Soil Mechanics/Geotechnical Engineering I
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Lecture – 15
Compaction of Soils (Contd.)

Good morning. Once again, I welcome you all in this lecture Soil Mechanics lecture and we are now, in still we are in 3rd week. And topic, I have just started Compaction of Soil and some of the aspects already I have discussed on compaction.

And there, I have tried to show that every soil will have a particular compaction characteristics curves, curve and that curve generally variation with moisture content dry density. And we have seen that for every soil there is a, and for a particular energy level; there is a particular maximum dry density and for particular moisture content.

And also we have shown some of the things with energy, if we increase then, your dry density increases with, but at a lesser effort; that means, with less amount of energy, water, moisture. Like that for different soil also we have seen different moisture density relationship; when the soil is finer then more moisture required, but we achieve less dry density. So, these are the things we have discussed and one thing, I just to remind you that this moisture density characteristics are applicable, when the soil contain some amount of plasticity. That means, when there is silt clay are present; then this is valid.

But when it is a completely cohesion less soil; then, this moisture density relationship what we see or what we have shown, it is not applicable. In fact, hardly there is a variation with moisture content in soil; granular soil. In fact, for a very small amount of moisture, water at initial stage, it will have some change and particularly at completely dry. It will have very high density or dry density; high dry density. And with the increase of moisture content 1 or 2 percent; because of this bulking effect.

Then, will be slightly reduction in dry density and again, when you further increase the water; suppose, to that that bulking is maximum at 4 percent and 3 to 4 percent and further increase of the water the bulking effect will vanish. And then again, at a complete saturation the (Refer Time: 03:08) will reach to it's maximum density. Again, if you add

water more than the saturation condition; then, that will be again a little decrease also. So, if you typically see the curve generally, it is generally, if it is having like this.

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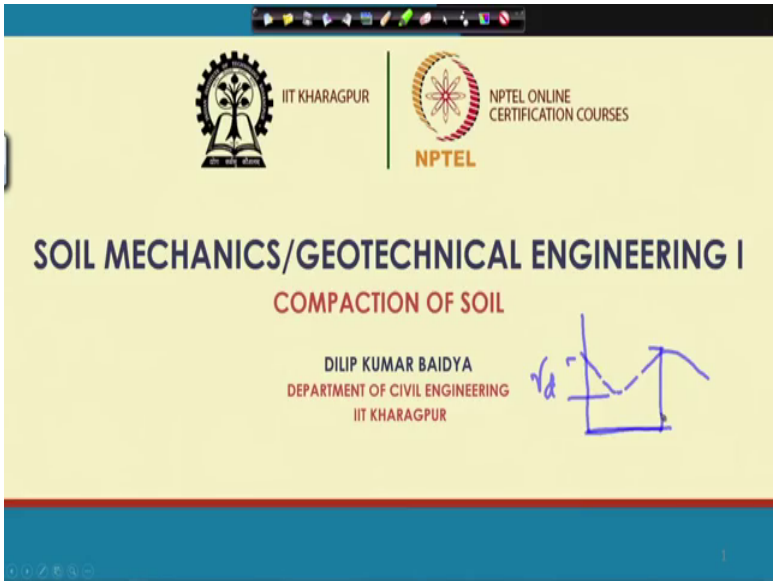

It is gamma d. So, for sand, it comes like this and like this. So, this variation is again not very large and this water content also is not a very large range. This is within a small range only, it change only you want 4 percent. Those effect goes and then, we will get at saturation we will get the maximum density. So, this is whatever, the moisture density characteristics we have shown, for a soil that is applicable when soil contain some amount of plasticity that will be silt and clay.

Now, I, we have we will discuss further.

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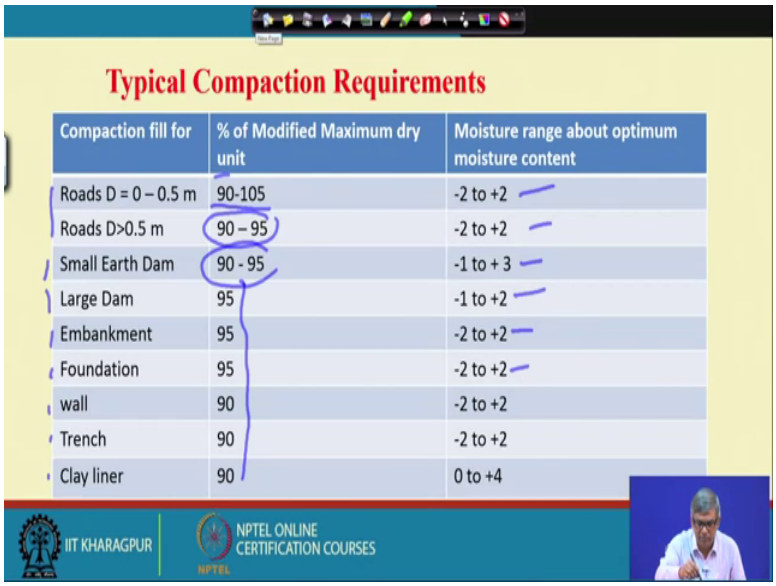

We have seen that there is a definite amount of moisture required for to, for achieving maximum dry density. But there is some situation that there are various application and particularly in the field, whatever you have achieved in the lab, exactly you will not be able to achieve.

