Soil Mechanics/Geotechnical Engineering I
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Lecture – 16
Deep Dynamic Compaction (Contd.)

Now, I am going to discuss another aspect of compaction of soil and this is actually I have discussed in my previous lecture or 2 lectures about soil densification by roller and similar type of equipment. And now I have mentioned that roller compaction main disadvantage is that we cannot compact in depth because there is a limitation and when there is a large area to be compacted that may be by roller and some other similar equipment may be difficult. In that case sometime we use another compaction technique there are several, but I will discuss another only one that is deep dynamic compaction and what it is let me uh show you what.

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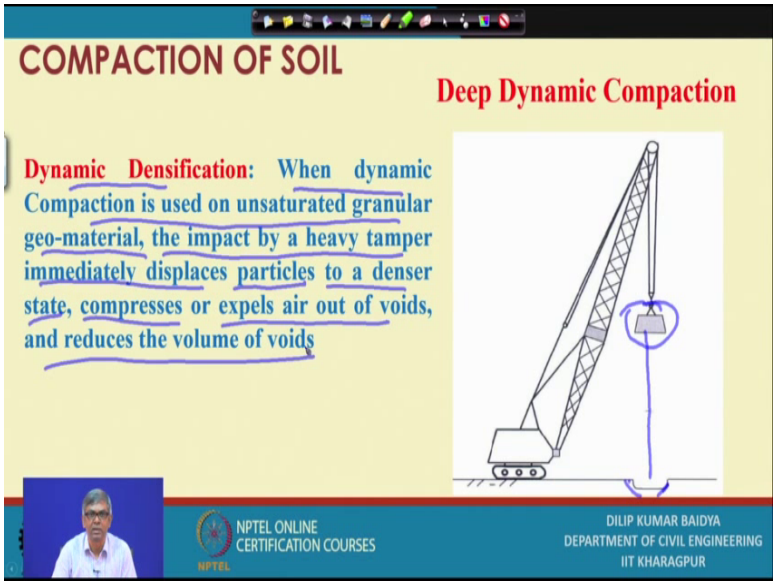

So, this is the typical deep dynamic compaction equipment there will be a crane and this through this cane crane there will be where it will be lifted at a sufficient height, what will be the height etcetera some calculation will show later on this height based on similar height will be lifted and this weight will be finally, released on the ground surface. So, it falls here you can see this mass is that depression; that means, some soil will be significant subsidence will be observed on the soil.

So, when there is a subsidence; that means, what will happen soil grains will be pushed and then they may come closer and it will result the compaction effect. So, that is technique generally used in deep dynamic compaction. So, what is dynamic densification? Dynamic densification is when the dynamic compaction used on unsaturated granular geo material the impact by a heavy tamper immediately displaces particles to a denser state, compresses or expels air out of voids and reduces the volume of voids. So, that is the our purpose compaction main purpose is removal of voids or reduction of void ratio. So, that is what this is the way it is working.

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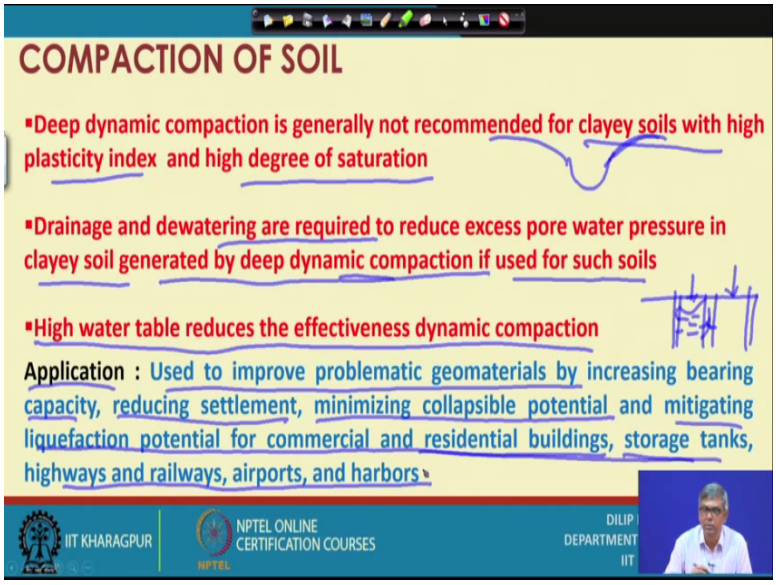

Now, you can see your deep dynamic compaction is generally not recommended for clayey soils, with high plasticity index and high degree of saturation because if it is a soft soil heavy weight falls on it, it will just displace it will not compress. If suppose this much compress happens, compression happens is similar amount of here actually it will displaced upward. So, there will not be any (Refer Time: 03:12) because of soil, when the little stronger soil because of this effect then this grain will be pushed and come closer and get (Refer Time: 03:25).

