Soil Mechanics/Geotechnical Engineering I

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Lecture - 14
Compaction of soils

Once again welcome you to this lecture series in Soil Mechanics and Geotechnical Engineering 1. And now I have completed a CPU's and permeability and other topic before that now I am going to the new topic that is a compaction of soil. This compaction of soil actually; why it is needed? What is compaction? All those things we will discuss one by one.

The soil actually we have classified at the beginning and based on the classification of the soil, we can decide or we can come to know that which soil is good, which soil is not good, which soil is bad or which soil is reasonably good, which soil is reasonably bad. So, like that we can characterize based on the classification and other characteristics, but a good soil is a good; that means, there is a no problem one can construct whatever design infrastructure they want.

But when the soil is bad, then how to solve the problem and, but there are 2 option. When the soil is bad we can change the location; that means, I can go to a new place, new location site for project or if that is not permitted because land is not. So, easy to get suppose whatever the site same site to be used.

Then what is the alternative is that you have to make the soil suitable for construction. How to make suitable? There are many ways to make the soil suitable for construction and one such method is the compaction; that means, by compacting the soil one can make the good soil.

So, that one actually and; that means, not only that there are also different areas, different types of soil. We immediately look to be good, but over the time they may create different types of problem. In general we call it problematic soil. There are different problematic soil in different reason and different areas and then those problematic soil actually immediately if you know the soil is problematic, then generally we do not construct anything without doing any modification in it. So, that means, we generally

classify the soil as a problematic soil and good soil and those problematic soil what are the different problematic soil? What is the source that I will show one by one and what is their potential problems?

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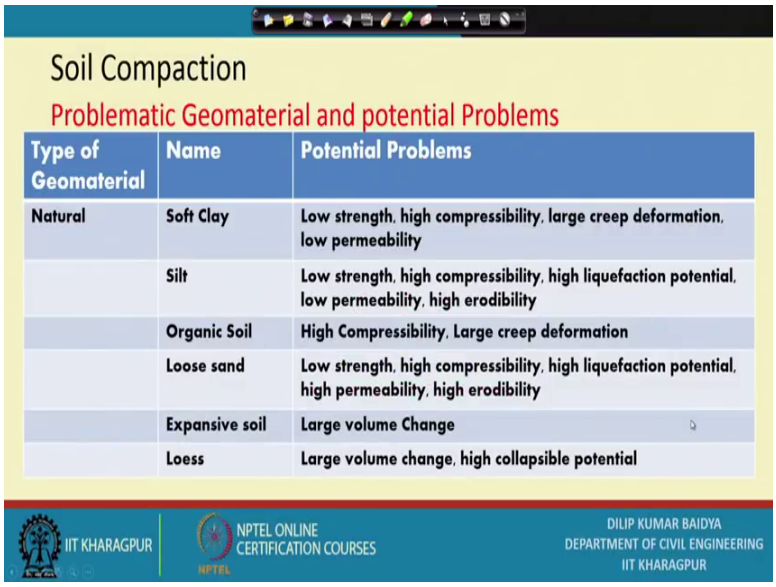

So, these are the things actually naturally we can get potential soil or we can get for the field soil also problematic soil. When you get natural soil, there is a soil called Soft Clay. I have also mentioned it before that Soft Clay is a very highly plastic soil and it undergoes lot of settlement.

When is naturally obtains soft clay it has low strength, it has high compressibility, it has large creep deformation and low permeability. So, these are all low permeability sometimes favorable, but other properties are not favorable. Because of that if you find at particular site soft clay, then we may think of modifying the soil.

Similarly, Silt is another soil where it also has a low strength, high compressibility, high liquefaction potential and low permeability and high erodibility. That means during flow or there is rain, soil can erode very quickly. Then immediately then another soil which is also available naturally that the organic soil. It is also a very dangerous soil. It is high compressibility and large creep deformation of course, strength also is low and loose sand. Loose sand is generally good, but if it is in the loose and fine then there is a problem. There it will have low strength. It has high compressibility and high liquefaction potential.

So, similarly if you get another type of soil where actually normally good, but when it come in contact, then it will soil and it cause the move building to move off and sometime noticeable also and when it will dry that mean in a dry season again soil contract and as a result again it pull that foundation below downward.

So; that means, which season if the foundation is there built on an expensive soil with seasonal variation building some time goes up and goes down and that way the structural damages takes place. And this loess is another particular type of rounded sealed and sand which I have explained the very beginning. That is also very a problematic soil. That it is large volume change and high collapsible potential actually. These are the naturally we can find these type of problematic soil.

Now, if I go to the fill.

