Ground Improvement

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Lecture No. 07

Shallow Densification (Contd.)

Hello, once again welcome you to this ground improvement lecture and this is module 2 and lecture 2. In the lecture 1 I have shown some of the basic principle of compactions and particularly shallow compaction and I will further some more aspect I will try to show here.

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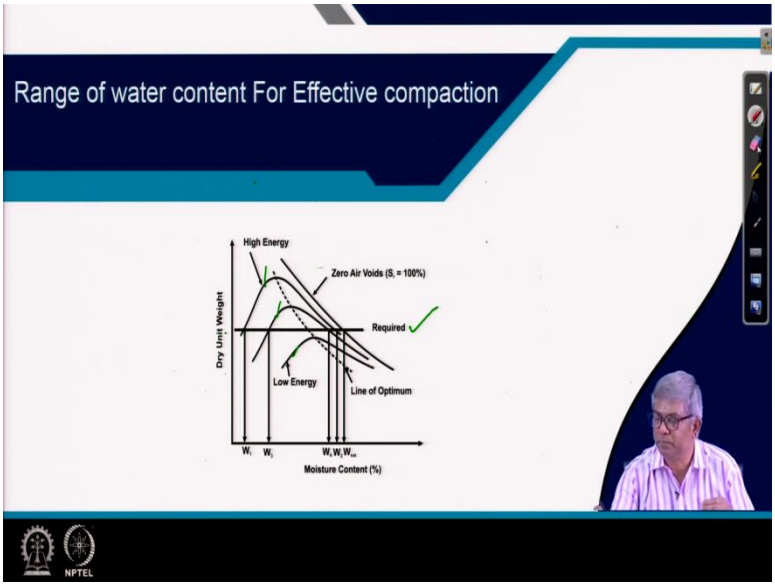

So, let me come to this slide, through this slide actually, as we have mentioned that there is a particular moisture content is very important for compaction particularly this by conventional shallow densification method and also, I have mentioned that, that if we use the same soil different energy level again the moisture requirement and maximum dry density achieved also will change.

So, here in this figure what as what is seen here you can see here there are 3 curves assumed to be on the same soil. This curve, this is again a compaction curve for high energy and this is another compaction curve with moderate energy and this is another compaction curve with low energy.

Now, these three curves and of course, zero air void lines here they are parallel to weight side of the each of the curve. When you want to do compaction in the field you cannot fix a

certain percent is generally, we apply a certain range. If we apply that range then the compaction will be by a large effective.

So, for example, there is a required MDD suppose required MDD is this line, this is the required MDD whatever the value maybe 20 or 18 or 16. So, I can draw a horizontal line and then you can see that it is intersecting the compaction curve. So, high energy compaction, the compaction curve which is done with high energy it is intersecting here and it is also intersecting here.

That means, this is the range W_1 to W_2 this is the moisture range if you use, then with particular the energy level you can achieve the required dry density. So, that means that is the range now fixed W_1 to W2. Similarly, you can see that same required dry density intersecting the second curve here suppose, this is W_3 and here it is W_4. That means, moderate level of energy when you are using and they are also to achieve a particular dry density we are getting another range of moisture content.

So, that means and you can see that range of moisture is now less. That means if you want to use higher energy level, then your range your moisture content will be wider than if you use a lower energy. From these figures it is quite obvious and you can see that another thing that another level of energy we are using and you can see it is not intersecting that MDD curve, MDD required line so that means by that energy, whatever may be the moisture, you apply you will not be able to achieve that mass dry density.

So, that is what in this figure, this is the conclusion that means, if we use higher energy level, then we may get a wide range of moisture content. And if we use lower energy level, then sometime you may not be able to achieve the targeted energy. This is the example of that, and when you will use moderate level of energy then you are getting moderate level of moisture range.

