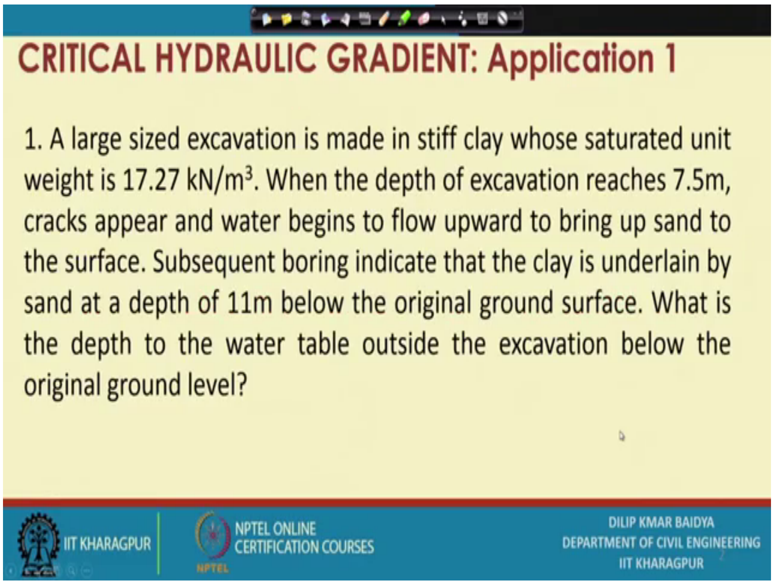
Soil Mechanics / Geotechnical Engineering I
Prof. Dilip Kumar Baidya
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture – 17
Permeability / Compaction (Contd.)

Once again welcome you to this lecture, soil mechanics or geotechnical engineering one, and I have completed my lecture on probability and seepage, and there I have taken one session for showing the application various method, various formula we have derived and, but partly I could not take it particularly on critical isolated gradient, which again will come again when I will discuss effective stress and all, but immediately I will try to take one or two application for showing the; application of critical hydraulic gradient, and also I have just completed the compaction, and compaction basically lot of information we have to keep in mind.

But simultaneously there are some small, small calculation and particularly to find out the optimal moisture content dry density in the laboratory and all some calculation will be there. So, actually with this session, I will take 2 problems from a critical hydraulic gradient, that is probability and seepage aspect and 2 problems from compaction, and then I will just show the application.

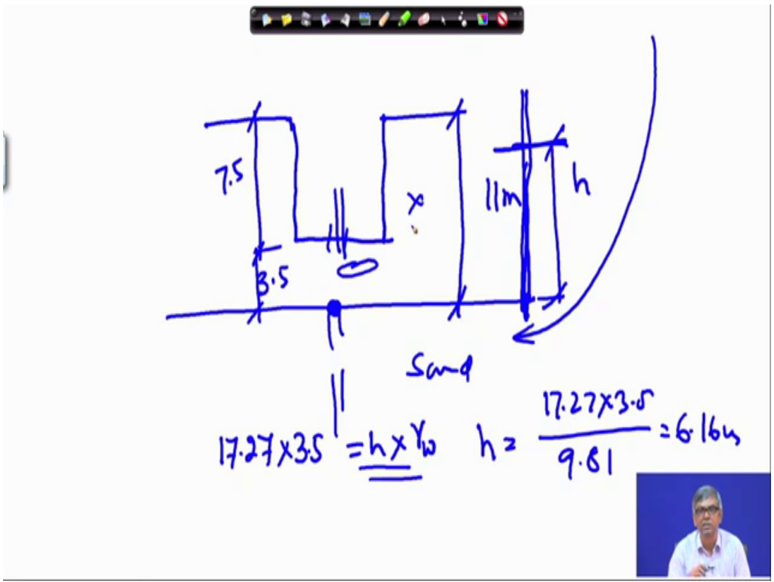
(Refer Slide Time: 01:49)



So, first problem will be this is a problem actually, first problem your a large sized excavation is made in stiff clay, whose saturated unit weight is 17.27 kilo Newton per meter cube. When the depth of excavation reaches 7.5-meter cracks appear, and water begins to flow upward to bring up sand to the surface.

Subsequent boring indicate that the clay is underlain by sand at a depth of 11 meter below the original ground surface, what is the depth to the water table outside the excavation below the original ground level? So, this is the one initially excavation is going on and there is no water visible it is saturated, but or saturated or partially saturated, but at certain when it reach to a sudden depth the bottom cracks appeared, and sand boiling type of effect started so; that means, there is some pressure from bottom that is was actually that is the concept of critical hydraulic gradient, I just show this application.

(Refer Slide Time: 03:15)



And we can see that typically I can show you this is the one, about this much disclamation is done and where actually cracks form, and subsequent investigation found that there is a sand layer on a depth of 11 meter.

So, this is 11 meter, and this is sand, and this is actually 7.5 and then this will be your 3.5. So, what happens there may be because of some source water is there, and it is giving some hydrostatic pressure here. So, if I put a piezometer here somewhere here, and it will represent how much high pressure is acting here.