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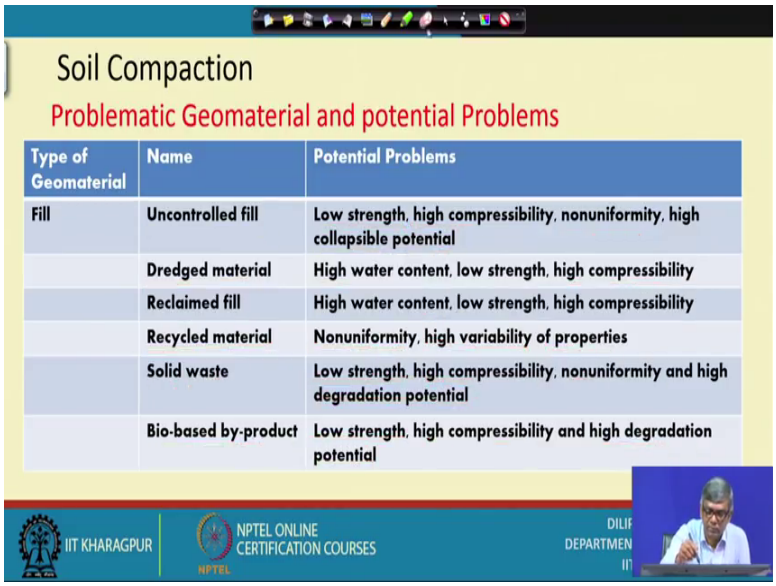

Fill material we can also different types of fill material is possible. If it is a uncontrolled fill, which will have uncontrolled. It will not properly filling sometime it can be done you put a layer and compact put a layer and compact. Then that is control filling and that will have these quality for construction. Whereas, is uncontrolled and randomly is dumped different direction, then this type of soil will have low strength, high compressibility, nonuniformity, high collapsible potential. So, that is why we has to be handled properly. Dredged material, when the dredging material comes in strong and if it is filled it then it will have high water content, low strength, high compressibility.

Then Reclaimed Fill high water content, again low strength, high compressibility. Then Recycled material nonuniformity, high variability of properties and if it is a Solid Waste it will have low strength, high compressibility, nonuniformity and high degradation potential. And bio based byproduct again low strength, high compressibility, high degradation potential.

So; that means, 2 types of material natural or fill, but these are the identified material where if you try to construct something, we have to be careful; that means, careful means what? Directly you cannot do anything particularly if it is important structure. What you have to do, you have to do some modification. After that when it becomes suitable, then only one can make thus desired structure.

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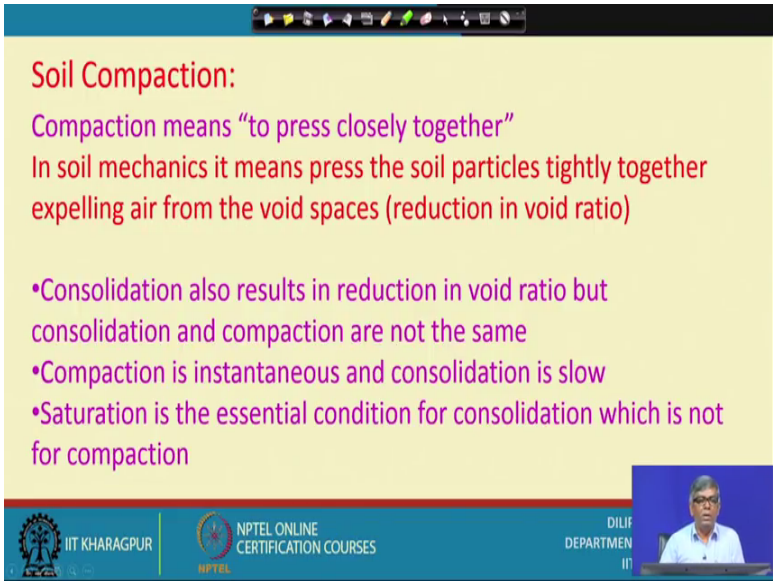

Now, we are in a topic of soil compaction. One of there are different ways soil can be modified. I will talk about soil compaction now. Compaction is means actually what to press closely together. Compaction means 2 particles. Suppose, you have to press them and then bring them closer and if you do that particularly in soil, then soil means to press the soil particles tightly together, expelling air from the void spaces. We have I have already done 3 phase diagram. I have shown that in the soil mass if I model it then I can get a solid volume and I can get the voids volume. So, that voids amount if I can remove and if I force the particle to come closer then voids automatically will be reduced and by that way soil get densified and densified soil will be better soil.

So, that is what the compaction. The purpose of compaction is to expelling the voids and bring the particles closer and then consolidation also reserves. There is another topic consolidation which I will be discussing maybe later on. Consolidation also is a phenomena for saturated soil and 3 phase diagram. We have shown 2 or 3 situation. One is entirely dry, in that case air and solids and there is in between and then there is other extreme the entire void is filled up with water and then solid.

So, then when in consolidation case actually it has to be saturate condition when we somehow we manage to make the water to come out. Then when water come out, then same amount of volume of soil also compress. So, that is also reduction of void ratio and here actually in the compaction also we are also by some means we are reducing the void, bringing the soil closer and reducing the volume both the cases reduction in volume.

So, consolidation I will discuss later on, but right now I am just mentioning consolidation also results in the reduction in void ratio. Compaction is reduction in void ratio, consolidation also reduction in void ratio and consolidation and compaction are not the same. Still they are not the same because the mechanism is different. Compaction is main instantaneous; that means, immediately I apply force and bring the soil particles to closer and get compacted whereas, consolidation is slow process.