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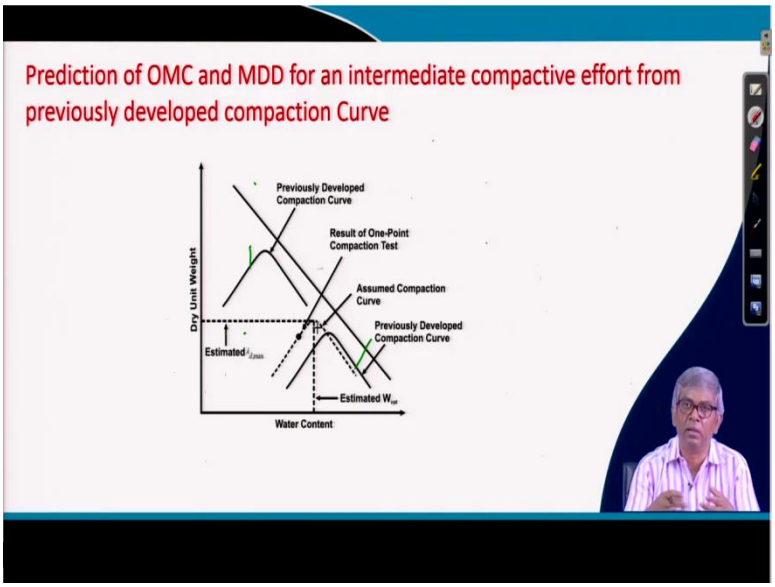

Now, sometime prediction of OMC MDD for an intermediate compactive effort from previously developed compaction capsules from the title I just read suppose, I have one compaction curve this, another compaction curve is these, but in the field and it has a definite amount of energy this is also definitely an ideal amount of energy and this has a zero air void lines and, in the field, I got some energy which is not same as either of these are these may be intermediate.

And by doing sometime by one compaction test, one can extrapolate what could be the MDD and OMC. So, how we can do it? Suppose a particular moisture we have done a compaction, the point is coming here and we know that that different energy level if we apply on the same soil, how the curve shifts that we have shown because his OMC is reduced and dry density increase.

So, that is the way and weight side is parallel and dry side is also parallel and it has a curved peak that all those things you know. So, keeping those points I can imagine a curve like this this dotted line is another curve based on one test I can draw and from this I can predict what would be the OMC. This is the OMC and this is the maximum that means, you stop using this energy or this energy for use this level of energy what could be the optimum moisture content or dry density required that can be obtained by doing this small extra exercise.

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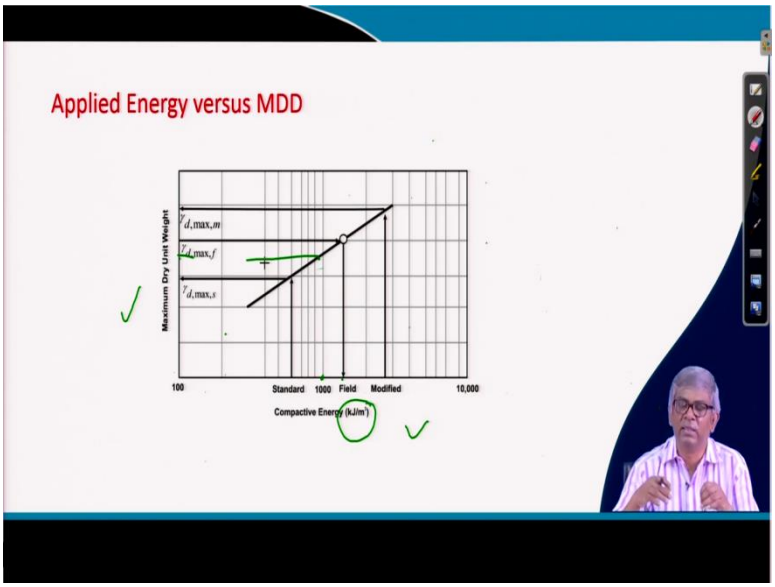

And here another thing is that I have shown that that when you increase the energy level that we apply more energy, then we get higher optimum higher maximum dry density. So, finally, if I do several tests several tests on the same soil on different energy level and finally, if you see that maximum dry density, it follows a particular pattern and that pattern is what actually?

If you plot on a semi log plot you can see here, this side is linear maximum dry density and this side is the energy which is in the log scale and energies expressed in kilojoule per meter cube in this axis and then you will see that this can be approximately linear relationship in this semi log plot.

So, if I know these, if it is established, then what additional information I can get? Suppose, I conduct a study, I have a data standard because I have a standard proctor I have a modified proctor I can carry out these two and I can plot and I can get the line, but if I want to use a some different energy in the field, what could be the maximum dry density expected that I can suppose here actually the field this one, so corresponding drag densities here, instead of here if it is a field is here, then corresponding it can be here like that I can obtain.