So, this is the one that clayey soils with high plasticity and high degree of saturation this is ineffective, drainage and dewatering are required to reduce excess pore water pressure, pressure in clayey soil generated by deep dynamic compaction if used for such soils. So, suppose clayey soil is used.

So, if you can put some sort of drainage arrangement and if you put load here sometime during the this heavy pressure the excess, excess pore pressure will develop and (Refer Time: 04:06) excess pore pressure is dissipated then the volume reduction is not able. Then when the excess pore pressure through this path the water actually will go through this drain and then pore pressure will be released and because of this release of this pore pressure then the subsidence will occur.

So, that is the thing the additional requirement, if that is not suitable, but deep at all if we use then what you have to do, you have to provide additional dewatering or drainage; that means, this drainage and then finally, water to be taken out then only is possible and high water table reduces the effectiveness of dynamic compaction water table if it is there this is not going to work properly.

Then application used to improve problematic geo materials by increasing bearing capacity. So, that is the purpose for always improvement of a bearing capacity is the first thing to be improved, reducing settlement that is second thing, minimizing collapsible potential and mitigating liquefaction potential for commercial and residential buildings. So, if there is a loose point soil and there and then water table comes and then giving earthquake liquefaction occurs.

So, because of that beforehand we need to densify them. So, how to do that? we can do dynamic compaction even, but grade depth. So, these are the various areas storage tanks, highway, railway, airport and harbors these area if you have which soil, problematic soil then we have to we have to improve it by some means and if you want to improve up to greater depth this is the perhaps the good choice for improvement.

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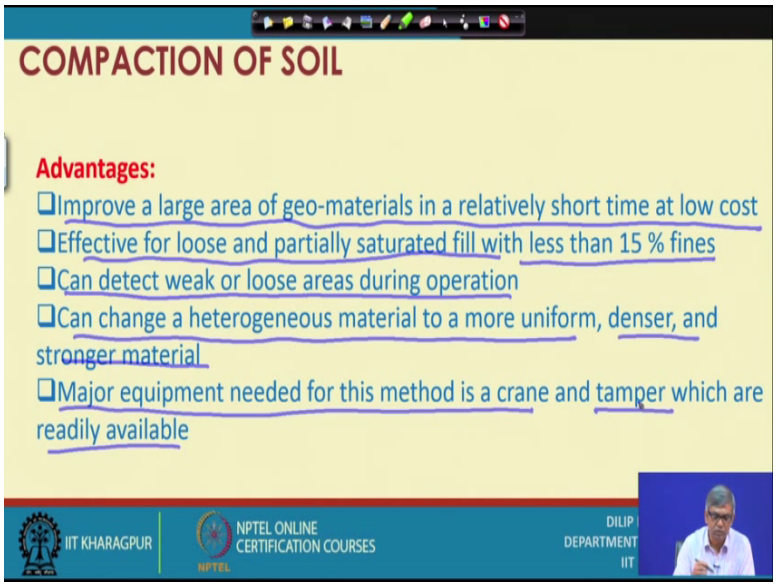

And it has several advantages I as I have got to mention that improve a large area of geo materials in a relatively short time at low cost. So, it will be crane which are having some arrangement, it can move around quite fast and if the desired location will go and lift weight and drop it, like that free very quickly it can be covered a large area. So, that is what it is relatively short time at low cost, effective for loose and partially saturated fill with less than 15 percent fines. So, fine quantity is more then it is not good that is what it can detect weak or loose areas during operation when there is a weight falls on the ground and if it sync too much then automatically you will get some information additional information that there is below there is some weaknesses.

Similarly, can change a heterogeneous material to a more uniform denser and stronger material so, by several drops and with predetermined location we can compare it uniformly.

And major equipment needed for this method is a crane and a temper, which are readily available. So, because. So, crane is there is there are tamper actually can make it, it can be of steel it can be of concrete. So, anytime it can make a weight. So, these are actually very simple equipment. So, this is these are the advantages and now there are some disadvantages obviously and disadvantages are generally less to more effective to not effective to improve saturated clayey soils.