That we apply some amount of load because of that such a load on the saturated soil, the initially excess pore pressure will develop and there because of these excess pore pressure, water comes out through the interconnected void spaces and when water comes out then the same amount of volume of water coming out, the same volume of soil mass will be reduced. That is the one and another thing difference. The compaction is instantaneous and whereas, this is consolidation takes a long time and consolidation actually saturation is the essential condition and whereas, compaction it is not required.

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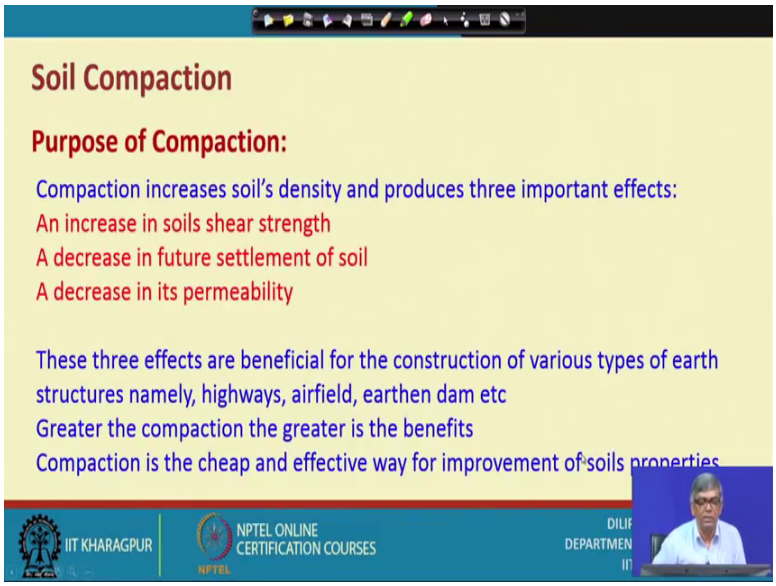

So, now Soil Compaction; what is the purpose? Purpose of compaction is compaction increases soils density and from immediate effect what do you get? The soil particles comes closer and density get increased and that actually gives you several benefits and that is most important 3 are actually increase in shear strength and decrease in settlement. That will compressibility and decrease in permeability.

So, these are top densification are this. This 3 effects are beneficial for the construction of various types of architectures, namely highways, airfield, earthen dam, etcetera. Greater is the compaction, the greater will be the benefits. The compaction is the cheap and effective way for improvement of the soil properties; that means, as I have mentioned that if you identify a problematic soil that can be modified in different ways. One simplest way is that inter soil can be removed and one can bring a good soil and fill it up. That is one way of course, but that sometime may not be feasible because of the cost.

So, like that there are several other alternatives and one alternative is compaction. This compaction why many times is chosen because it is a very cheap and effective and it is not required any specialized workman people for working. No need of very specialized equipment. So, because of that this is very popular.

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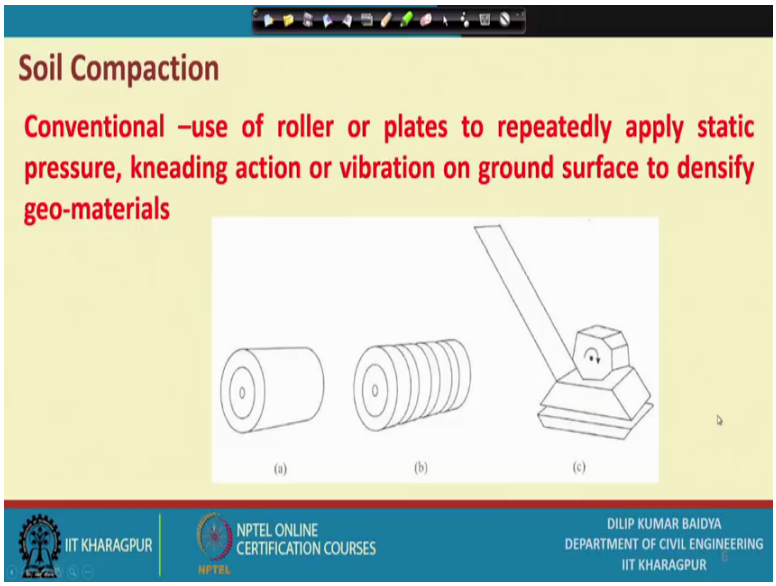

So, soil compaction typically we do by using different things. This is a roller. This is also sometime rubber tire roller. This is smooth wheel roller and this may be sometime plate compactor. So, different way on the soil we put a layer of soil and then we can by some way you can apply over a dense.

Soil automatically will get compressed. That is the simple mechanism generally used in compaction and plate vibrator actually some soil if I apply just pressure load sometime soil will not get compacted. Particularly soil granular soil when you apply vibration in addition to the weight. Because of this vibration the soil particles actually smaller particles can enter in the bigger particles and make more compact stable arrangement. Because of that sometime this type of compacter is used. That mean in addition to the weight we had some vibration.