So, this is again another observation that when we apply or when we increase the degree our amount of energy, then we obtain always greater density. Now, how this, what is the relationship between these energy and dry density. So, different energy level on the same soil compacted and finally, that energy versus maximum dry density is plotted in a semi log plot and it is observed that they are approximately linear.

So, this if this observation is used then sometime by doing a standard compaction proctor test and modified proctor test and then in the field actually neither standard nor for modified if something in between then also I can find out what could be the maximum dry density can be achieved by this method. So, this is the summary of this figure.

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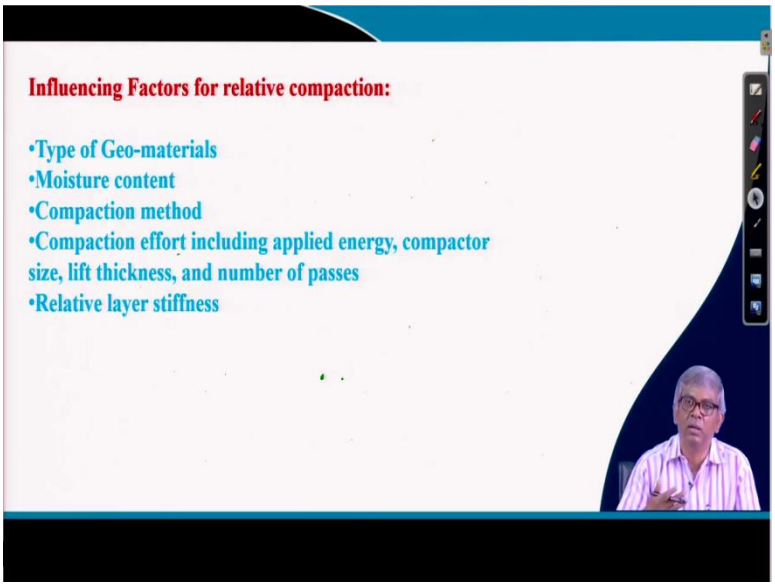

Now, the influence factor for relative compaction. Relative compaction means what? That means, I can level three standard proctor compaction is I get optimum right entity suppose 1.6 and, in the field, suppose the 5% less or 5 % more sometimes we can achieve. So, that is the relative compaction. So, it is the 95% or 100 %. So, that actually that is called relative compaction and this relative compaction depends on many things already I have mentioned that type of geo material is one of the most important because all soil cannot be compacted equally.

So, some soil requires more energy some soil require less energy. So, the geo-material or type of geo-material one of the most important factors influence the relative compaction and moisture content obviously, you are if you are close to the optimal moisture content, then you are going to get optimum our maximum dry density otherwise you may get a little away from that.

Then compaction method how you compact that is also depends and compaction effort including applied energy and that means compactor how we are using and then so, in this actually compacted compaction effort including applied energy, one is that how much energy you are applying then what is the order the compactor may use whether it is roller or the plate or something else, then what is the size, then what is the lip thickness and number of passes.

So, all those things actually influence the relative compaction and the relative layer steepness actually if it is a on a soft layer and if lay another soft layer and try to compare then that top layer will not be a compaction will not be that effective, if you have a very steep layer over that if you lay the sharp layer and then come back.

So, I could make I hope I could make the point that means if your support is a not strong enough, then after giving a layer and try to compact, then compaction will not be affected. If the support is very strong the steel and on that if you put the layer and then compact, then compaction will be more effective.

So, that is the one that means type of geo-material is very important then moisture content, compaction method and then compaction efforts including applied energy compactor size, lift thickness and number of passes and then relative layer steepness that means bottom layer is already weak, then layer over that if you want to compact it will not be that efficient. It will be so first of all you have to make the base strong, then if you want to compact the upper layer then it will be effective.