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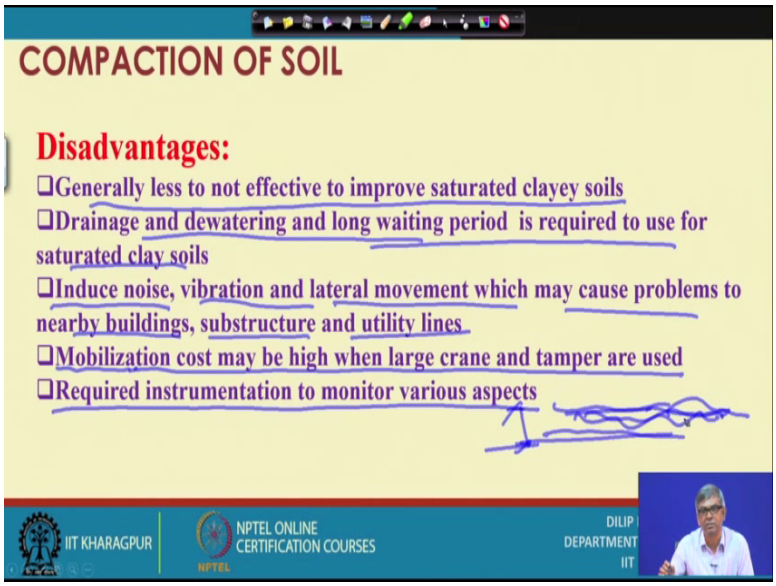

So, when this saturated soil it is generally not sometimes used with less effective. So, that is most disadvantage for this method, drainage and dewatering and long waiting period is required to use for saturated soils. Saturated soil I have mentioned that that is provision of drain and all dewatering can use and then you can apply, but for dissipation of full water pressure and subsequent subsidence it takes some time.

So, waiting to period will be there. So, that is also a disadvantage and most another most important disadvantage induce noise and vibration and lateral movement which may cause problems to nearby buildings, substructure and utility lines and also remaining people. Sometimes who do these type of operation entire locality will be vibrating and people may complain. So, that is another most disadvantage for this (Refer Time: 08:47) and another is not that big, but minor, the mobilization cost may be high when large crane and tamper are used.

So, when compaction after great depth is required then we have to take a huge crane and who is loading and for which if it is proper access is not there may be that mobilization cost will be a significant amount and also required instrumentation to monitor various aspects. That means, instrumentation; obviously, required and also another disadvantage which is not mentioned here that inter improvement work cannot be done by deep dynamic compaction because when you do deep dynamic compaction that it is improved at a greater depth, but surface soil will be highly disturbed. Suppose this is the one

because of dropping of waves shortage will be very irregular and this thickness sometime 0.5 meter to 1 meter actually disturb depth. So, in conjunction with this deep dynamic compaction we have to use roller to finally, get a finished surface. So, that is another disadvantage of this method because deep dynamic method alone is not sufficient to improve the surface site.

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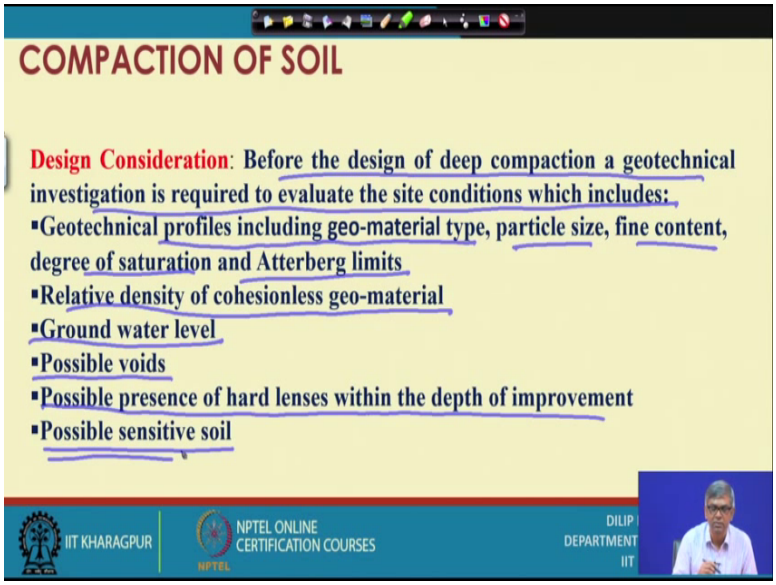

Then design consideration what are the aspects we have to look at when we go for design, before the design deep compaction a geotechnical investigation is required to evaluate the site conditions which includes. That means, we know for which soil this method is applicable which soil is not applicable. So, geotechnical investigation you have to do and then you have to first characterize the material and at the same time we have mentioned that if the water terminal is at higher great higher depth that time is not that effective.

