soil, if you know the type of trial we will be knowing, will be able to tell that the up to what depth you can get improvement. You can see, if it is sand up to 10 meter you can get easily densified and if the cohesive soil and clay fill this can be effective only up to 5 meters, it cannot go beyond that.

That is what, so this is actually depth you can estimate based on your weight and height. And what if you do not have that, then if you know the type of soil you can also judge up to what depth you will be able to densify by deep dynamic compaction this is some recommended depth is there. And what is the area actually if I use this, what is the area of densification.

That is actually, with the tamper there is a particular dimension not only below that soil will be densified it will be something more than that area will be densified. So, how much it is, that is here that area of that improvement should be that beyond the area of loading with a distance equal to the depth of improvement on each side.

So that means, if this is the tamper with dimension and depth of improvements suppose this much so 5meter, so these plus 5meter, suppose this direction, this plus 5 meter this direction it will be densified. That is what the area of improvement. I hope it is clear. So, if the depth of improvement is supposed 5 meter and if this is this dimension is supposed 1 meter. Then 5 into 1

6 meter this side, 5 into 1 5 plus 1 6 meter this side, so that much area. So, if you plan area if you see, if this is the tamper, then your area will be improved this much, this material will be densified. So, let me go to the next slide.

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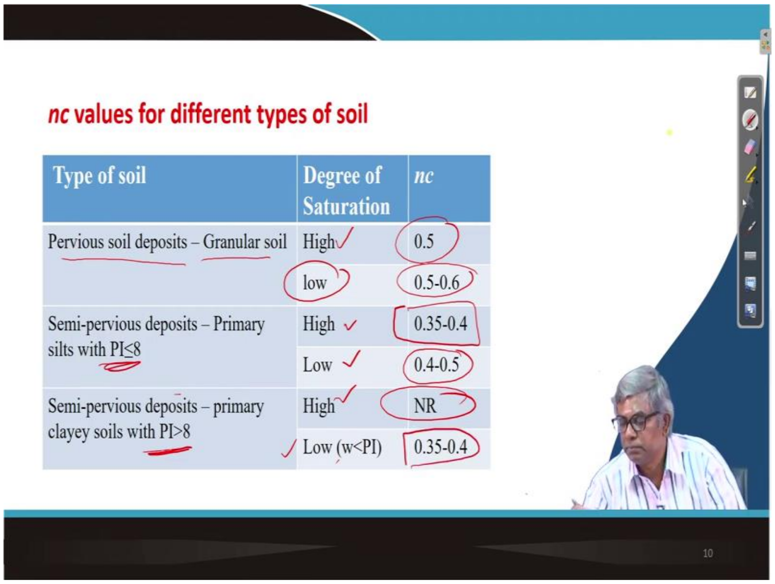

And you can see the nc value, as I have mentioned that we want to estimate the depth of improvement based on you're the available level tamper and the crane with how much weight you can, height you can lift. So, we can initially estimate the depth of improvement and to that, for that calculation, we require that nc, that a constant.

And that constant already I had mentioned that depends on type of soil and you can see here, that is given here, you can see we have pervious soil deposit, granular soil and degree of saturation if it is high, then it is value should we use 0.5 and degree of saturation is low, then again 0.5 so slightly higher value. As I mentioned that when a degree of saturation, saturated soil it is difficult to compact, and if the free running it is possible, if it is not free running again almost very difficult.

So, if the sand sometimes had, it can be saturated, it can be unsaturated or dry. So, if it is actually low saturated, then you can use high, little high value 0.5 2.6 and if it is highly, saturation is high then it is 0.5 or even less sometimes can be used. And semi pervious deposit that means primary silt with PI less than 8. And again, if the saturation is high or low it can be, when it is high you can see the value of nc 0.35 to 0. 4 and if it is low, then it can 0. 4 to 0.5. So, low saturation always more effective shot obviously nc value will be more.

