Ground Improvement

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Lecture No. 06

Shallow Densification

Hello, good day to everyone. Today we are going to start second module on ground improvement and the topic of second module is shallow densification. Already in the introduction part I have mentioned wherever the soil is not ready or suitable for construction, then we need to improve the ground and there are wide varieties of ground improvement techniques are available.

And out of that, the simplest one is the shallow densification. Shallow densification from the name itself, it is quite obvious that it is shallow. It can only densify the surface soil and typically it is used in embankment making or similar type of work where we compact in layers. So, the limitation is maximum half a meter, the soil can be densified by this method. And we will just start how the shallow densify work what is the principle.

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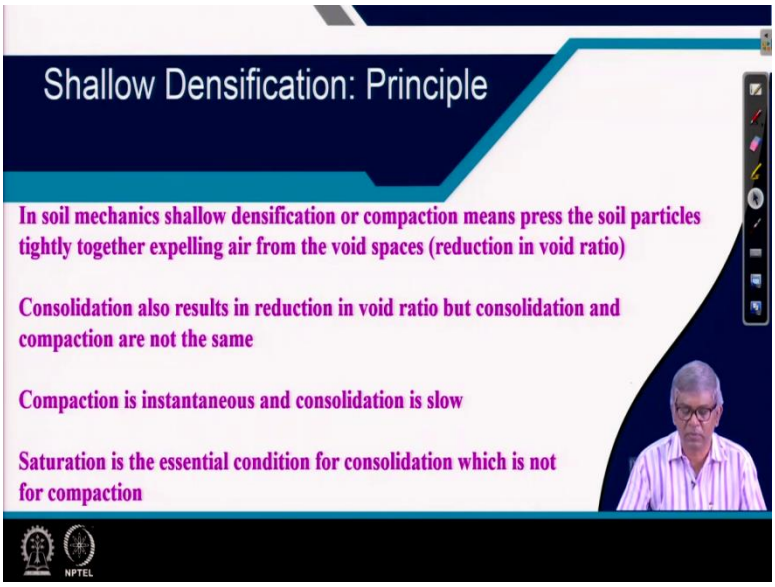

In soil mechanics shallow densification or compaction means; press the soil particles tightly together expelling air from the void spaces. So, that means, the compaction basically is a method where the soil consists of solids and voids. We need to remove the voids and if you remove the voids, then the because of some pressure soil particles will be coming closer.

The compaction actually the method where we apply some energy and that energy helps to remove the air particles from the voids and bring the soil particles closely together. So, that is the mechanism of compaction and this densification or reduction in voids also possible by some other means, which perhaps most of you gone through in soil mechanics that is consolidation.

In the consolidation actually, that your void spaces also reduced and their mechanism is totally different. There actually that consolidation is possible for a saturated fine grain soil. When saturated fine grain soil load is applied then that, the load immediately will not be transferred to the soil grains because of the incompressible nature of water or moisture present in the voids.

Because of that when load is applied, then that water inside the void spaces will be pressurized and in and they exit pore pressure develop at that pressure actually when you develop, then it cannot sustain for long since the soil particles are interconnected and through interconnected void spaces, they will find like a narrow channel through which the water will try to seep out and this excess pore water pressure will dissipate.

So, that is the way in the consultation process actually we apply load then this load will be transferred to the water itself and water will get pressurized and this pressurized water will try to seep through the inter-connected void spaces and try to dissipate the pore pressure. So, this is the mechanism.

So, when the pore pressure or because of the applied load whatever excess pore pressure is developed, when that excess pore pressure becomes zero, then whatever load was applied initially that load will be transferred to the soil grain and then soil grain will be compressed and close together.

That is another way of your bringing the soil particles closer that is consideration process another which I have just mentioned at the beginning that certain amount of energy is applied to the soil and because of this sudden application of the energy some void spaces will be removed from the voids and then air will be removed from the voids and then when the air comes out, then because of this heavy energy, the soil particles will be coming closer and it will become more compact.

So, these two things are basic parameters. This is the removal of or reduction in voids, the mechanism is different one is instantaneous another is slow, your consolidation is a very slow

process, also in the concentration there is an essential requirement that soil has to be saturated, where in the compaction saturation is not the essential that it requires some amount of moisture but in fact if it is saturated, it may not help that way. So, these are all basically two things where soil can be densified, one is called consolidation and one is compaction and what are the basic difference I just explained here.