So, that also to be seen and geotechnical properties profiles including geo material type, particle size, fine content, degree of saturation and Atterberg limits these have to be essential part through which seen relative density of cohesion less geo material. So, unit density is reached what level it is there may not be reason behind how much it will densify, if it is at relative density at site is nearly 80 percent hardly any densification is required and if the relative density of the soil is on 30 or 40 percent then you need significant compaction.

Then ground water level as I mentioned, possible voids if there is any unseen void below the possible presence of hard lenses within the depth of improvement; that means, if there is somewhere soil almost uniform suddenly there is a thin layer of hard rock or something that to be investigated before doing this, otherwise below that it will not be effect will not reach the possible sensitive soil. So, if there is sensitive soil that to be. So, by geotechnical investigation these are the things first have to be identified [vocalized-noises] and then influencing factor.

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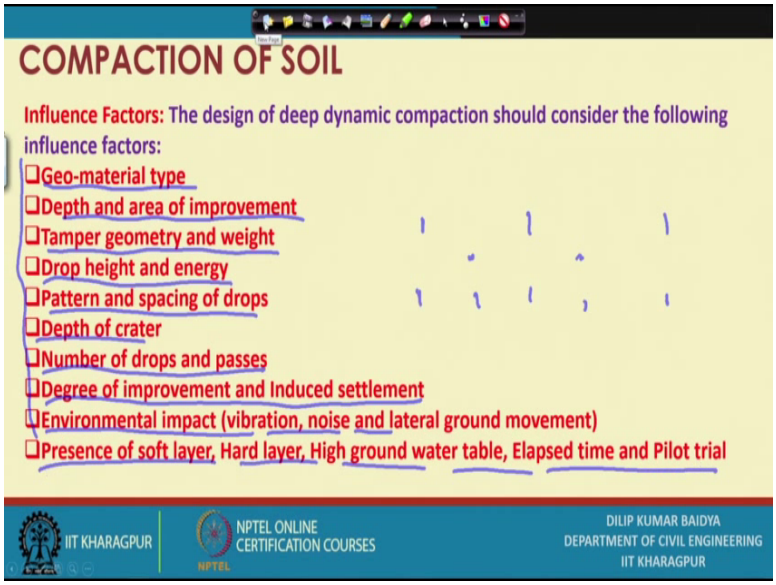

What are the factors it can affect the compaction? So, these are the things mentioned you can see influence factor can include geo material type; that means, it is a soft soil not good then the soil is good. So, geo material type is 1 type depth and area of improvement. So, how much depth is required, if it is required within one meter or so then we need not go through this because we can do quickly (Refer Time: 11:39) or you can do by roller, but when required a great depth like 10 meter or 8 meter and then sometimes it is not good and also if the area is very large then soil is not good this will go.

So, this is the depth and area of improvement that is influencing parameter, tamper geometry and weight. So, if you use smaller weight smaller effect, if you use bigger weight bigger effect again if bigger weight, but smaller contact area you have something and bigger weight also bigger contact area there also some effect. So, those things also

influence the compaction efficiency drop height and energy. So, drop height; obviously, relate to energy, more the height more will be the energy and height and weight these 2 together actually give you the energy. So, that is actually to be sometimes influence the compaction efficiency the pattern and spacing of groups. So, drops actually. So, how will place, what distance sometime you are doing like this, like this then doing this instead of that or you are doing this, this, this and some are doing in between this, this, like, this.

So, there are different ways you can place the load and accordingly your effectiveness will change depth of crater, then how much is going number of drops and passes. So, how many drops you are giving that depends on that actually your effectiveness of compaction will also there and degree of improvement an induced settlement, how much settlement you can permit.

Environmental impact; that means, if you use a particular weight and particular height you can find out what is the vibration level or peak particular velocity and if there is a nearby locality there is a limit for peak particular velocity and so you can calculate that and you can finally, decide what way to use and recommend and presence of soft layer, hard layer, high ground, water table etcetera these are all actually influencing the compaction.