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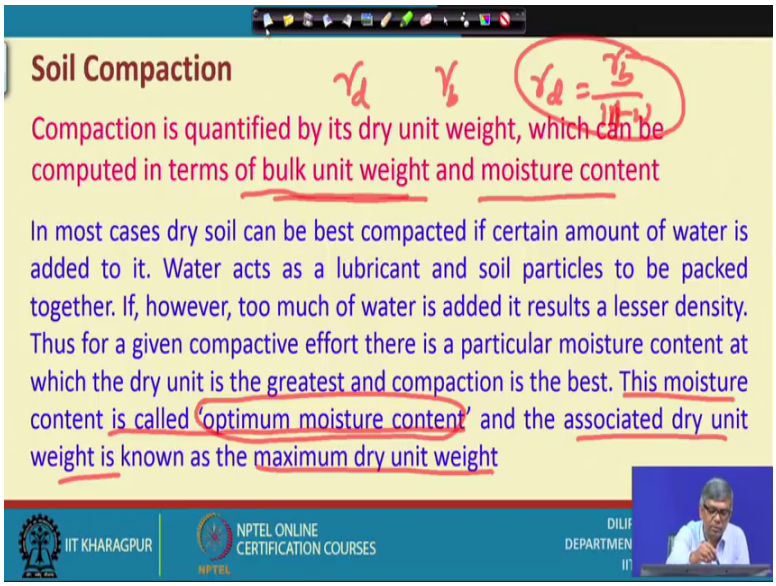

Compaction is quantified by it is dry unit weight which can be computed in terms of bulk unit weight and moisture content. We have actually at the beginning we have done so many things. Actually, we have done gamma d, we have done gamma bulk and we have got the expression relationship become gamma d and gamma b relation is 1 plus w. This is done at the beginning. That is what?

So, when you compact the soil how to quantify the soil compaction whether it is good bad by measuring or by estimating by calculating the gamma d. When this compaction is taking place, we occasionally we go and some interval we measure the do some measurement and find out the dry density. When we see that dry density this to desired value, then declare that compaction is satisfactory or compaction is done properly.

That is what that is initially dry density we cannot do. We can find out the few bulk unit weight or we can determine the moisture content. So, by knowing the bulk unit and moisture content we can find out the gamma d by using this equation. That is the quantification. How we quantify the degree of compaction? Some soil can be compacted with gamma d equal to 1.6.

Some soil can be compacted gamma d with 1.7. Some soil can be 1.8 like that. At 1.6 compared to gamma d 1.6, gamma d 1.8 definitely is a better compaction. In most cases dry soil can be best compacted if certain amount of water is added to it. Dry soil if you compact, it will be compacted, but it will not be efficient. So, you can if you can add

some amount of water in it. Then that water will act as lubricant and which will help the soil particles to come closer, but together that way actually you can. Some amount of water is necessary to add to make compaction efficient.

But, again if I add excess amount of water, that again will not give you the good result. After certain amount of water, it will reach the maximum dry density, but if you further adding water then again dry density again will fall. So, that is why in this actually compaction we get every soil will have a particular characteristics. When the energy level actually lowered or and other energy level is kept constant, then for a constant level of energy, for a particular soil, will get a particular maximum dry density and corresponding maximum moisture content.

But at that which it will give you maximum dry density and those 2 terms actually is called this moisture content is called the optimum moisture content; that means, how much water we have to add? And by adding that; you will get the maximum dry density. That moisture content is called optimum moisture content. At which actually you will get the maximum dry density and the associated dry unit will; that means, based on that amount of moisture content if you compare and this resulting dry density is called maximum dry unit weight. So, that has to be specified most of the time.

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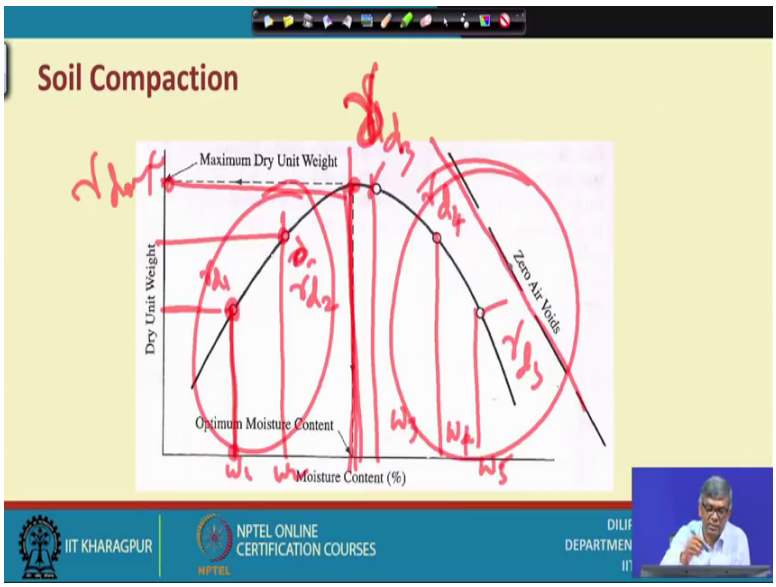

And this is actually to test soil, if soil is tested in the laboratory and then generally we get a compaction curve. So, as I have mentioned that we have to see we cannot add water

excessively. You have to do travels actually initially. We have to start with some minimum level of water content 4 to 6 percent and you have to compact the compaction; that is a standard procedure.