So, in that case, what are the ranges which we can do for to achieve satisfactory result. So, for this actually we have shown this table. You can see here, actually as it is shown different types of work like Road with 0 to 5 meter, Road with greater than 5 meter, Small Earth Dam, Large Dam, Embankment, Foundation, Wall, Trench, Clay Liner; different types of works where, we do this, this type of compaction which I have discussed that this shallow compaction or densification by Roller and all other equipment.

And in that actually percent of modified maximum dry density that will be 90 to 105. That means, how much whatever dry density we get, how much we should at least achieve. So, we can achieve 90 to 105. So, that means, less or more also. And, in Road if it is 90 to 95; Small Earth Dam 90 to 95. Most of the cases actually approximately 95 percent is the most common work; where, actually whatever we get in the laboratory, we should at least able to achieve 95 percent of that most of that.

This is the specification generally we will give, in terms of proctor compaction that you have to compact with a proctor density, 95 percent of proctor density 98 percent of proctor density like that.

And similarly, similar to that maximum dry density; there is also moisture content variations because you may get in the laboratory 15.2 more percent water content maximum dry density, but in the field, you will not be able to achieve that exactly; in that case we have to put some range. So that, range maximum permissible land range for different work.

It is given for this Small Earth Dam, it can be minus 1 to plus 3 percent; that minus 1 means less than optimum 1 percent and plus means more than 3 percent optimum. Similarly for large Dam minus 1 to 2 for Embankment minus 2 to 2 and it is foundation minus 2 to 2, again like that all variation. So, these are the things guidelines actually, when you do, when you practice this compaction activities in the field; these are the things one has to keep in mind.

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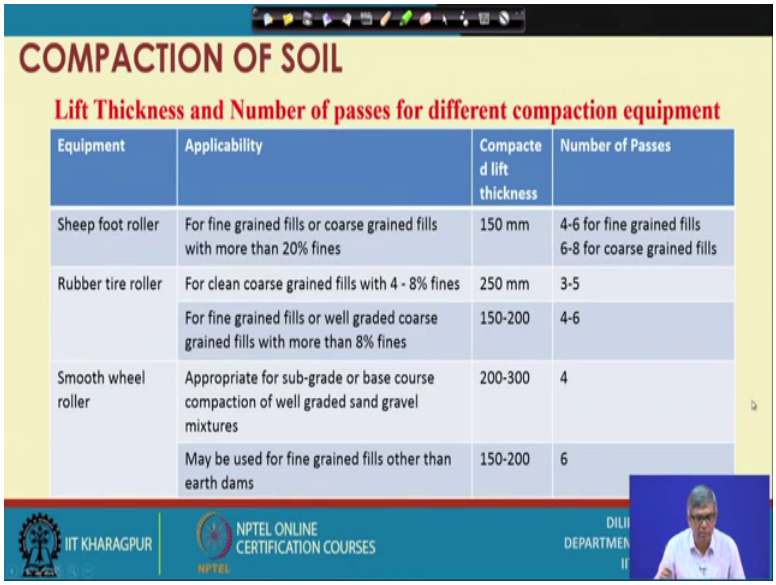

Next, this actually partly I have told, perhaps in the my previous lecture that different equipment, compaction equipment we may have, but how to select that and if you select that, what will be the lift thickness and what will be the number of passes? This is for different rollers actually it is shown here, you can see that if it is a Sheep foot roller; then, what type of soil you can apply for fine grained fills or coarse grained fills with

more than 20 percent fine; that means when silty when fine soil is present; then, only we go for Sheep foot roller.

So, that is the requirement shown here and when you compare this type of soil, you have to use lift thickness of 150 millimetre; that means, 6 inches approximately and how many passes depends on how many, how much dry density you want to achieve sometime 4 to 6 passes or fine grained fills and 6 to 8 percent for coarse grained fills.

Similarly, Rubber tire roller, this is clean coarse grained fills actually with 4 to 5 percent fine; then, we have to we can use 250 millimetre of lift thickness that is around 10 inches and it will have to given 3 to 5 passes. Similarly, if it is Rubber tire roller when used for fine grained fills or well graded coarse grained fills; then, with 8 percent fine, then we can vary the lift thickness between 150 to 200 millimetres and passes 4 to 6 passes.

Similarly, Smooth wheel rollers approximate appropriates for sub grade and base coarse compaction of well graded sand gravel mixtures and this is in fact, we can go for lift thickness of 200 to 300. And how many passes we have to give? We have to give 4 passes.

Like that it is go on next.

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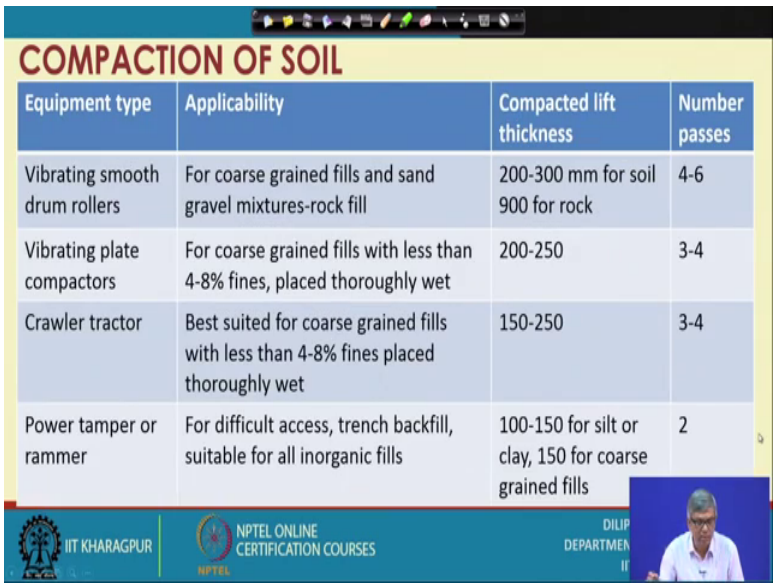