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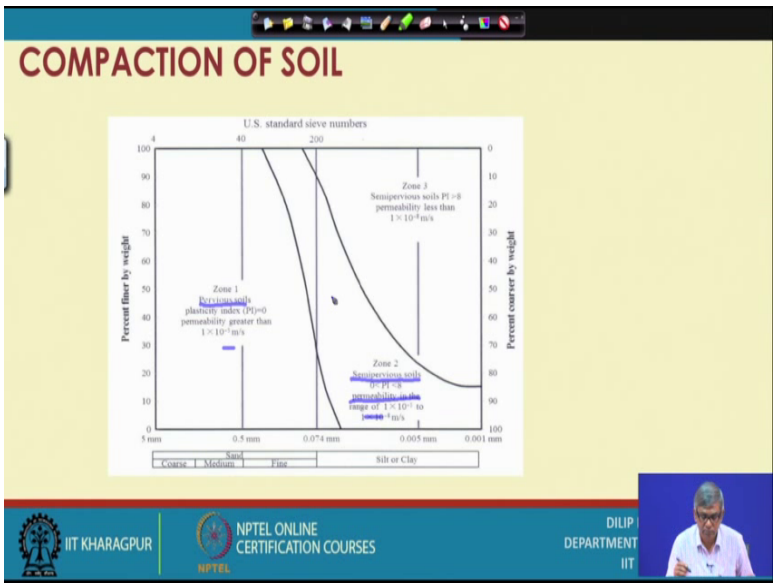

Now, I have qualitatively mentioned that some soil is good, some soil is not good, this figure actually shows the range of where actually it is good you can see. So, pervious soil

plastic index 0 permeability greater than this and zone 2 semi pervious soil permeability is this, this is the range and this is the zone 3 with p I greater than (Refer Time: 15:55) this is the zone actually where actually you have good for the dynamic compaction.

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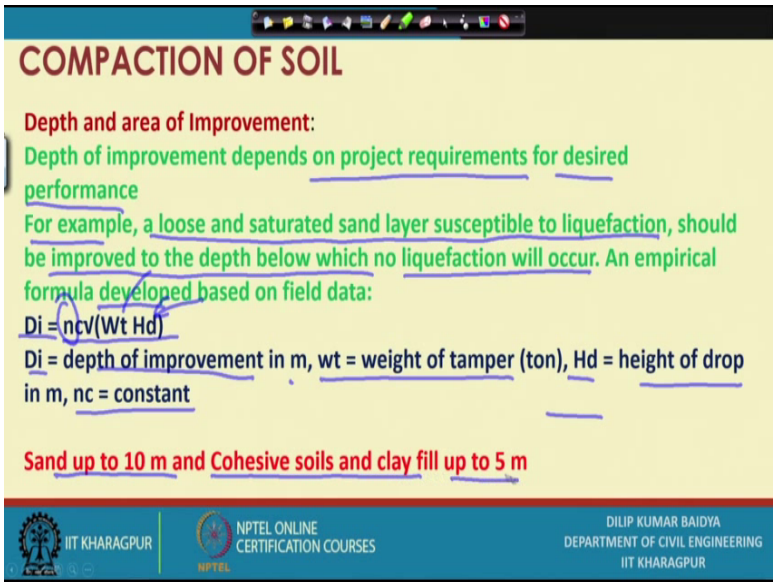

Now, depth and area of improvement, you can see now how much depth to be included that I had mentioned that it is related to energy, energy again related to weight of tamper and the height of drop. So, depth of improvement depends on project requirements for desired performance for example, a loose and saturated sand layer susceptible to liquefaction should be improved to the depth below which no liquefaction will occur. So, that means, up to what depth you have to improve that has to be based on geo technical investigation you will get.

Suppose if you get a 5 meter depth and we get a loose saturated sand and that thickness may be in order of 5 to 6 meters; that means, from 5 meter to 10 to 11 meter of that soil has to be improved. So, that is a requirement and that is that is a requirement this method can be used and so to use this method as know how much depth it will reach the effect when you use a particular weight how much depth effect it will reach that calculation can be done. So, the depth of improvement will be n c under root, n c into under root w t into h d di is a depth of improvement in meter and how much meter it is going, weight of temper in ton h d the height of drop that also in meter and n c is the constant.