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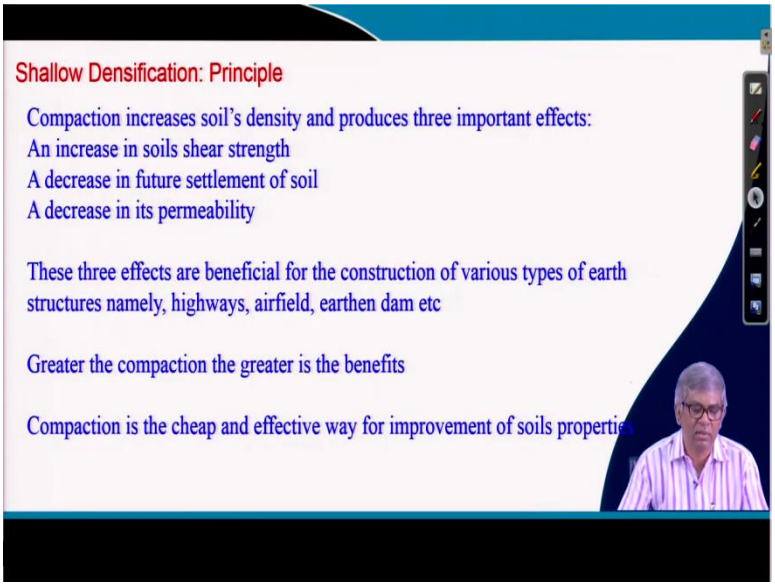

Now in shallow densification that means, whatever maybe whether it be shallow or deep by densification by compaction it helps or it changes the profile properties and those properties basically are, one is shear strength another is settlement or compressibility characteristics another is permeability.

So, when you compact by applying energy to the soil, then it will increases the soil shear strength, it will happen when that is one thing at a decrease in future settlement of the soil that will compressibility also be reduced and decreasing its permeability and these are three important effects happens when we compact the soil.

These three effects are beneficial for the construction of various types of earth structures namely highways, your field earthen dam etc. So, that means when you want to make a highway or airfield or earthen dam, that soil should have sufficient strength, it should have minimum compressibility and it should have desired permeability or limited to certain value.

So, by compaction process it helps all three. That is the reason why we compact soil when the soil is not suitable or when soil is weak and we compact and try to make it suitable for the

construction of different earth structure which is named here like highways, railways, airfield, earthen dam etc.

And greater the compaction the greater is the benefits that as I have mentioned that by compaction process, we remove the void spaces but complete removal is not possible. So, if you use lesser amount of energy, less amount of air will be removed. If you more amount of energy applies then more amount of air will be removed.

As a result, that grid the compaction greater is the benefit. So, that means if you want to have a greater compaction, you may have to use a greater energy or similarly, some other things that we have to is applicable and at the same time the compaction is the chief and effective way for improvement of soil properties.

That means why it is cheap and all I will explain, it is actually very simple equipment will be used and it is a very old process. Since long or since several years people are using people are experience and it can be done easily, it can be monitored easily. So, because of that, it is a very cheap and effective way for improvement or densification of soil properties particularly when it is required for a larger area.

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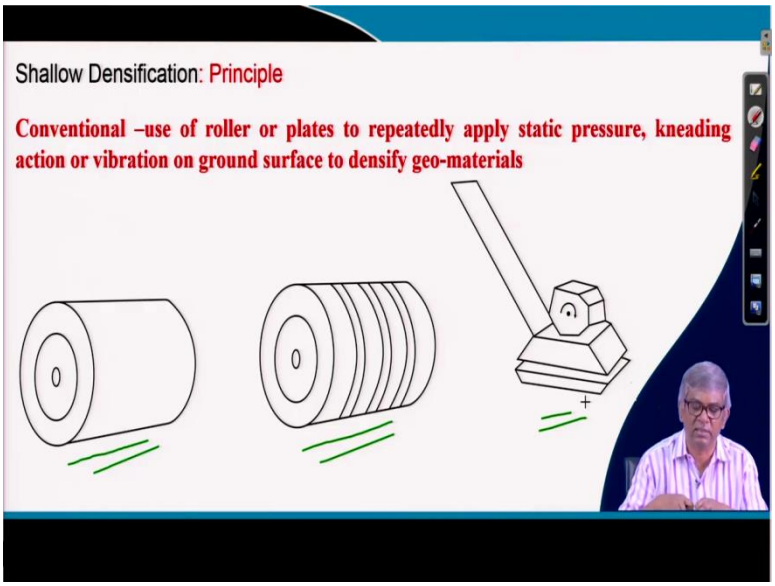

And you see those conventional ways we do compaction and sometime we use you can see that here this is a roller. This type of roller actually it is a heavy roller, this is generally steel wheels, it is separate itself will compact, only one engine will pool and while moving over the soil, it is by its own weight soil will be densified.