There are some of Roller type that is Vibrating smooth wheel roller as I have mentioned that is used for coarse grained soil for coarse grained fills and sand gravel mixture.

Generally, this vibrating roller is required why it is? Because of vibration then, particular arrangement is possible otherwise that granular soil by just impact given pressure then particulars cannot be brought closer.

So, in that type of soil, the lift thickness can be used 200 to 300 millimetre for soil and 900 millimetre for rock. And how many passes required? 4 to 6. And Vibrating plate compactors for coarse grained fills with less than 4 to 8 percent fines and lift thickness will be 200 to 250 and number of passes 3 to 4. Then, Crawler tractor power tamper or rammer like that there are some more applications are there; they have lift thickness 150 to 250; 3 to 4 passes. Here 100 to 150 for silt or clay 2 passes and again, 150 for coarse grained fills that is there are also 2 passes.

So, these are actually some guidelines, when you will be in practicing this compaction work; then, you need to select appropriate uh equipment based on soil type and not only soil type that soil has to be tested in the laboratory and then, you have to find out up to a moisture content, dry density. Then you have to decide what dry density and moisture content to be used in the field? And then, we have to monitor and then, based on that we have to select equipment and then, after selecting in addition to the selection of equipment, you have to also give requirement how many passes because contractors ultimately will be doing this job and they should know what they have to do.

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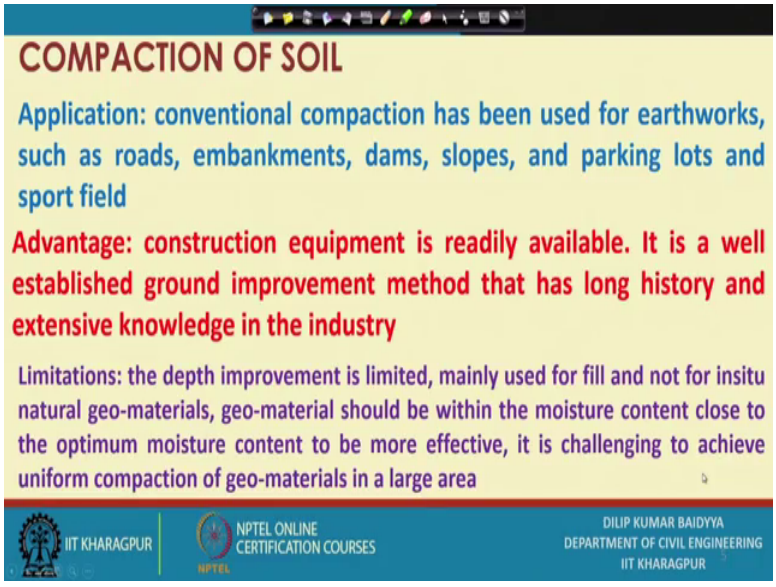

And this is compaction, conventional compaction actually is used for earthworks, the road, embankments, dams, slopes, parking lots and sports field. These are the areas actually commonly that type of compaction equipment; I have mentioned they are used for this type of work mostly. And it has some advantages and it has some disadvantages. What are the advantages?

Advantages at construction equipment is readily available; that means, this type of roller and whatever I have mentioned, they are very easily available and it is well established; since, long people are using for compacting the soil this type of method and extensive knowledge in the industry. The people are having knowledge also; what we use? How to use and which will be effective, which is not effective? All those things actually contractors know well.

So, that is the advantage and there are some limitations also. If I do this type of compaction, compaction equipment; the roller and all you get actually very thin compaction that is the depth is not much. It does effective will not go much because that impact, we are doing a particular lift thickness and mainly used for fill and not for insitu natural geo-materials.

So, insitu, suppose, kilometres up kilometre land suppose, you have to improve. Then, by using roller may not be a practical work; then, geo-material should be within the moisture content. These are the limitation actually you want to compact that whatever borehole material you will be getting that material should be close to optimum moisture content also; otherwise you have to add water. So, these are all you can say disadvantages and it is challenging to achieve uniform compaction by this.

Obviously, roller sometime they will make back and front motion and then, sometime not be able to go partly, sometime will go fully. So, like that, that maybe not very uniform compaction over the entire area which is designed actually. So, these are the few limitations.