Semi pervious deposit primarily clayey soil with PI greater than 8 and again it can have high saturation and low, and low saturation. So, for that actually, when high saturation not recommended you can see here, semi pervious soil is there with PI greater than 8 and again highly saturated, then it is not recommended. And if it is a low, and plasticity water content is less than PI then only it can be recommended and the nc value only 0.35 to 0.4 can be used.

So, these are actually recommended value when you go do design, this table can be referred and can be used to initially estimate the depth of improvement. Of course, whatever depth of improvement you are getting based on calculation, this is not guaranteed this is the initial estimate. Finally, you have to make sure that, that must depth is densified by the help of some other test, field test like CPT, SPT or some other parameter test. So, that I will discuss later on.

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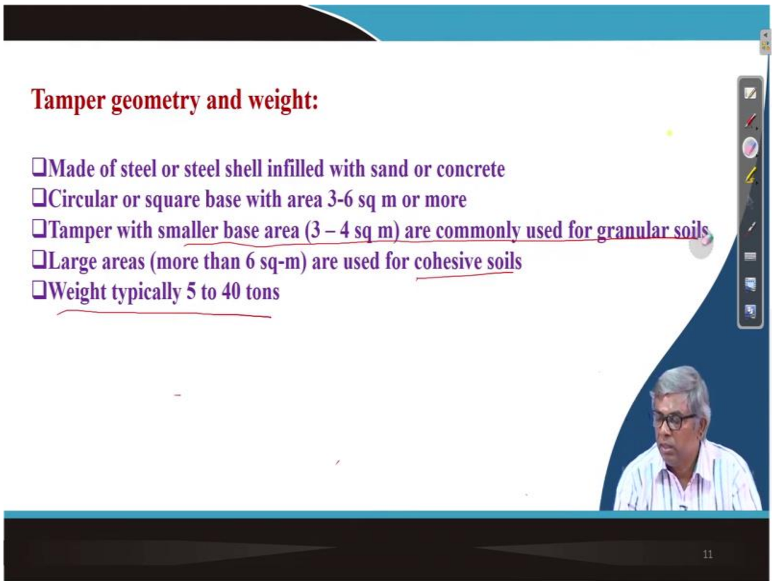

And tamper geometry and weight and you can see this, this tamper that means, this has a generally of steel or steel shell with infilled with sand or concrete that tamper generally will be used. And it can be off circular or square base with area 3, 2 square meter or more 3 to 6 square meters. Circular or square base, it can be circular or it can be square and with area 3, 2 square meter or even more.

And tamper with smaller base area, that is 3 to 4 square meter and are commonly used for granular soil. When granular soil actually you need smaller area and when it is some other soiling may require a larger area. And large areas that is more than 6 square meters are used for cohesive soil otherwise the contact pressure will be less and more and a punching will be more and pore pressure will be developing all those things will happen.

And weight this is actually about geometry and size is mentioned, last, initial 3, 4 points. last point actually typical weight 5 to 40 tons So, this is of course, different contractors will have different one and generally if they have smaller words, they can use height of drop more, because energy is important finally, to densify the soil. And if some contractor having a larger weight, then you can have, have more or less or hide. So, that energy level will be also similar. So, this is the way actually, not much about these is to be discussed. Let me go to the next slide.

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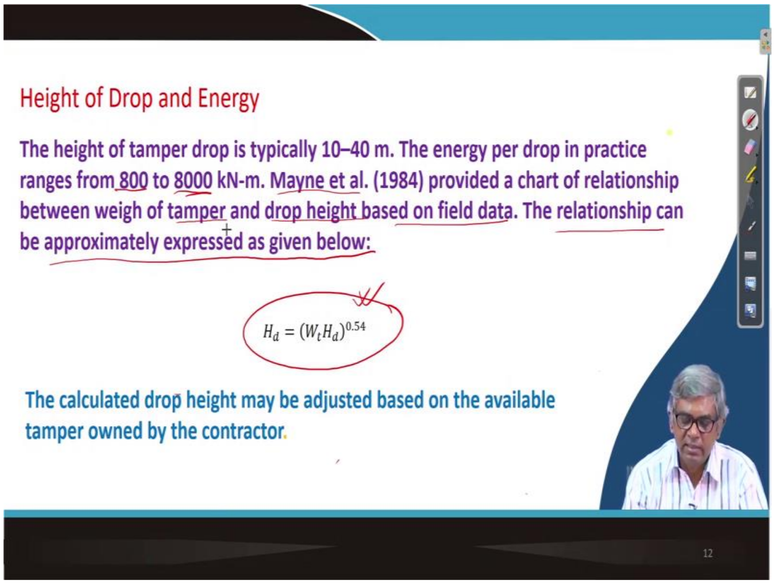