So, if I know this then I can find out how much depth it will go accordingly I can adjust this height and weight. So, to reach a desired depth and sand up to 10 meter can be improved by this dynamic compaction where cohesive soil and clay fill can go only up to 5 meter these are the limitations by this method.

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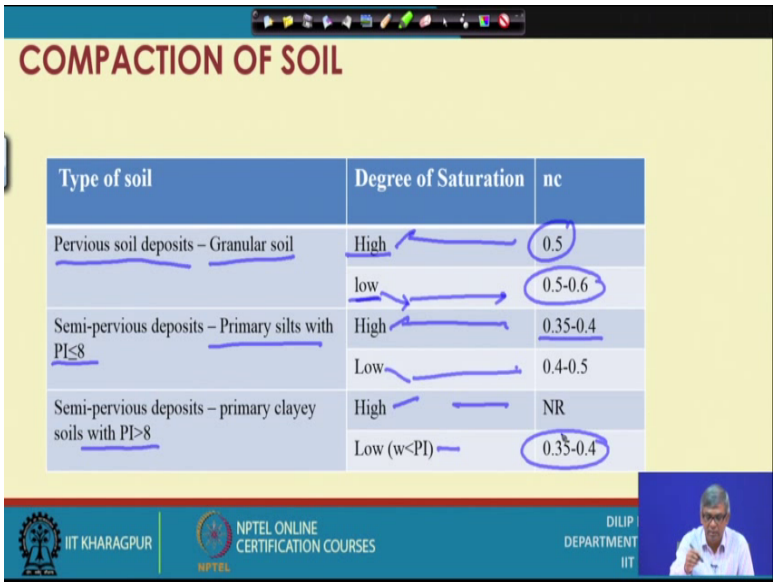

And that n c values gain constant n c value you can see that different types of pervious soil if you deposit granular soil and degree of saturation is high and low, two categories it can be there then n c to be used for 0.5 and here actually 0.5 to point 6. So, pervious soil deposits that is granular soil high to low, high degree of saturation low degree of saturation if it is high 0.5 is low 0.5 to 0.6 semi pervious deposits, primary silts with p I less than 8 and then it will be high saturated saturation, low saturation then high if it is high saturation 0.35 to 0.4 and low saturation 0.4 to 0.5.

Semi pervious deposits primary clayey soils with p I greater than 8 in that case you have again high degree of saturation and low in that case not available and this low is point 3 to 0.4. So, so bigger the value n c value can be taken for calculating and to decide whether the depth of improvement is suitable for the particular weight and height if it is not you can change the weight and height to adjust the requirement.

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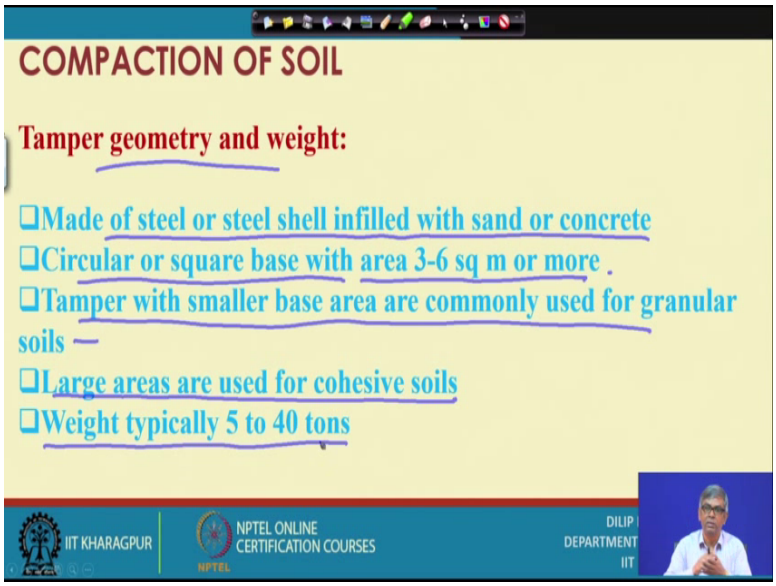

Now, temper geometry and weight here also different geometry is possible made of steel or steel shell infilled with sand or concrete that is another type of material can be made, fully steel possible steel shell that will be shell of steel inside shell of concrete will be there. Circular or square base with area 3 to square meter or more, then tamper with smaller base area are commonly used for granular soils large areas are used for cohesive soils because otherwise more contact will be displaced and weight typically 5 to 40 tons. So, this is a weight tamper weight is 5 to 40 tons.