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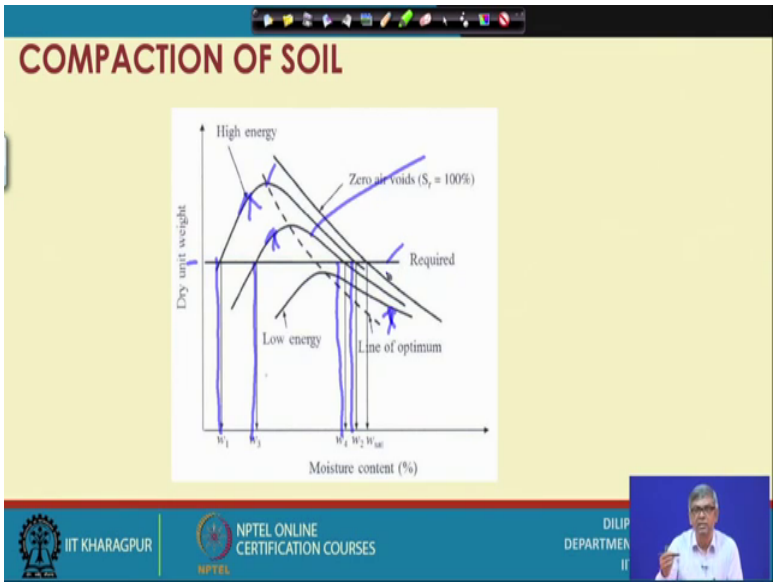

And then, another thing is as I have mentioned that when we change the level of energy then, automatically what happens? Your compaction curve shifting lift left and with higher dry density like you have 1 compaction curve for a particular soil, with this much energy the another is second level of energy; there is another third level of energy.

So, everywhere actually we are shifting left and with higher dry density and suppose, in my requirement, my requirement is some gamma d which is actually this one and I have drawn a line from here to here and with 3 compaction curve, with 3 different energy level is drawn here. And then, my required dry density I made a horizontal line and you can see that the lowest energy level, the compactions curve is actually below that requirement; that means, we cannot choose that, that energy.

So, and other case actually there is energy level 2 and 3; there actually intersecting in my requirement, required dry density. So that means, we can choose either this and this and if you choose this one, energy level 2; then, your moisture range actually narrow from here to here. And that means, if you vary the moisture between this and compact then, I will be achieving will be able to achieve with this much of energy in your required dry density.

Similarly, if you use this energy level; then, you have a wide range of moisture content from here to here. And that means, between this to this, this much water, any amount if you add and compact. So, you will get the dry density greater than your or greater than or

equal to your required dry density. So, these are the things sometime you have to do some trial with different energy level, you have to draw compaction curve. Then, you have to see your requirement. And then finally, you have to decide, how much we can vary in the water and how much dry density we can vary in the field those things to be decided.

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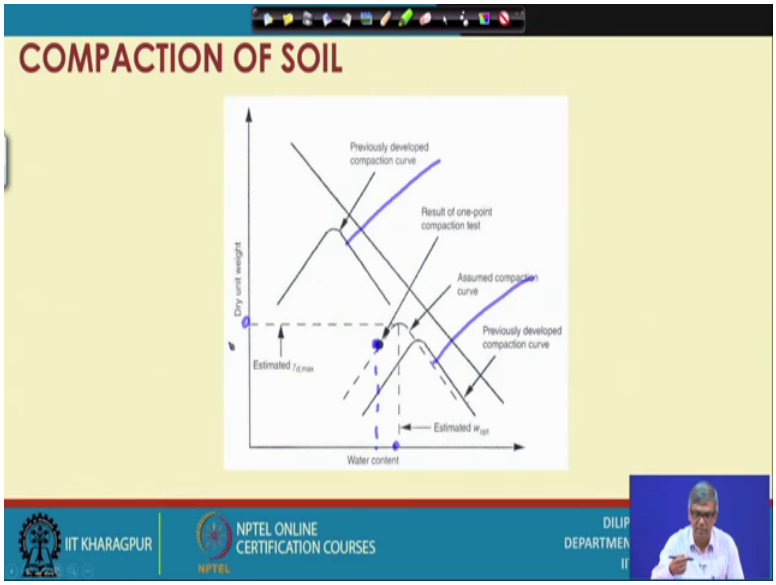

Similarly here, sometime we have some compaction curve of different energy level and suppose by 1 point method also sometime we can find out, what will be the optimum moisture contents. If I use I have suppose a curve with 1 energy level, I have another energy curve with another energy level; but I neither use this energy neither nor use this energy.

Then, I have to use some other energy and by that energy if you can draw or you can conduct 1 test and find out the point and that can be imaginary compaction curve taking with respect to this can be drawn and from there, we can actually find out the optimum moisture content. How? Suppose the imaginary at the 1 point where dry density and moisture content, if you plot in this; it come suppose here and then since the trend of curve like this.

So, if the energy level is between this and close to this then, I can draw a curve approximate curve passing through this point and you can see, you know that it shift parallel the left side. So, we have done so and after completing this curve, I can now a

tangent I can draw here and I can draw here also. So this will be the desired water content; this will be the desired dry density. So, that way also can be obtained sometime in the field.