The procedure is given by standard factor is a name of the person. He has given the specification for factor compaction. What will be the energy level actually; that means, there is a hammer. It will fall for the particular height. The hammer weight is 2.5 kg and it will fall from 30 centimeter and you have to give in 30 blows, 25 blows actually. And then by that standard if you compact the soil and then if you take the weight, bulk weight and find out the unit water content, then from there you can find out the dry unit weight.

So, suppose at 4 percent of water, suppose you have got 1 point and based on that water content is exactly this and dry unit weight is this. Then again 2 percent of 1 percent you have added and then we got another sample. Now compacted sample and based on measurement we have got dry unit weight of this much. So, this is w1 and this is w2, this is gamma d1. This is gamma d, gamma d2. Similarly, at w3 we are getting gamma d3 and w4, we are getting gamma d, gamma d3, gamma d4 and this is w5 and this is gamma d5.

So, like that we get a curve. When we assume or when we can decide ascertain or you can come in conclusion that we have done test correctly. Generally when you correctly conduct a test, you should have actually 4 to 5 trials and out of these 4-5 trials, 50 percent should be worth dry side and 50 percent should be weight side. If I take this is a peak optimum moisture content. 2 points is in the dry side and 2 point side 2 to 3 points in the weight side.

During test actually how you will be doing, when I will find out the bulk unit weighted a particular volume. In a particular volume and with a particular energy we compact the soil. Then that volume of soil generally will take bulk unit weight. When we change the bulk initially bulk unit weight also increase with additional water and it leads to a maximum and then bulk unit try to drops.

So, always during test we have to take that dropping side 2 and lesser side 2 also. Like at least. That we will get a smooth curve like this and from after drawing this curve, one can find out the optimum moisture content, smooth curve if you do, optimum moisture content is this. And gamma d max is this. This is the one and of course, when we do the

test then soil is moist, but not saturated. Because of that during this test if I can draw a 0 air void lines; that means, when completely overall of varieties is totally difficult very difficult. So, theoretically we can draw a 0 air void lines. What it is? I will discuss later on, but these 0 air void lines will be somewhat parallel to the end of the curve. That is the convention generally we have the standard and it should be. Whether your test is correct or not by observing this we can decide.

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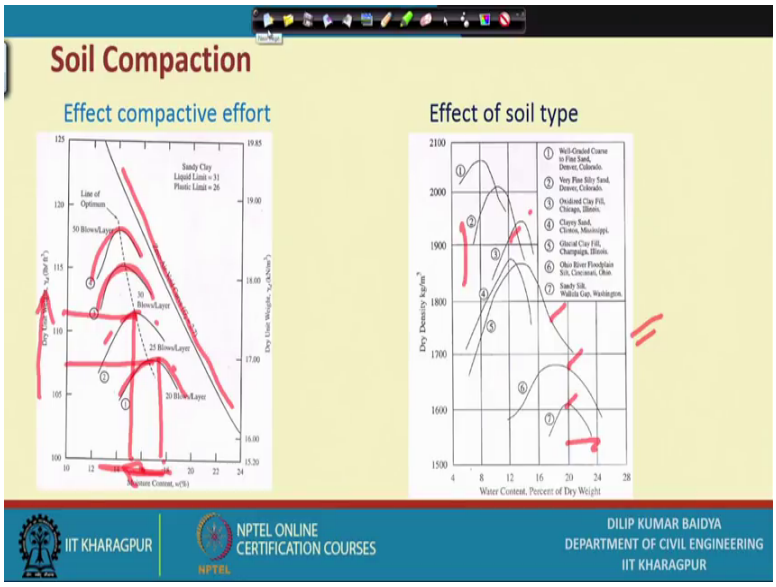

Now, as I have mentioned, when we conduct the test we are talking about the energy, we are talking about the soil type. So, some soil actually can be using a constant energy can be densified to some dry density. If I take some other soil it may not able to densify that amount by same energy so; that means, it depends on that compaction that optimum moisture content and dry density that actually characteristics of the soil in a particular soil we will have a particular optimum moisture content and a particular dry density.

So, that is what and another thing is if I change the energy again in for the same soil, if you change the energy again optimum moisture content and dry density also will change. That is the thing is explained through these 2 diagrams, 2 figure here. You can see here. This figure is shown 0 air void lines are here and I have same soil with 20 blows applied and this is a gap operand. When I have increased the blows to 25, I have got another curve here. When I use 30 blows, I have got another curve here. When I use 50 blows, I have got another curve here. So, like that you can see with the increase of the number of

blows, increase of number of blows means we are increasing the energy level. When you are increasing the energy level, then with the increase of energy level you can see the compaction curve is shifting left side. Also it is dry density also increasing.