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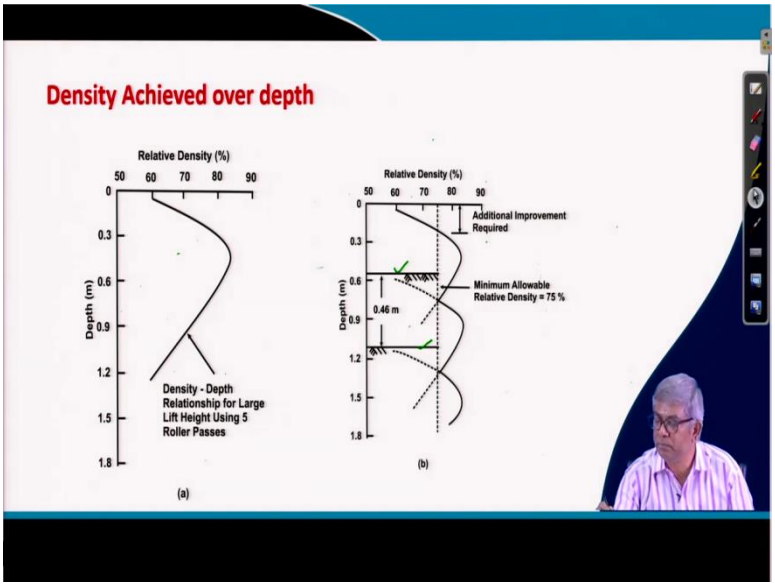

You can see here that when you compact by roller or by any means, on the surface, how density varies over depth. You can see here that it will not be densified at the surface. Maximum density will never be on the surface. You can see close to the surface density will be comparatively less and little deeper it will be maximum. And again, if you go further deeper the it will be density will be reduced.

So, that means, there is a some somewhere in the in between in the footing also you will see that when you apply pressure through the footing that vertical pressure actually a lot be close to the surface maximum will be at some depth. So, your similar effect almost here happens that at some depth only it will have maximum compaction or maximum relative density happen.

This concept can be but when we will come back with a different lip thickness, let us suppose this is the first lift, then this is the second lift and like that if we go on then how this helps to compare or improve the overall compaction. You can see here then when you are in this lift, then overall compaction pattern is this, when you are going to this live then overall compaction pattern is this.

So, there will be some overlapping and you have to make overlapping in such a way that minimum level of relative density should be achieved otherwise, if you give too much of lip thickness, then it will have average relative density is less than the required. So, accordingly you have to design how it would be the lip thickness. So, you can see here minimum allowable relative density equal to 75%. So, this is the line suppose, then accordingly you have to design lift thickness in such a way that they pass through the intersect along this line.

And after doing this several lift a you compact and you can see here at this close to the surface already whatever seen here similar to here also will be after that close to the surface will have lesser density. So, you have to put some additional effort to densify further this top surface. So, this is the way overall all compaction to be achieved.

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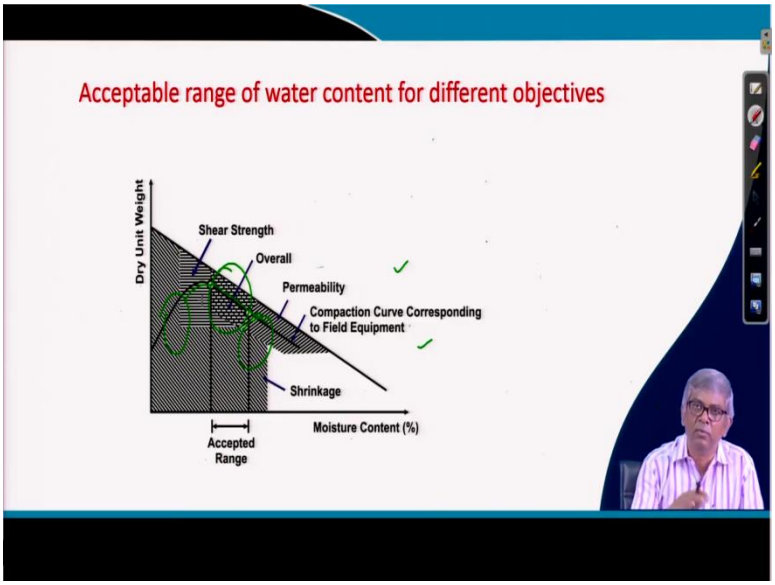

And here actually you can see that the total compaction curve and this is supposing a total compaction curve this one is that total compaction curve and then in these actually you cannot in the field particularly cannot compact at the optimum moisture content. If the if you can compact optimum moisture content then you will get maximum density obviously, but you cannot do that.

But we can there is an allowable range that how much less or how much more moisture content you can use. So, there is a limit whether we will be using this is the optimum moisture content if I consider then this side is called W_8 side of moisture content, optimum moisture content and this side is called dry side of optimum moisture and this side is called wet side all of your moisture content.

So, in some work, it is preferable or it is desirable to compact dry side in some application it is desirable to compact in the wet side of the compaction curve. So, here actually they are shown these are all different. So, when you required high shear strain, then you should compact in the dry side and if we want that permeability control, then always you should compact in the wet side of the compaction and then.