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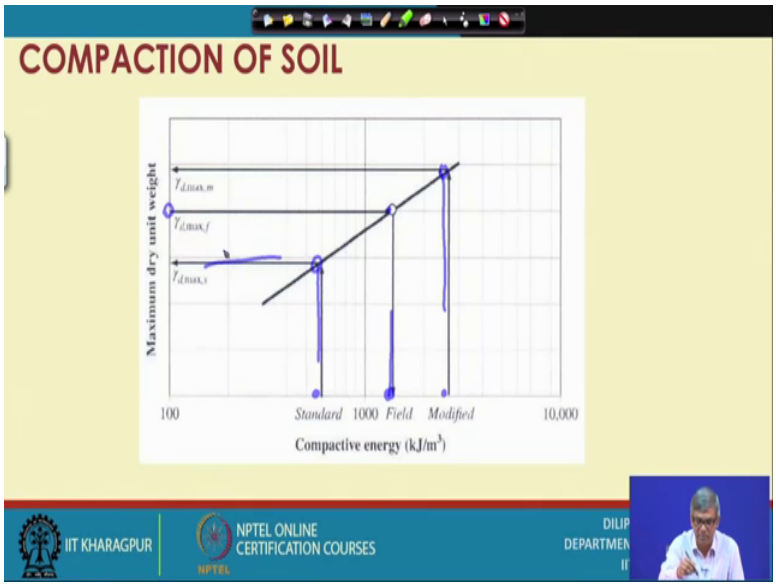

This is also another technique sometime can be used. So, different energy level we have, we have conducted the test and corresponding dry density, we have got. Suppose this is 1 point with energy 1 and this is another point, energy 2. So, these 2 points are actually plot and this is the lower curve. It is observed that it is a straight line and then, in this curve we have and if you want to use some other energy and corresponding dry density and energy suppose, if it is plotted like this; this matches this and this by this.

And now, suppose I leave some other energy, some are here; then, I will produce on this and then from here I can get the, what is the dry density I can achieve with this much variation of energy. So, that also can be sometime can be obtained in the based on if you have already some data and because these are all standard energy; suppose and if you want some other non standard energy then, by all sometime some definite energy for that corresponding to that energy, what will be the dry density can be achieved; that can be obtained by this.

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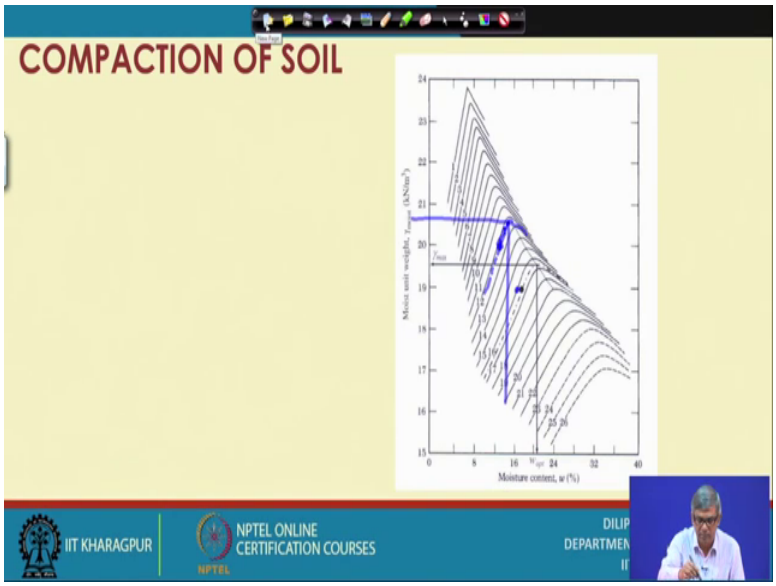

This is another of course, we are going to have different energy level curve here and from there actually again, we can put our uh obtained 1 point from here, from here; obviously, we can they are all very close lines. So, automatically the curve will fall somewhere here. So, from here also one can find out optimum (Refer time: 18:46)

So, if you have the moisture curve for same soil for different energy, if you have this plot then, if you do one test with different energy that can be come that can come somewhere here; here also slightly here below. So, then I can draw a curve like this and then from there I can find out optimum moisture content and dry density.

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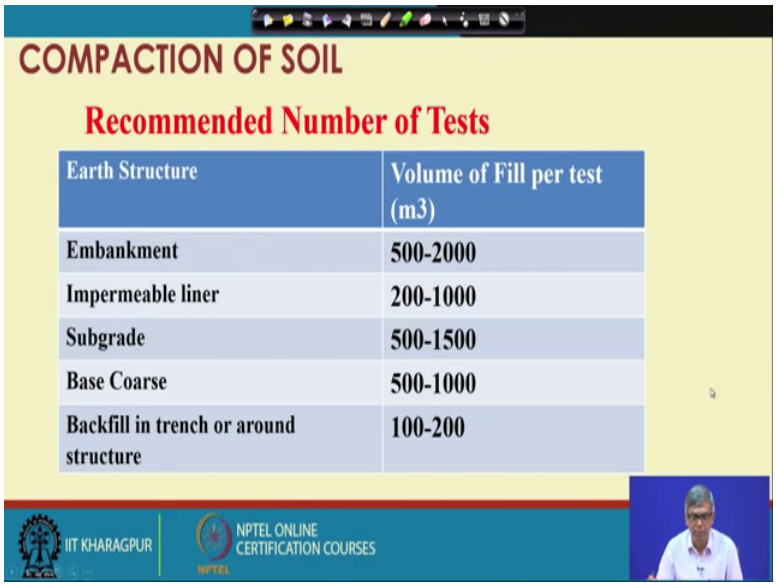

And then, recommended Number of Tests. That means, if you how many tests you have to do? This is the thing actually that is Embankment work, if it is Embankment work; then, 500 to 2000 meter cube of work 1 test at least has to be drawn. If it is Impermeable liner, so, 200 to 1000 meter cube work, you have to do 1 test at least that is Control test. Then if it is Subgrade work this the one, 500 to; if it is base course 500 to 1000 and if it is the Backfill in trench; then, 100 to 200. That means, this much volume of work we have to test otherwise this is the by which actually you can do the quality control.