Height of drop and energy and as you can see this height of tamper drop is typically 10 to 40 meter it is known, but the energy is important. So, because of that, the height and weight can be adjusted to give energy. The energy per drop in practice ranges from 800 to 8000 Kilonewton meter. This is the energy requirement 800 to 8000. So, accordingly we can adjust and this person Mayne provided a chart of relationship between weight of tamper and drop height based on field data.

$$H_d = (W_t H_d)^{0.54}$$

Between these two and that relationship can be approximately expressed as a given. So, this is the expression finally, whatever they have given chart, that chart finally can be converted to an equivalent equation, an empirical equation which is Hd equal to Wt Hd to the power 0.54. So, you can see both sides is Hd is there. So, you have to trial and error you have to adjust this one. And so, the calculated drop height may be adjusted based on the available tamper owned by the contractor.

So, as I have mentioned before the different contractor may have different cranes size, different tamper size. It could depend on the tamper wait we can height can be adjusted because the energy requirement actually is a fixed a particular soil, what to do the degree energy requirement and that energy based on that energy requirement that you have to adjust height and weight. So, let me go to the next slide.

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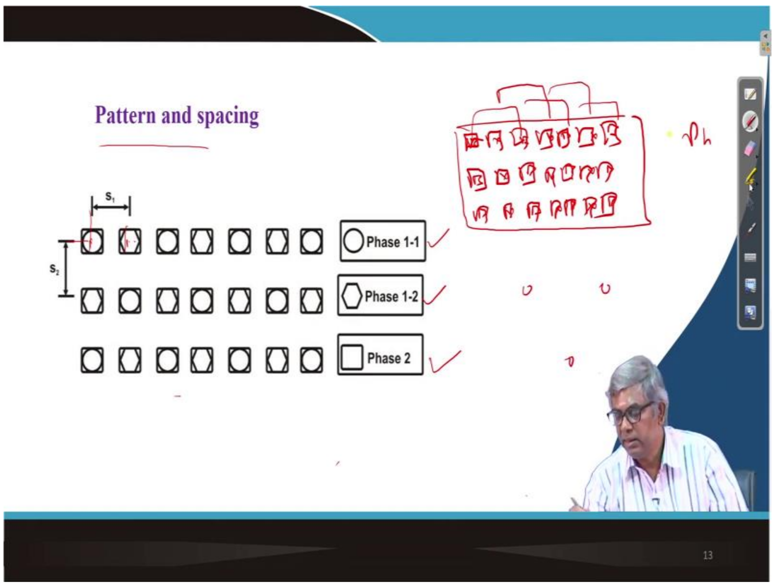

Pattern and spacing this are most important. You can see here the pattern as I have mentioned that already this is shown actually square pattern and both actually square pattern and triangular pattern will be there. And you can see here, Phase 1, 1 and phase 1, 2 is mentioned and there is phase 2. So, phase 1, 1 and phase 1, 2 what is the meaning of it? Suppose this is the area So, initially dropping point is this, this is the dropping point this, this the dropping point, this is the dropping point, this is the dropping point, this is the dropping point, this is the dropping point, this is the dropping point, this is the dropping point.