So, by observing this figure what we can conclude? With the increase of the energy level, your optimum moisture content is reducing. It was here. It is reducing. It is moving in this direction, optimum moisture content is reducing so; that means, if your energy level if we increase with lesser amount of water, we can achieve the higher density and another observation; that means, with the increase of energy, optimum moisture content is decreasing, whereas, with the increase of energy level and dry density was here and next dry density also the dry density is increasing.

So; that means, with the increase of the energy level your dry density will be increasing, but at a lesser moisture content. So, that is the observation and here actually another one I have tried to show that when different soil if you test with the same energy then you can see different curves you are getting. Different curves actually you can see one. When well graded coarse fine sand. 2 is the very fine silty sand and something. Then 3 is oxidized clay fill and 4 like that.

So, when you will have the finer the soil particles; that means, towards clay, then will have optimum moisture quantities higher and dry density is lower. We can see 7 is sandy silt 6 is river silt. This figure actually is not different soil is shown by this actually what we have explained that different soil has different characteristics.

By my conclusion or observation is when you go from coarse set to finer per soil. When soil is finer, then your optimum moisture content will be more and dry density will be less and. That is the thing. Clay soil will have this side and sandy soil will have this side. This is 2 observation we can make from this.

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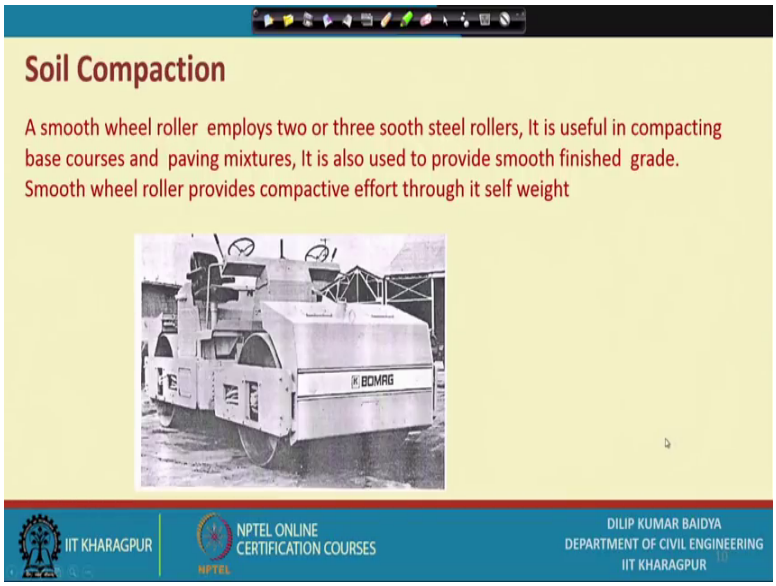

And now the soil compaction. I have several things I will discuss, but during for compaction, generally different types of compaction is used. There is a smooth wheel roller of compaction. The smooth wheel roller employs 2 or 3 smooth wheel rollers. It is useful to compacting base courses and paving mixtures.

It is also used to provide smooth finished grade and smooth wheel rollers provides compactive effort through it is self (Refer Time 27:29) That smooth wheel roller generally rollers are huge and made of steel and that weight itself will give you the compacting energy and where actually these are suitable. These are actually it is useful for compacting base course paving mixture and also provides smooth surface.

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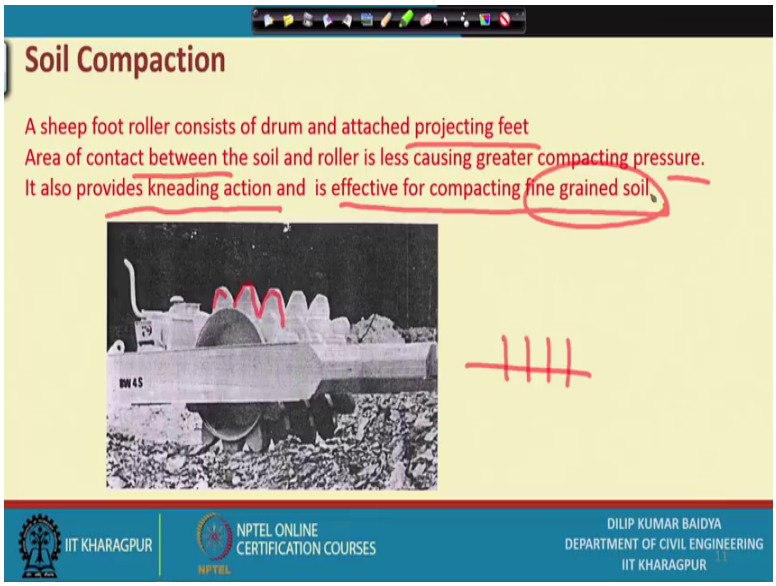

And the next one, this is another type of roller. That is actually smooth sheep foot roller. Sheep foot roller actually what it is? When the soil is fine grained, I have mentioned that you need more moisture and less dry density to improve the dry density sometime we have to give more energy actually. So, to give more energy what we can do? That roller actually there is a extended part.