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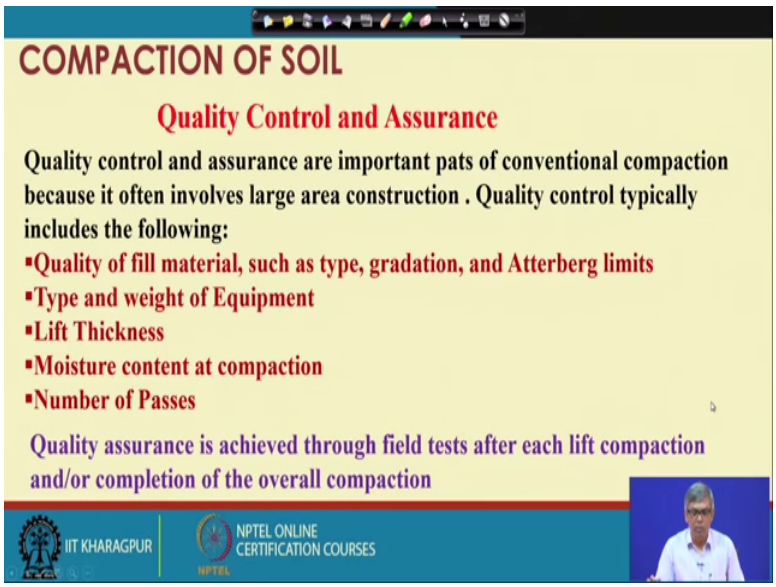

And this Quality Control and Assurance, that is very important because compaction work mostly done this way like this this is first of all you have to select if there is suppose, road will be constructed; then, first road alignment will be fixed and then dimension will be fixed and then, nearby there will be more of will be fixed.

There are several location maybe available and based on that you have to collect the soil from different sides and then, test and then considering several aspect transport cost, material cost; then, moisture content, optimum dry density to be obtained, based on all those things, we have to select 1 or 2 and after selecting that so, it will be excavated, transported by truck and put it in the construction site. And then, it will be spread in desired lift thickness and then, it will be roller; foot roller and if there is a moisture requirement, there will water will sprinkle over it.

This is the way work done, but this work actually when the large amount of work to be conducted, completed and then, several workers will be working there and sometime quality; that means, whereas, desired sometime may not be maintained. So, that for that actually grossly you have to check time to time, what is the compaction achieved? And then only you have to certify that it is done and go to the next.

So, like that for Quality Control, this type of work is very important and for this Quality Control work, important for conventional compaction it is often involves large area construction, Quality Control typically include the following Quality of fill material; whether are light material is chosen, then type gradation and Atterberg limits. So, because you are using some sheep foot roller, but there is no plastic; it is a sand or it is sand and only smooth wheel roller is used.

Then, will normally correct. So, all those things to be checked; then, type and weight of equipment that we have to see. Then, Lift Thickness that has to be seen because it is recommended that every 250 millimetre of Lift Thickness to be used, but if it shown that 400 - 600 lift thicknesses; then, compaction will not be enough.

Then, Moisture content and at compaction. Again, moisture content is very important to achieve the optimum dry density, if the moisture content less than that or more than that you will not get only within the range only you will get. So, that has to be seen whether when, what are required to be spread, the sprinkled whether they are doing on not? That we seen a number of passes that is also very important.

If the (Refer Time: 22:52) 4 passes, but if it is doing more or less both are not correct, sometime. So, quality assurance is achieved through field test after each lift compaction and all completion of the overall compaction. So, every lifts; so, long distance 200 millimetre suppose thick layer will be compacted; after completion of that stage one can do a fill compaction test sorry density test and then finally, ensure that required dry density is achieved.

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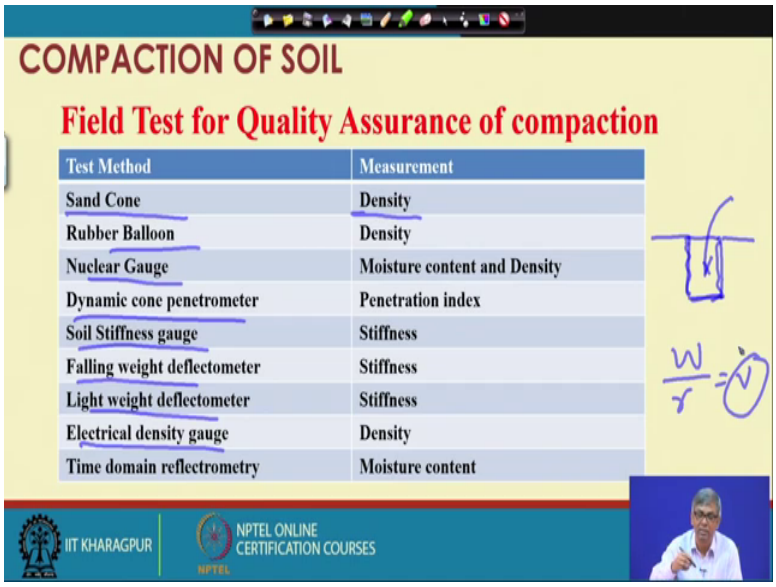

So, for that actually, there are number of methods are there Sand Cone method. There is a method called Sand Cone method. Then that to find out density the Rubber Balloon, Nuclear Gauge, Dynamic cone penetrometer, Soil stiffness gauge. There are so many equipment nowadays available, but typically most easy way, easy easiest way actually what we can do that sand replacement method.