This is suppose phase 1, 1 and phase 1, 2 is what, so in between. So, that is so, the area is covered with particular spacing initially first and then same spacing we use an in between, it is dropped. So, these two together entire areas are covered. So, that is why, it is called phase 1 and this is actually the spacing, spacing is, can be decided how much spacing and this is a square pattern is used. Now, at second level actually you may use everywhere you may use everywhere you may use now everywhere, you may use everywhere now, you may use now everywhere drop.

So, that is why it is called second, phase 2. like that, so this area, this is the area and again in the phase 1 how many drops at a 1 place that is actually to be designed, even phase 1, 2 how many drops and then phase 2, how many drops all to be design. So, this is actually pattern and spacing. When you are doing these to these, actually we are doing first here then here, that means this distance between these is the spacing of drop.

And similarly in these directions, this is the spacing of drop and pattern is this is a square pattern, and instead of that, if you have this and these, this is the triangular pattern. So, this is one thing how we do, now let us go to the next slide.

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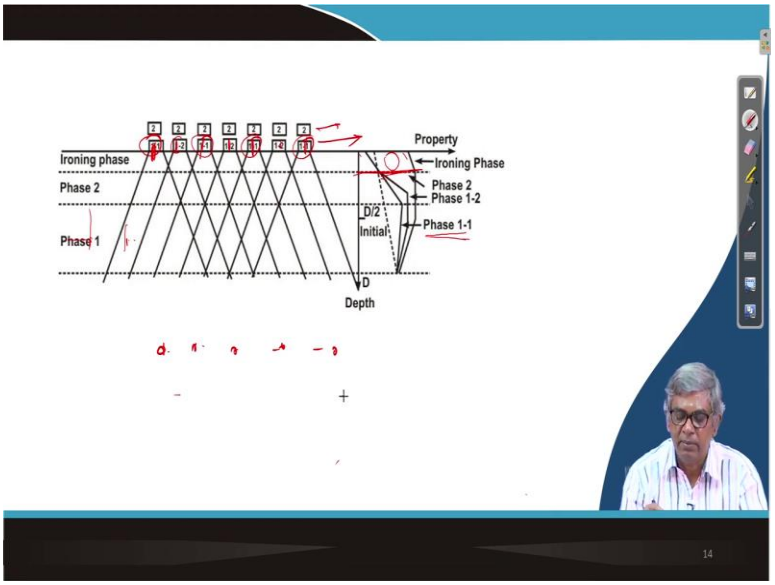

And you can see here, whatever I have explained same thing is explained here you can see, this is the phase 1, actually phase one, this is the 1, 1 you can see, this is 1, 1 this is 1, 1. So that means, and this is actually 1, 2 that means in between again there are drops. So, that is what I have shown in the plan.

Between first phase whatever spacing was used in between again there is another and with respect to that same spacing, maintaining same spacing between the second stage in between there is another drop. That means, if you have here, if you have here, if you have here, then you do here, you do here.

So, that's what I initially first phase, phase 1, 1 here, phase 1,1 here, phase 1, 1 there, phase 1, 2 here, and then phase 1, 2 here, phase 1, 2 here, phase 1. So, this is the way, phase 1 is completed, and phase 2 you can see everywhere now dropped. And if I do this, then you can see how the improvements happening. So, when you do the phase 1, 1 this is the phase 1, 1 the improvement taken place like this, when phase 1, 2 is this is the improvement taking place, and when it is a phase 2, 2 this is the improvement taking place.

And then the actual improvement will be from here, because when deep dynamic compaction will do on the surface, there will be too much of disturbance and those disturbance sometime by using bulldozer it has to be level and then there will be ironing pass has to be done and that ironing pass is done by using the rollers and sub whatever using the shallow densification same type of roller to use that top around half a meter disturb soil to be finally to be done.

So, this is the one, the death process improvement like that can be obtained. Think I will close this section here itself. So, for this, what we have done again, some of the design aspects we have discussed, but still we have not actually designed so, actual design process we have not started some requirement we have mentioned. So maybe in the subsequent lecture, I will be able to show all those things. Thank you.