So, in this again dry side and wet side with the different requirement is there also here there is a range is given, these range if you keep the moisture content and they are actually acceptable in the most of the work. So, this is the way actually if you can grow the compaction curve and finally, depending upon your requirement, where and what level of moisture content you should use to achieve your target that can be determined.

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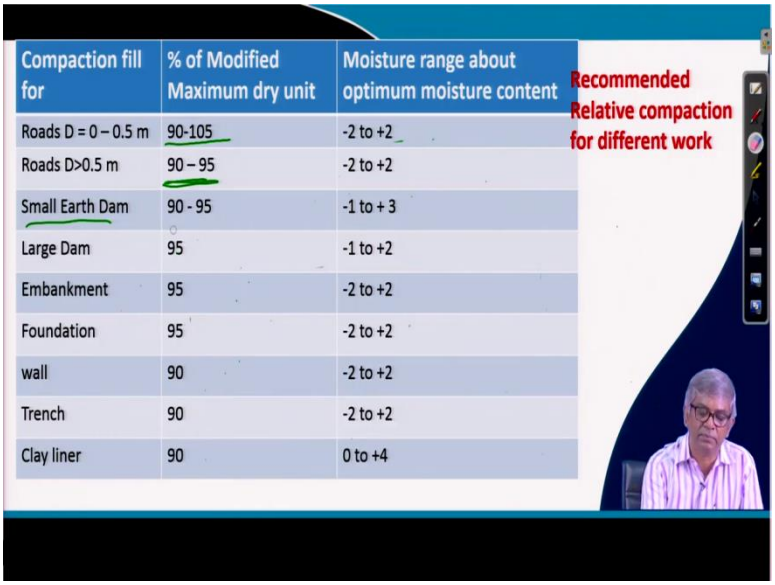

Compaction fill for	% of Modified Maximum dry unit	Moisture range about optimum moisture content
Roads D = 0 – 0.5 m	90-105	-2 to +2
Roads D>0.5 m	90 – 95	-2 to +2
Small Earth Dam	90 - 95	-1 to + 3
Large Dam	95	-1 to +2
Embankment	95	-2 to +2
Foundation	95	-2 to +2
wall	90	-2 to +2
Trench	90	-2 to +2
Clay liner	90	0 to +4

Now we can see here the recommended relative compaction for different work. Relative compaction means what actually here? As I have already mentioned that you get leveled at some 16 it can be more than 16 or less than 16. So, different work so, what is the range actually?

It is shown here actually you can see suppose the road work and thickness is o to 0.5 meter, then percentage modified maximum dry unit weight, it can be 90 to 105. It can be 90 percent to 105. That is the range actually, the recommended range you can have and moisture range +_ 2 %. So, it can be +2 % of optimum or -2% of optimum.

Similarly, if it is road less than 0.5 then you can see that the range of dry density should be a relative compaction will be 90 to 95 % and moisture actually again +_2 %. Then small earth dams again 90 to 95% and moisture is actually -1 to 3%. So, it is not same. So, all I have told that dam actually you need to do weight side.

So, that is the one is here, large them actually 95 % -1 to +2% like that for different work the range of relative compaction and range of, permissible range of moisture content is mentioned here so, this to be followed when a particular job to be executed.

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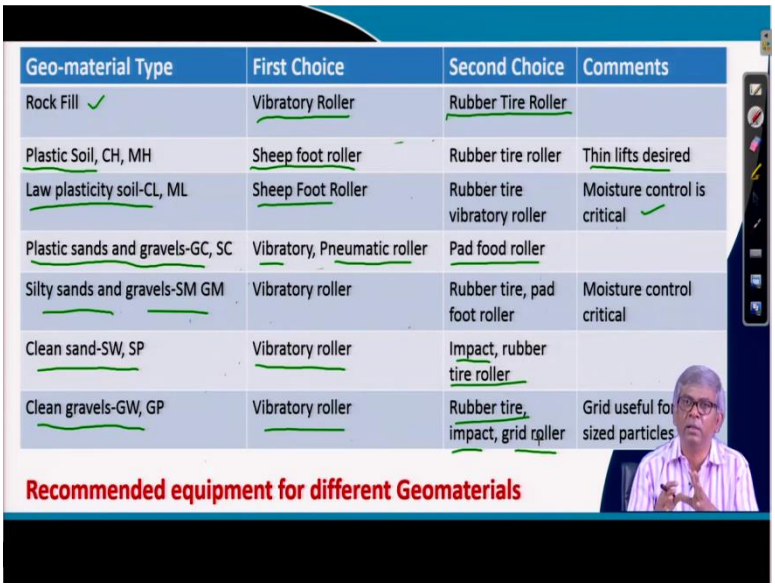