So, you have to choose in between an height also adjust to adjust the requirement, also while choosing for height and weight you have to see that what peak particle velocity it is giving and that also this is one of the controlling factors because if you allow if you adapt that and it gives you lot of vibration there will be complain and then work will be stopped finally and how we can actually compact actually.

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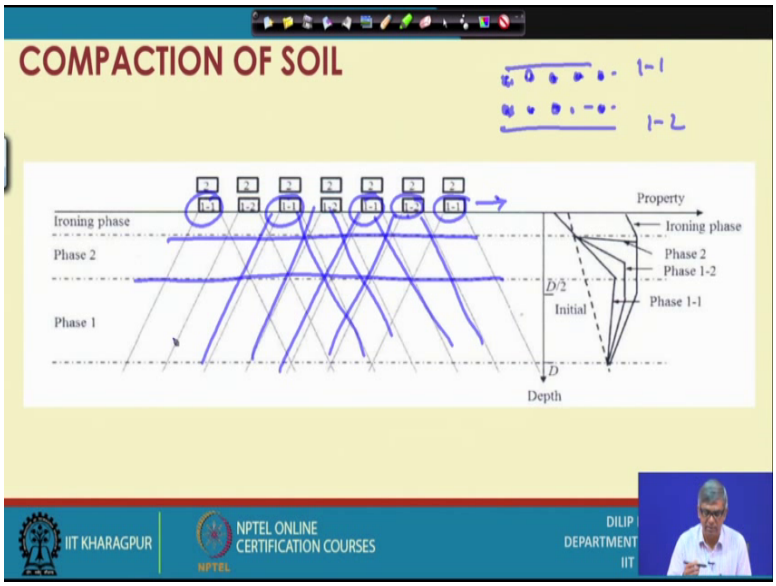

So, this is the alignment actually this is 1 1 sorry this is the 1 1 level this is 1 1 and this is 1 2 is written so; that means, if I have a geometry something like this. So, I can do here, I can do here, I can do here, I can do here, do here, do here like this I will doing and then this is simplify doing that is marked as 1 1 and then I do here, here, here, here these are marked as 1 2 that is the first level of compaction phase 1 and phase 2 so. That means, I have done here, done here, done here, done here, done here, done here this is marked as 1 1 you can see.

Over here 1 1 this is another 1 1 this is another 1 1 another 1 1 and next level in 1 2 level we are putting this, this, this, this so; that means, entire area now covered. So, that is phase 1 phase 1 1 and phase 1 2. So, after covering this entire area still your might have not achieved the required compaction then everywhere now second phase we are putting gap everywhere that is written as 2.

So, that is the plan different ways and then plan. So, that is the way when it drops here the effect will go this to this, this to this and when you put this one effective going this to this and when you put here the it will able to join this to this like that the area is there is overlapping there is overlapping. So, compaction is going on and then when you go to the higher layer again it will compact overlapping will become closer. So, this way the your compaction will be achieved. So, there will be different pattern one can use according to the requirement.

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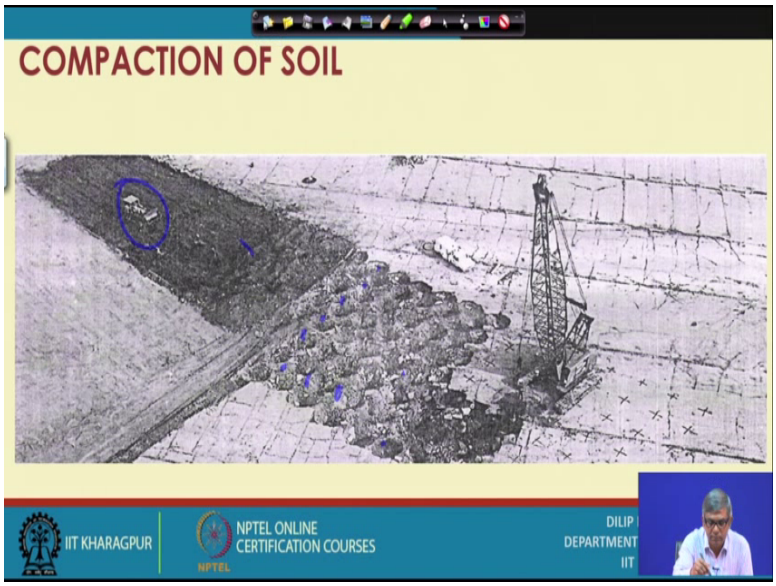