There is a small hook like and when this roller will be moving through the soil, then it contact area will be small. When the contact area will be small, then there is a small pressure so; that means, more pressure means ultimately same weight will be acting on a small energy is more. So, that is one thing if it is a sheep foot roller; that means, the projected rollers. If it is there that is called sheep foot roller.

Through that we can apply more pressure, that mean contact area is reducing. Another thing is since this is like spotlight is there. It is having a kneading effect. When it is a fine gained soil, this is very much suitable. So, sheep foot roller consist of a drum and attached projecting feet area of contact between the soil and roller is less causing greater compacting pressure and it is also provide kneading action and is effective for compacting fine grained soil so; that means, if it is a clay soil, this type of roller is good.

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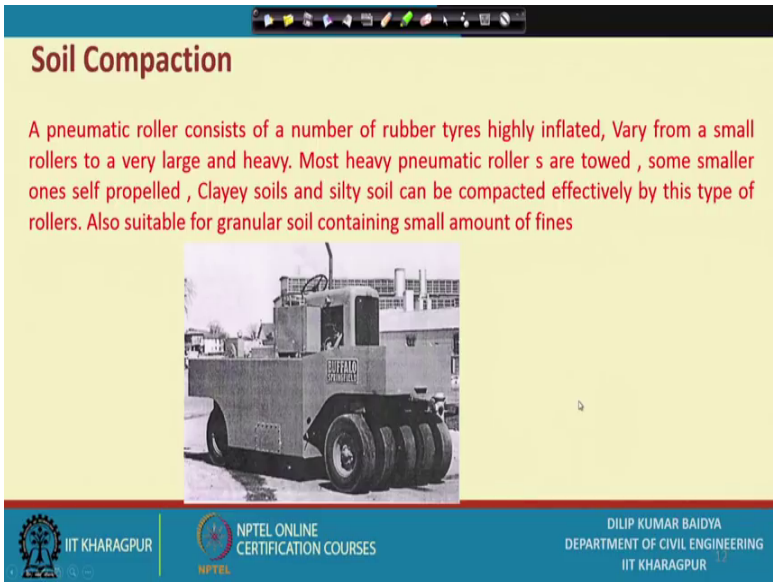

And this is a pneumatic rubber tire roller and the pneumatic roller consist of a number of roller rubber tires. Highly inflated very form a small rollers to a very large and most heavy pneumatic roller are towed and some smaller one is self propelled and clayey soil and silty soil can be compacted. So, what type of soil it is suitable? Actually it is clayey soil and silty soil can be compacted effectively and also suitable for granular soil. Containing small amount of fines and this is the time of roller actually these are. So, many types are there; large area it covers actually.

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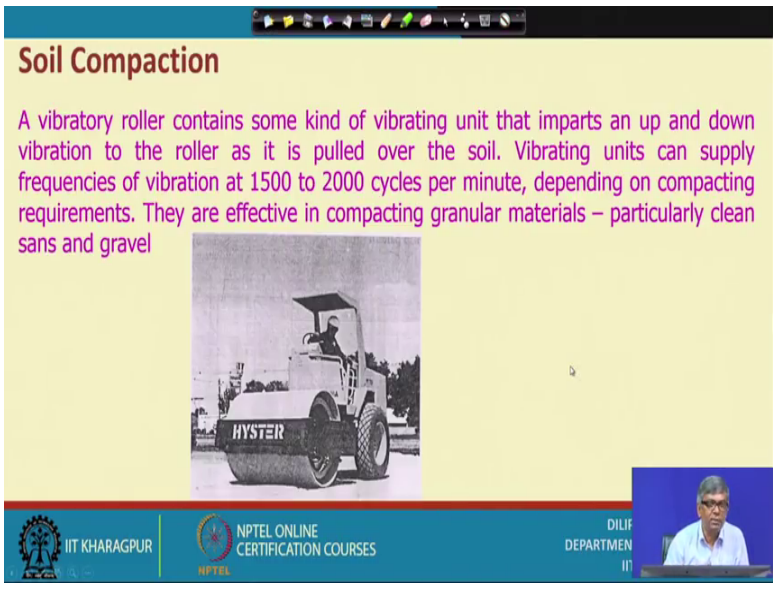

And then the soil compacted. There is another type of roller. As I have told that when is a granular soil by wet generally compaction is not that effective. So, because of that if you can provide some sort of vibration along with this weight pressure. Then it become effective. So, this type of roller where actually we can; there is a moving element while moving it also vibrates. That vibrates actually cause the particles the particle adjustment and also there is a pressure through this weight. So, these 2 together the soil get compacted nicely.

So, a vibratory roller contains some kinds of vibrating unit in that imparts an up and down vibration to the roller as it is pulled over the soil. Vibrating units can simply will supply frequencies to vibrate at this to this and depending on compaction requirements. They are effective in compacting granular material that I already mentioned and particularly clean sand and gravel. This type of roller are very good. This will have a vibration in this.