Similarly, as I have told you that different compaction equipments are available and all the requirement equipments are not suitable for all type of soil. Here actually there is a choice of equipment depending upon your soil type. You can see here that when the soil is rock field, then what type of equipment to be used, vibratory roller and this is the first choice. Suppose, if you do not have hybrid roller then sometimes, we can use rubber tire also.

So, that means if it is a rock field where the in a particular side you have to do rock field, then if you want to contact, how will you, what equipment to be used either vibratory roller or rubber tire roller. Similarly, if it is a plastic soil, plastics soil has clear of high plasticity or sealed of high plasticity if this type of soil is there, then sheep foot rollers actually to be used, why sheep foot rollers is to be used?

Sheep foot roller actually will have some protruded parts and when that that roller when it moves it will be resting on some points and because of that it will give a new kneading effect when the soft soil compaction is by roller will not help so, kneading effect is required one thing and second thing when it will be resting on a few points it is applying more pressure.

So, when it is a plastic show it will require more energy actually more pressure. Because of that when is a plastic sheep foot roller is the first choice of course if it is not available, then you have to use rubber tire roller and when he used plastic soil, lift thickness should be thin. That is another important point to remember.

Then low plastics oil again, since it is a plastic soil again sheep foot roller and if it is not available rubber tire roller and moisture control is important here. The plastic sand and gravel

then actually sand and gravel will be best compacted by vibration actually. So, it will be roller but in addition to this roller, they will be vibrating unit. So, vibratory roller or pneumatic roller, if it is not valid then pad foot roller also can be used.

And if it is silty sands and gravels, then this type of soil again closely best choice is the vibratory roller and if it is not available, then rubber tire roller or foot ruler can be used and here moisture control again is very important. If soil is clean sand, like well graded sand or poorly graded sand. The vibratory roller is the best suitable for the compaction. Of course, if it is not available then impact or rubber tire roller can be used.

Similarly clean gravel that means well graded gravel or poorly graded gravel, then again is the best choice is a vibratory roller if it is not available then rubber tire roller and impact or grid roller can be used. So, this is actually depending upon the type of material you have to select the equipment and the equipment sometimes there can be a number of options, the best option second best option like that it is given and accordingly it should be chosen.

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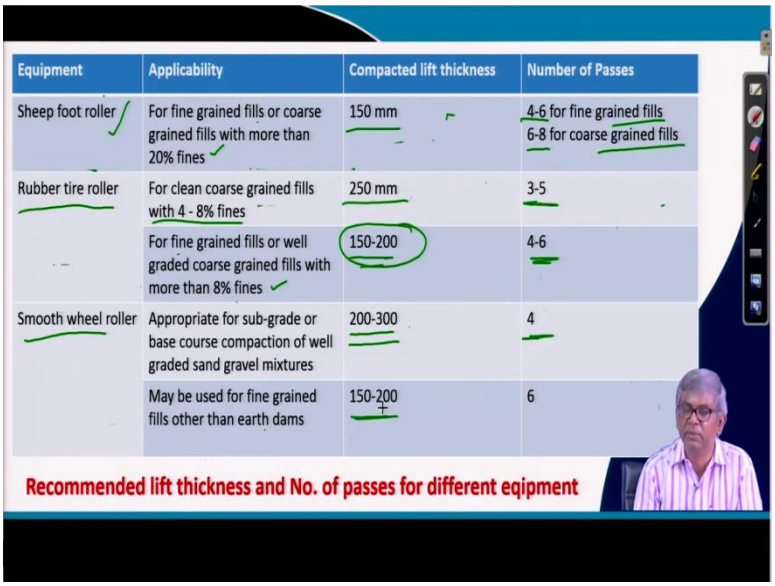

You can see here again, here actually if you again use different types of equipment and what should be the equipment and then where we generally apply and then what should be the lip thickness and how many passes there is some guidelines is given here you can see here if sheep foot roller is used and sheep foot roller already you have mentioned that fine grain fills or coarse-grained fills with more than 20 % fine.