And this is another type of fills which is actually tired, there will be very large size of tires will be kept one after another and these are of course, this is suitable for some soil this is not suitable for some other soil. So, all are not applicable for everything. So, this is one type this is an only steel wheel and this is rubber-tired wheel and sometime if we use this roller and compact and then majority of the areas you may able to compact by moving the rollers back and forth.

Whereas in the corners or some edges you will not be able to reach, at those places sometime we use some plate compaction compactor that is like this. So, there will be plates and it can be some energy will be applied through these and those are inaccessible area it can be compacted. So, use a roller or plates to repeatedly apply static pressure needing action or vibration on ground surface to densify geometry.

This is the principle actually either by rolling, rolling and vibration, sometimes some soil is by rolling will not help. So, there are some leading actions those things I will discuss one after other and there is a plate which I have shown here already. So, these are these are different some examples I am giving of your compaction equipment by using we can densify the soil.

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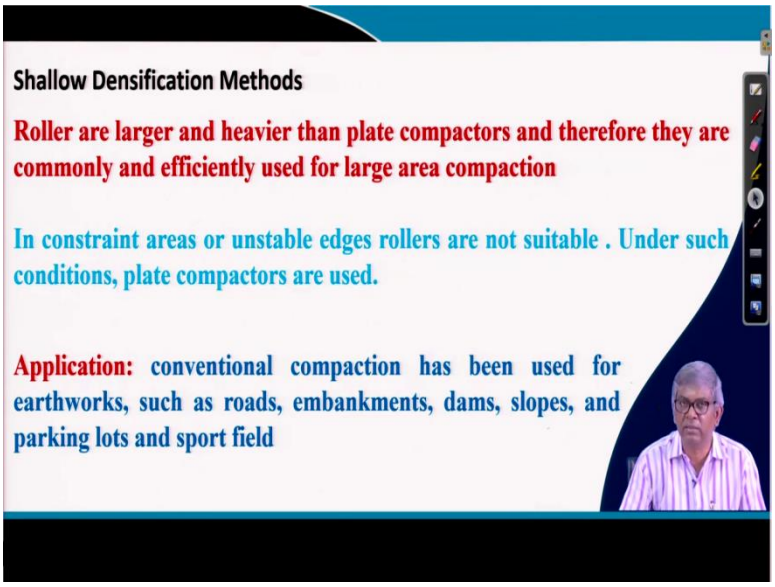

So, next is as you can see that roller a larger and heavier than plate compactors obviously, I have mentioned that rollers by back-and-forth movement, soil will be densified and plate compactors there will be some impact will be produced and they are only applicable for inexorable inaccessible areas.

Therefore, they are commonly and efficiently used for large area commercial roller and in constant areas or unstable edges rollers are not suitable as I have already mentioned that suppose we are compacting suppose these area this is the area we have to compact and roller can reach suppose up to this roller can reach up to these.

Because beyond that if it goes then that may be unstable the thing may become unstable. So, in that situation whatever possible by roller it will be done or even in places will be used by plate compactors and the applications obviously, the conventional compaction has been used for earthworks. Earthwork means filling are any type of fillings like road making, embankment making, dam making, slope making and sometimes parking lots and sports fields.

So, particularly sports will mean what suppose a cricket pitch to be developed. There are also some specifications will be there and accordingly you have to apply a particular you have to use a different type of soil and then you have to apply definite amount of moisture and then you have to apply a definite amount of energy and compact then only it will be suitable for cricket pitch.

So, like that when you make road the requirement is different, when it is a dam, the requirement will be different. So, those requirements and also of course, we can discus one after another. So, the application will be that means, it is used for earthwork such as roads, embankment, dam, slopes and parking lots and sports fields.