And as I have mentioned that this is typically a picture shown from a site this is its crane and the weight is dropped from here and because of that surface you can see highly disturbed the other places disturbed and as I have mentioned that deep dynamic compaction alone sometimes cannot do the complete job. And it is seen that you can see this area already suppose deep dynamic compaction is done and the surface is somewhat leveled by a something and then finally, there is a roller, it is done in here to final finishing of the work. So, that is the small disadvantage for this, but advantage is more because I am putting a weight here, but its effect is going more than ten meters depth. So, that is very uh effective way to compact the soil.

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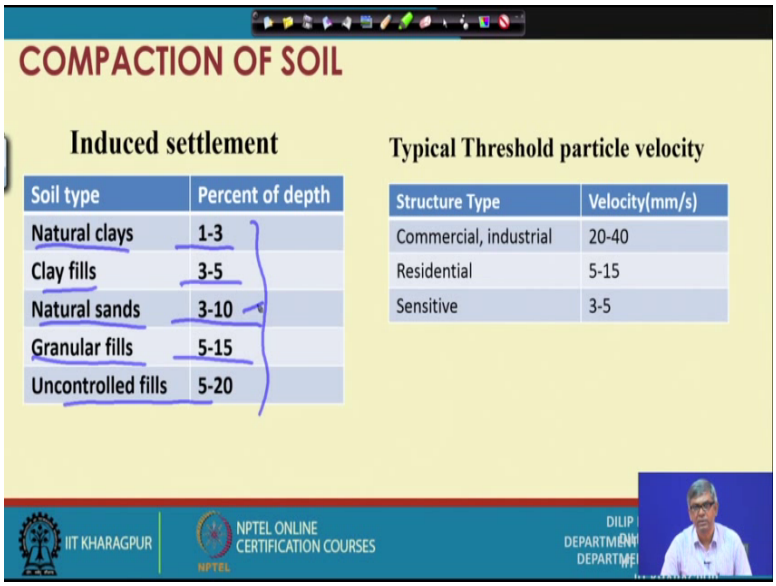

And these are the few things you can see that induce settlement. So, how much these permitted. So, natural clays 1 to 3 percent and clay fills 3 to 5 percent, natural sands 3 to 10 percent, granular fills 5 to 15 percent uncontrolled fills 5 to 15 percent. So, these mass actually induce when you do compaction the how much settlement takes place this is the in percent of the depth, if it is compaction is done 3 meter or 3 percent of 3 meter; that means, half of settlement we are expecting or suppose if you do here 10 percent. So, if you 3 meter 10 percent (Refer Time: 25:14) compaction is get here.

Similarly, they have mentioned another governing parameter is the peak particle velocity; that means, in a in a soil if you do the compaction and during that compaction lot of vibration will be there, vibration will be in major of this particle velocity that will propagate and because of that some method is there I am not discussing that not important at this level perhaps. So, peak particle velocity can be calculated based on weight, height and soil type and that calculation if you do and there is a (Refer Time: 25:54) limiting value. So, limiting values are given here actually, commercial and industrial the peak particle velocity permitted 20 to 40 meter per second whereas, residential building 5 to 15 and sensitive building 3 to 5 you have to calculate and see that those values were below this then only you can go for it.

So, now with this actually various aspect of compaction I have just completed and like shallow compaction, deep compaction there are many other compaction method (Refer

Time: 26:38) vibration there is a vibro protection and there are many other compaction like soil improvement there are many other methods like routing then there may be dewatering also that is another method to improve the soil. So, ground improvement soil sight actually not suitable for construction, we have to improve it and if there are different ways soil can be improved and what I have discussed is the dead specification aspect.

That means, the soil is loose and if the loose is the shallow that then we can do by roller and all and if it is up to a significant depth then you can use densification depth. Another method of improvement ground improvement we are not discussing here because it is not the right place because those types of ground modification for improving the site will be the aspect major aspect of ground soil sorry foundation engineering part or sometimes site investigation ground improvement there may be separate types of courses.

So, those areas with detail can be learn, but whatever undergraduate level compaction related things I think I have covered more than that. So, I hope that will be useful for you.

Thank you.