Fine means actually fine particles when silt and clay if it is there, then sheep foot roller will be best and when you see for roller what should be the lift thickness, 150millimeters, only 6

inches not more than that and number of passes say is a 4 to 6 passes for fine grain fields and 6 to 8 for coarse grain fills.

So, these are the requirement when they sheep foot rollers is used and in rubber tire roller is used, then actually again for clean coarse-grained fills with 4 to 8 person fines, then you can use 250millimeter of lift thickness, here instead of 6 inches nowadays 10 inches and here actually 3 to 5passes will be enough. And if for fine grain fills are well graded coarse-grained fills with more than 8 percent fines, then again you can use the rubber tire roller with 150 to 200 lift thickness and 4 to 6passes.

And smooth wheel roller that means your steel wheel rollers appropriate toward subgrade or base coarse compaction of well graded and gravel mixtures and if this is the type of soil, then you can use 200 to 300lift thickness and number of passes will be 4. Number of passes means what? 4 times you have to roll over the particular lift. Similarly, it may be used for fine grain fills other than earth dams. And there actually you can this same smooth wheel roller can be used and if you use that, then 150 to 300 lift thickness and the number of passes will be 6.

So, these are some guidelines actually when you in the when you will be executing in the field you need to follow little 5-10% sometimes variation is possible but if you go beyond that, then your compaction will not be effective. So, you have to select that type of equipment properly and you have to select that lift thickness, you have to select number of passes depending on required requirement depending upon your requirement.

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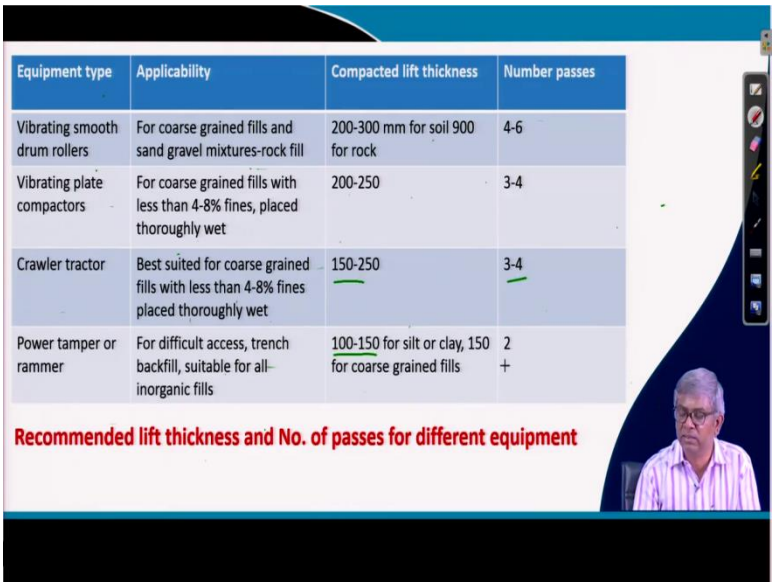

Then here still once again, some more equipment types are mentioned here. You can see here that vibratory smooth wheel drum rollers and what are the type of soil for coarse grain fills and sand gravel mixture rock field. They are actually 200 to 300millimeter for a soil and 900 for rock. So, this lift thickness will be 200 to 300 for soil and 900 for rock and 4 to 6 passes and vibratory plate compaction for coarse grain fills with less than 4 to 8 percent fines placed thoroughly wet and then it has to be lift thickness with 200 to 250 and 3 to 4 passes.

And crawler tractor power temper or rammer. So, all different again type of equipments are there based on that. Here actually 150 to 200, here also 150 to 200, here to 3 to 4 passes, you have two passes. So, these are all different guidelines based on your equipment and type of soil. So, this has to be followed if you do not follow, then your compaction or densification will not be effective.

This module I will be closing and again some more things will be there that means when you compact, then there is some quality control that means, I decided that I required this mass density and because this is the soil type and based on that I have decided this is the equipment, this is a lift thickness, the number of passes, all those things are happening in the field, but still whether really, I am able to achieve that or not, that has to be monitored.

That monitoring actually that means, a filed finally, what is achieved that has to be checked. So, that checking the process is quality assurance and quality checking, so that some aspects will be there. So, we will discuss that and then certain problem solver related to some compaction related issues. We will discuss in the subsequent lectures in the module 2. Thank you.