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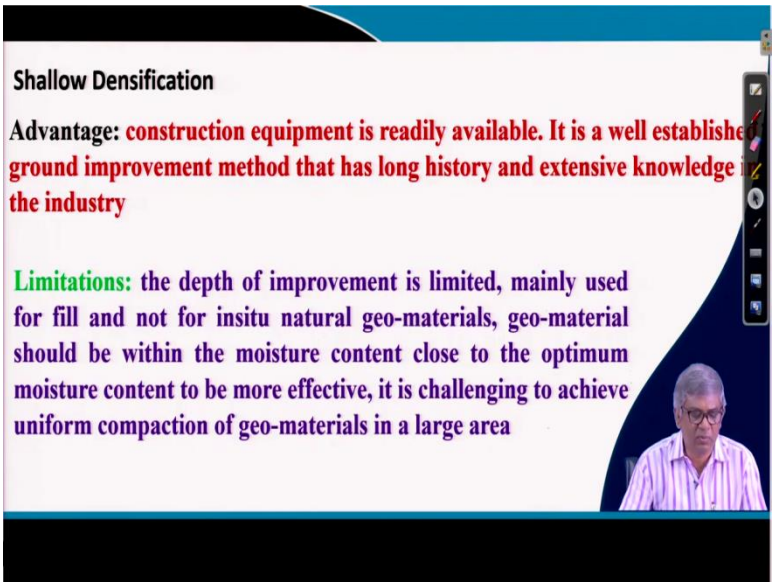

And what is the advantage in it? The advantage is already I have mentioned that construction equipment is readily available, to whatever rollers and all it is readily available that it is not very special type and it is well established because since ages people are used for ground improvement purpose these types of things and has long history and people have extensive knowledge.

Sure, because of all those reasons, it is very advantageous, very easy to adopt and very cheap also, it has also limitations. So, limitations actually one of the most important limitations here is the depth of improvement is limited. At the beginning itself, title itself we have mentioned that there is a shallow densification that when it cannot go beyond 0.5 meters and so, that is the major limitations.

In addition to that, it is mainly used for field and not for in-situ a natural geo-material. So, if suppose an in-situ soil if you find suppose on a two meter or three meter or four-meter soil is not a good and if you want to use by this shallow densification technique that means by roller it will not help.

So, that is what that this is only used for field that means, you suppose when you are making an embankment, you make a thin layer of 30 to 40 centimeter and then compact it again if you want more height, then you can again later soil spread the soil up to some thickness and again compact like that it will goes.

Geo-materials should be within the moisture content, so close to the optimum moisture content to be more effective. So, that means when you want to use this roller or the shallow distribution method, the moisture content is also very important and you have to apply that close to that that that particular moisture content that is called optimum moisture content, what is optimum moisture content I will just explain maybe in the subsequent slide.

And that is one thing that you have to apply very close to optimum moisture which is very close to optimum moisture content and another disadvantage is it is challenging to achieve uniform compaction. So, we make the roller back and forth movement and maybe 3 passes maybe 4 passes sometime because of overlapping some places is going 4 passes somewhere it is going 3 places Some are going 5 passes.

So, like that it happens when the large area is compacted whatever way you do, how carefully you do still there will be in a non-uniformity. So, that is another biggest disadvantage is that this challenging to achieve uniform compaction of geo - materials in a large area.

So, first limitation is that it can it is limited to a very shallow depth and it cannot be used normal geo-material it can be used only for field and it has to be used the moisture content is very close to optimum moisture content otherwise it will not be efficient and it is very challenging to achieve uniform the compaction over a large area so these are the limitations.

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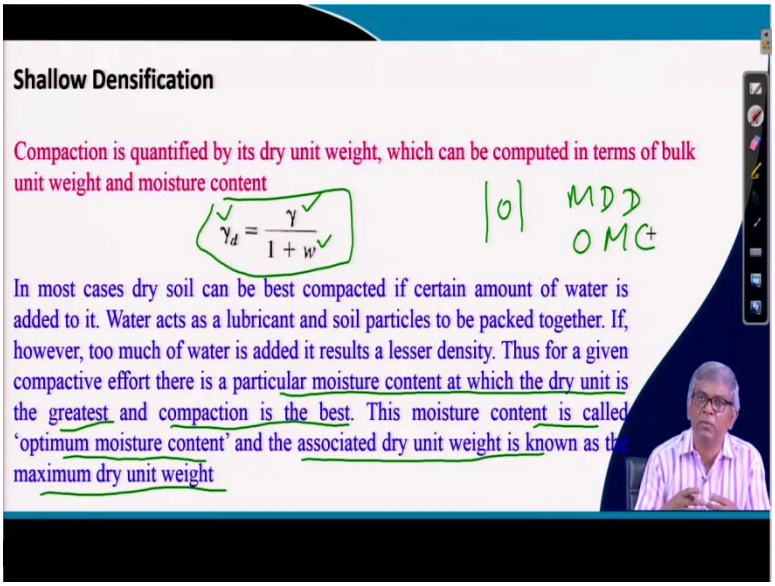

Now, you can see here that the compaction so, whether the soil is compacted or not or how it is compacted, we measure by dry unit weight. So, compaction is quantified by dry unit weight which can be computed in terms of bulk unit weight and moisture content. You can see that, in a particular area is compacted and I can collect a sample and then I can find out the bulk unit weight that means in-situ whatever you need to it and then I can find out the moisture content and then the dry unit weight and bulk unit weight and moisture content this is the, this is a relationship.