I will make a hole or pit in the site collect the soil and you find out the work weight and moisture content. If you can find out the then whatever pit we make; suppose, there is a ground surface is there pit is made something like this and if you the pit generally cannot make such irregular such a regular shape maybe some irregular shape. So, you have to find out this volume this volume generally determined by filling by sand and that sand actually having definite density. So, how much sand has gone here and where to be taken and if I know the density then, this by gamma you get the volume.

So, once you get the weight, weight divide by this volume will give you the bulk density and bulk density divided by water 1 plus w, will give you the dry density. That way actually easiest way you can do, but for doing this actually we need 1 day time minimum because to determine the moisture you have to keep it (Refer Time: 24:53) and this 24 hours you have to wait. So, for that nowadays, many alternatives are there. Actually you can do directly in the field and one such method is that is Non-destructive method.

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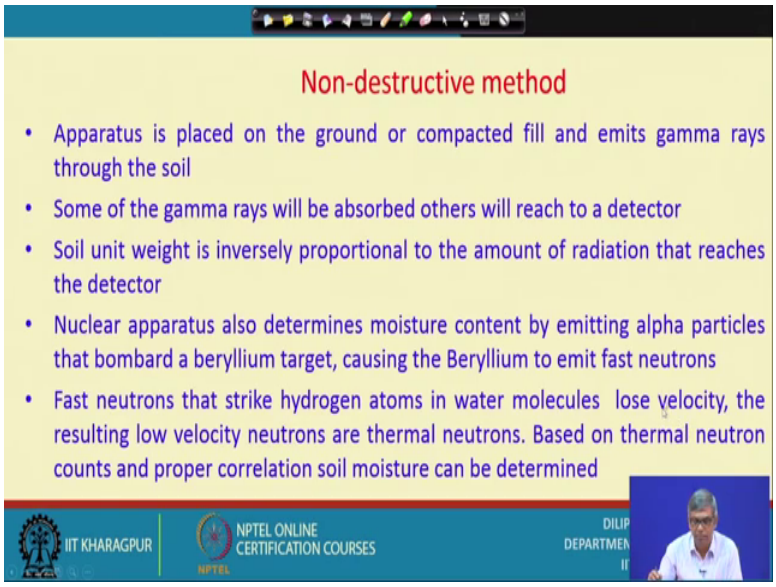

There are actually there is a one such method is shown here.

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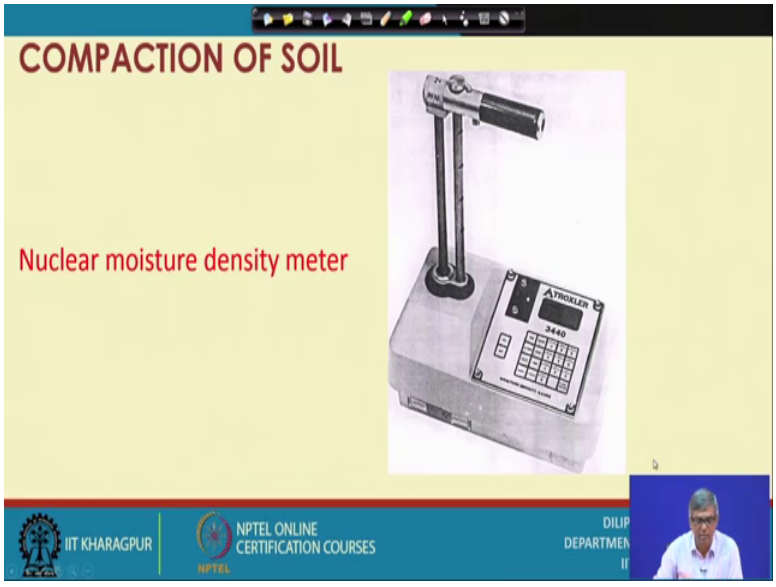

Nuclear moisture density meter; like that. In the field directly we can get moisture and density and how this it work actually? The Apparatus is placed, Apparatus placed on the ground or compacted fill and emits gamma rays through the soil. Some of the gamma will be absorbed other will reach to a detector. And Soil unit weight is inversely proportional to the amount of radiation that reaches the detector. So, that is the way it works and it also can sometime measure the moisture.

So, how Nuclear apparatus also determine this moisture content by emitting alpha particles that bombard a beryllium target, causing the Beryllium to emit fast neutrons. And Fast neutrons that strike hydrogen atoms in water molecules lose velocity, the resulting low velocity neutrons are thermal neutrons based on the thermal neutron counts and proper correlation soil moisture can be also determined.

So, this is the equipment nowadays, directly we can do and time to time; obviously, we have to calibrate whatever based on this count we are since we are doing. So, whether they are doing correctly or not that has to be calibrated time to time.

So, and then.