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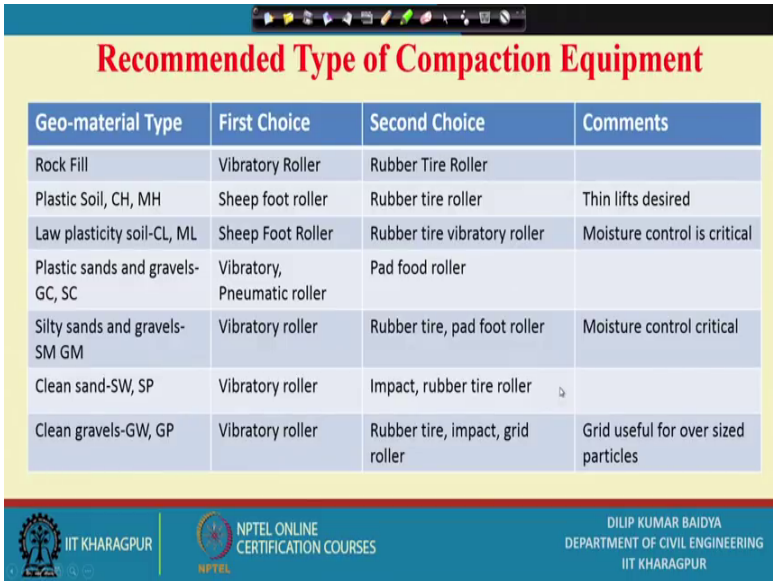

And then there is recommendation actually what type of roller will be or compaction equipment will be used for what type of soil. That some guidelines. If it is a rock fill, your roller type is vibratory or rubber tire. Second choice actually this and if it is a plastic soil, then sheep foot roller as I have mentioned my previous slide and rubber tire roller also can be used in the second choice and thin lifts if desired; that means, at a time one meter and then compacting it will not be effective. So, what we have to do when this

type of soil we have to put in layers at that 2 should be thin. Low plasticity soil CL, ML. Again sheep foot roller and rubber tire roller also can be used in second choice, but not the first choice. Moisture control is a critical and plastic sands and gravels. Then vibratory and pneumatic roller both can be used and pad food roller that is also another which we have not discussed yet.

That is also second choice and silty sands and gravels that is again vibratory roller. Second choice is rubber tire roller and moisture control is critical here. Clean sand that is SW SP again vibratory roller impact and rubber tire roller also can be used that we have not discussed yet. Clean gravels that is again vibratory roller. So, rubber tire roller impact grid roller. This is also I have some of them are not discussed grid useful for.

This is also I have not discussed. This comment I will not discuss much here so; that means, these are the different types of soil we may have while construction and then what is our choice? The first choice are these and some time second choice that with this type of equipment also can be used. If sometime not available other type of equipment.

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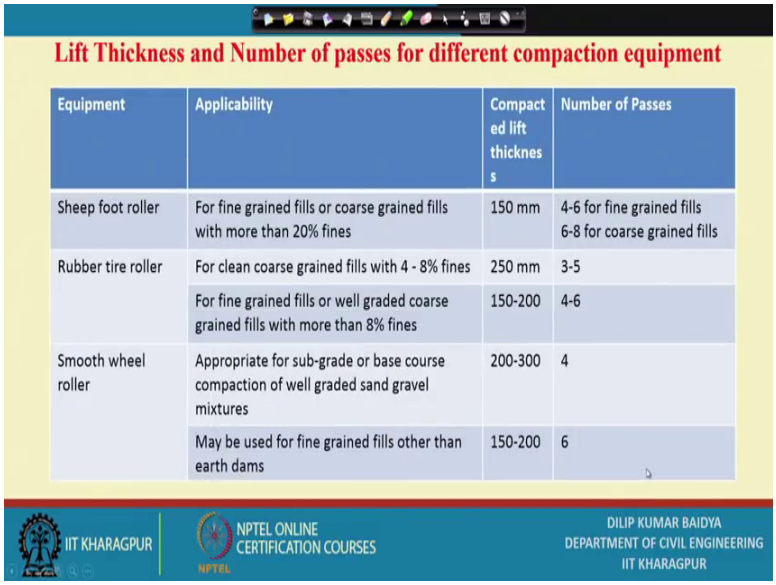

Then this is sheep foot roller. Generally of what do we have to do? Sheep foot roller when it is their applicability for fine grained fine fills coarse grained fills with more than 20 percent fine and compacted lift thickness is given here. That is 150 millimeter thickness and 4 to 6 for fine grained fills; that means number of passes 6 to 8 for coarse grained fills. If the rubber tire roller is there, then this type of soil. Then 250 thicknesses

if this type of soil; that means, fine grained fills or well graded coarse then 150 to 200 and here actually 3 to 5 passes.

Here is 4 to 6 passes and if it is smooth wheel roller, if this is the soil then you have to give 200 to 300 and pass actually 4 and if this is the soil fine grained fills other than earth dams, then thickness lies in each table 150, 200 and it has to given 6 passes has to be given for reasonable good compaction.

So, these are actually last 2 slides what I have shown how to choose the compaction equipment and once you choose the compaction equipment then what are the guideline; that means, how much thickness you have to put in this layer and how many passes you have to give. These 2 guidelines can be used for selecting during compaction. I think with this I will conclude today.

Thank you.