That means, bulk unit weight divided by 1 plus water content is the dry unit weight. So, this is the way so the dry you need to wait finally, after compaction you find out if the drive unit is very high, then the compaction is good if the dry unit is less, then compaction is not that good. So, in most cases dry soil can be best compacted if certain amount of water is added to it.

$$\gamma_d = \frac{\gamma}{1+w}$$

So, as I have mentioned also at the beginning that the compaction is the instantaneous application of the energy and whereas, consolidation is the slow and it is a saturated soil and

when the compaction is done when you apply the instantaneous energy, there actually if you have complete dry, then compaction will not be that efficient. If you have little amount of moisture that will help to lubricate or lubrication effects and this will help to particles slide over another one to another and it helps to come closer easily.

So, that is what water acts as a lubricant and soil particles to be packed together. If, however, too much of water is added it results a lesser density. So, that means you need the compaction process, you need certain amount of moisture which helps to as a lubricant and which helps to bring the particles closer, but if you apply again excessive, then it will give you lesser moisture content dry unit rate mainly because of that it will occupy some volume and you know the unit weight is or specific gravity of water is lesser than the soil particles.

So, obviously, if you have excessive water, then its dry unit weight automatically reduced. Thus, for a compactive effort, there is a particular moisture content at which the driver is the greatest and compaction is the so that means for a particular moisture content at which the dry unit weight is the greatest and compaction is the best. So, that means these two things, one is at a particular moisture and particular degree of compaction these two things to be quantitative to be fixed.

This moisture content is called optimum moisture content and the associated dry unit weight is known as the maximum dry unit. So, maximum dry unit weight sometimes it is called MDD we use very commonly MDD and optimum moisture content we use commonly OMC, optimum moisture content. So, these are the things two things actually that means, when you compact the particular soil purely dry or purely saturated soil compaction will not be efficient.

If you have dry soil and add certain amount of moisture that will help to compact, but the certain amount of moisture that amounts to is what, that amount for which the compaction gives best compaction gives that moisture content is called optimum moisture content and the best on this on the optimal moisture content or dry unit density achieved that is called maximum dry density. So, this is the things the basic terminology to be used here, which will also subsequently in some more slides.

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So, here actually you can see whatever I have explained just now, you can see here typically, for compaction test, we take samples of 4 or 5 samples of given a quantity sample 1 suppose, 2, 3, 4 and 5 suppose and each sample will be added certain amount of moisture content support this is w1 this is W_2, W_3, W_4 and W_5.

So, like that if we add and then there is a compaction standard procedure, when you do proctor compaction that is 2.5 kg weight and 25centimeter height or 30centimeter height 25 blows in a layer and it will be done in 1000 cc mold and three layers, all those standards, any soil already the soil mechanics you might have learned. So, I will not repeat that.

So, these 5 different moisture contents if I compact and then I will get corresponding to each moisture content I will get different dry density 1, 2, 3, 4, 5 and if I connect them, then I will get a curve like this and from this curve, I can see that the maximum dry density here I can mark that is MDD and corresponding to this is optimum moisture content. So, from the curve from the graph itself we can find out this.

As I have mentioned that that complete saturation sometimes will not so, even though this curve is done and it is there some compaction is done, but it is not completely saturated, when it is completely saturated that is called zero air voids. So, theoretically zero air voids actually it is very difficult to do by compaction.

But theoretically if we drop zero air void lines that means, saturation complete saturation and that means particular different moisture content and dry unit weight, you get a curve, parallel

to the weight side of the curve. So, this is the zero air voids line curve. So, that means zero air void curves cannot intersect the compaction curve.