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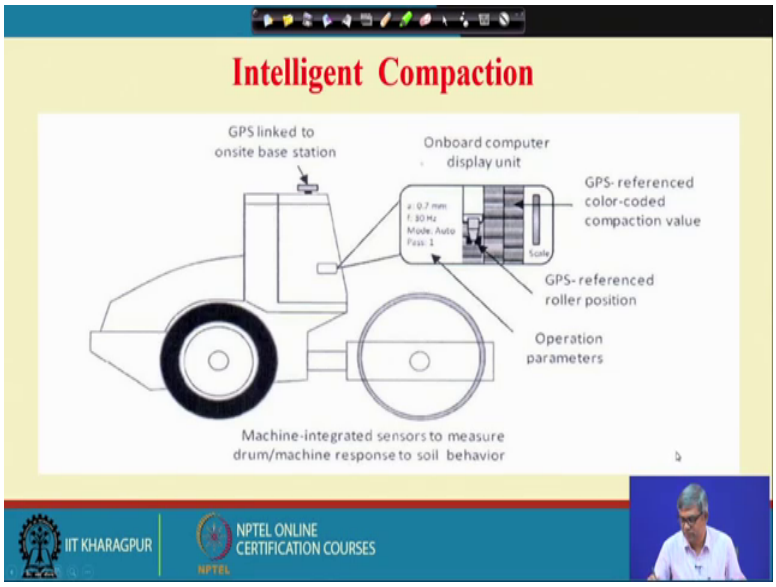

There is nowadays, we have intelligent compaction that intelligent compaction means that equipment is (Refer Time: 26:39) by itself will have some various accessories which

actually can monitor the through some sensor. It can find out the how, what is the amount of moisture? What is the amount of density achieved?

All those thing, can and it will direct and you where actually it is weak and you have to repeat the work. So, this is the typical intelligent compaction equipment and it will have these other number of things shown here. GPS linked and then, it is having Onboard computer display unit, from where you can see GPS- referenced colour-coded compaction value, like that.

So, many uh accessories will be there and this type of equipment of course, not readily available. It has lot of advantages because we can find out the weak places by itself and we can do additional compaction, but it is not readily available and also expert operators are required. So, lot of disadvantages are there.

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So, Basic Concept of Intelligent compactor is you can see the Intelligent compaction is a continuous construction technique with quality assurance and control processes incorporated in the construction. This technique includes automatic measurements of geomaterial properties through preinstalled sensors on the machine and adjustment and optimisation of the vibration amplitude, frequency and/or speed using a feedback control system by the machine operator to achieve uniform compaction and desired target values.

So, these are things (Refer Time: 28:23) and it will also receive information and then, where there is a mismatch; it will instruct you to do those. And Suitability is same as conventional compaction equipment it will be useful, but additional advantage that you do not have to do any quality control separately.

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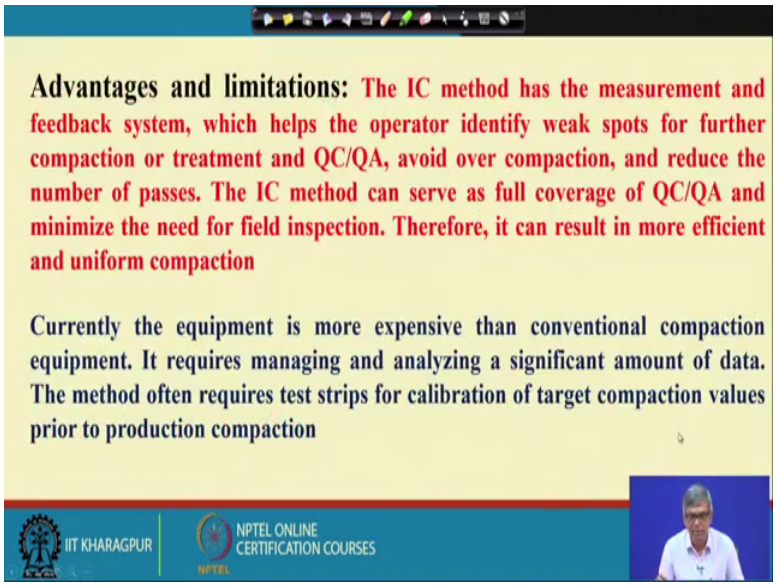

And advantage will be you can see the IC that means, Intelligent Compaction method has the measurement and feedback system which helps operator identify weak spots for further compaction or treatment and Quality Control or Quality Assurance avoid over compaction, and reduce the number of passes. So, suppose though we have recommended 6 passes for a particular dry density, but if I find that the 4 passes we are achieving that. Then, we can stop that is the advantage.

Thus, Intelligent Compaction method can serve as full coverage of QC, quality control and Quality Assurance and minimize the need for the field inspection. It can result in more efficient and uniform compaction. So, these are the duty of this equipment, but this equipment currently is not very expensive and than conventional equipment and it requires managing and analyzing a significant amount of data. The method often requires test strips for calibration of target compaction values prior to production compaction. So, these are the few things you have to know and there are specialized people also required for handling this equipment.

So with this, this compaction, I just closed this shallow densification and I will take another topic on (Refer Time: 30:15) that is dynamic compaction and sometime if you, if you want to go deeper then this is not sufficient. So, you have to use some other technique that is called Deep Dynamic Compaction and which I will discuss in my next lecture.

Thank you.