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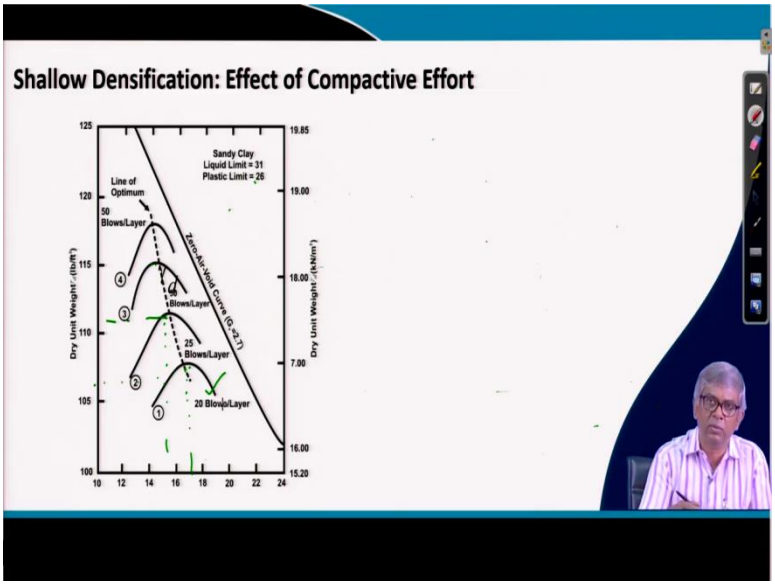

So, now as I have mentioned that, if you want to have better compaction, then you sometime may have to use greater energy. So, here in this curve, it is shown that you can see here that a particular sample same sample, when 20 blows per layer is applied and then compaction curve is at drawn, the compaction curve is here that means optimum moisture content somewhere here and maximum dry density somewhere here.

Now, if you apply 25 blows, which is standard proctor test, then I get up to a moisture content here and dry density here and then if I grade 30 blows per layer that weighs more than the standard, then I am getting optimum here and maximum dry density here if I give 50 blows per layer, then I am getting so, this is the way.

So, that means, how energy is affecting the optimum moisture contents and maximum density you can see with the increase of energy level that with the increase of energy level that means a greater number of rows means more energy. So, with the increase of energy you can see that after moisture content is reduced and maximum dry density is increasing.

So, this is the effect that means, when you we will more energy you require lesser amount of moisture to achieve a better dry density, this is the one it is shown in this in this figure and you can see that a zero air void lines are also drawn here you can see that they are all parallel to the weight side of every curve. So, this will happen always. So, we can discuss and I will take some problem also later on how zero air void lines can be drawn.

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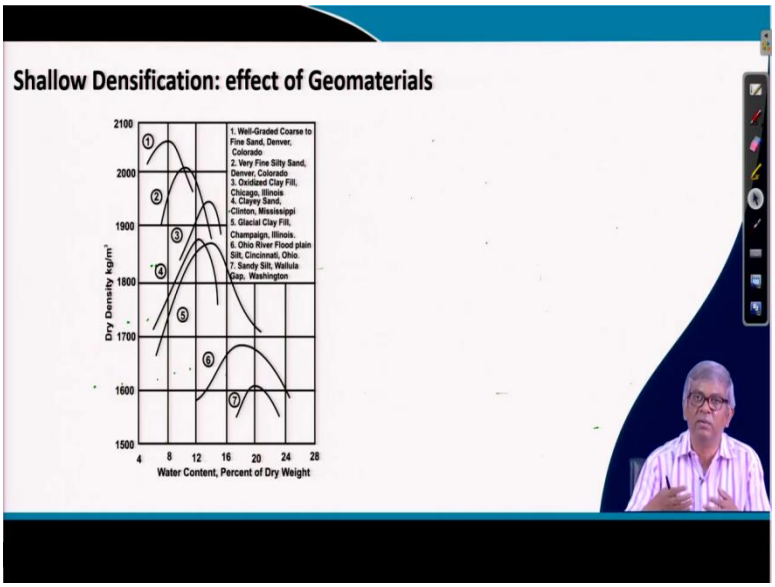

And another effect that means, effect of geo-materials actually. Same energy if I apply to different materials, the effectiveness of compaction will be different. So, that is what is shown you can see there are 7 different types of soils are shown and you can see same energy is applied, but it has the seventh one is the sandy, silty and as you can see that it has a very high moisture content and very low dry density.

Whereas, number 1 is well graded course to fine sand and you can see here it has it is required very little moisture, but it achieved very high density. That means the compaction degree of compaction can be achieved. It depends on type of materials; even though you apply same energy on different soil will get different moisture optimum moisture content at different dry density.

So, with this here actually by a large principle of compaction initial, how it works and what are the advantage, limitation etcetera. With this, I close this lecture 1 model 2. I will now next I will show some more aspect in the subsequent module. Thank you