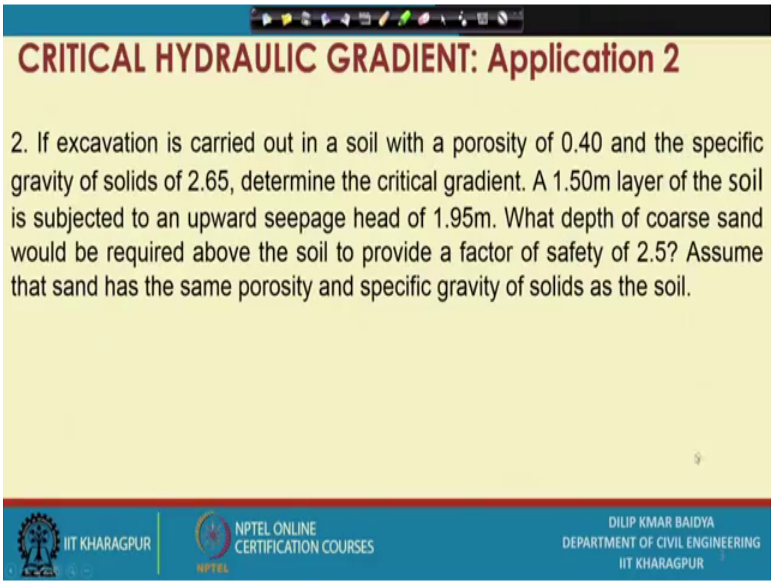
So, that height may be you can (Refer Time: 04:20) if I insert the piezometer here, that the water will rise up to that level, since it is a (Refer Time: 04:27) layer probability is very low you will not see with the water, but when you pass this layer and make a piezometer, then you will see the water layer, suppose this is the water level edge then, what will happen?

I have to consider the equilibrium at this point; that means, whatever weight downward weight is coming, and whatever upward force because of this water is going, this when they are equal that is the problem critical point, and that point actually cracks stable of if it is, if you go further then complete burst will be there.

So, that simple calculation will be since the unit weight of the soil is given 17.27 and multiplied by the depth is only 3.5 and equal to, h into gamma w. Since I am not taking any factor of safety at that depth probably it is cracked occur occurs. So, I will consider just this is the just (Refer Time: 05:28) job instability. So, that condition. So, this this and this must be equal, or this is become just slightly greater because of this has to happen. So, this the limiting height; that means, at this condition if I put a piezometer what height you will see the water. So, that will give you from this calculation. So, it gives you h equal to 17.27 into 3.5, divided by divided by h sorry 9.81 gamma w. So, this gives you 6.16 meter.

So, this is a very simple application, sometime this soil is stop I have taken as it is sometime maybe the weather is saturated partially saturated, then accordingly you have to calculate unit wise and all there can be some type of problem, but this is another very simple problem just considering the equilibrium at this point.

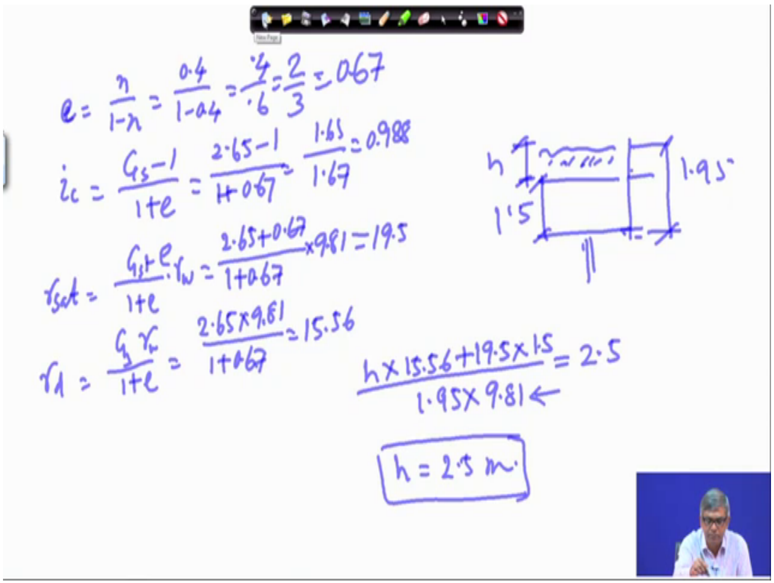
(Refer Slide Time: 06:37)



Now, I will go to second problem, this is a second problem is if a if excavation is carried out in a soil with porosity of 0.4, and the specific gravity of solid of 2.65, determine the critical gradient. So, this is the thing I have given; I have derived the expression, the critical hydraulic gradient equal to G s minus 1 by 1 plus e. So, that will come straight forwarded, but here e is not given, but porosity is given and again we know the relationship between porosity and void ratio that will utilize, then next part is a 1.5 meter layer of the soil is subjected to a upward seepage head of 1.95 meter, what depth of coarse sand would be required above the soil to provide a factor of safety of 2.5, assume that sand has the same porosity and specific gravity of solids as the soil.

So, when you are do the equilibrium then you need to find out the unit weight. So, void ratio etcetera is required. So, sand also whatever will be used that porosity is which is given that can be assumed the same, if you do that then how you will proceed we can see this way.

(Refer Slide Time: 08:06)



We can see e equal to n divided by 1 minus n, and this is 0.4 divided by 1 minus 0.4, that is 0.4 by 0.6 equal to 2 by 3 and which is nothing but 0.67. So, e value is obtained now, once you get the e value and G s value is given 2.65, then I c is equal to G s minus, 1 by 1 plus e, and if you put all those values that will 2.65 minus, 1 divided by 1 plus 0.67. So, it will be 1.65 by 1.67. So, that gives 0.988 this.

Now, another situation is given that, there is a 1.5 meter of sand and some water is given from allow to pass suppose this way, and with a head of suppose head is suppose weight applied is 1.95 it is shown here, 1.95 and this is only 1.5. So, that is the requirement is how much sand to be put here, this is this is height is more, the critical hydraulic gradient it will be something, and it may because of this height, when you allow flow from this then this sand, may washed away. So, because of that you have to put additional weight to balance it, and that too we have to provide factor of safety 2.5. So, that consideration you should take, then you can see we can consist of clay to be used.

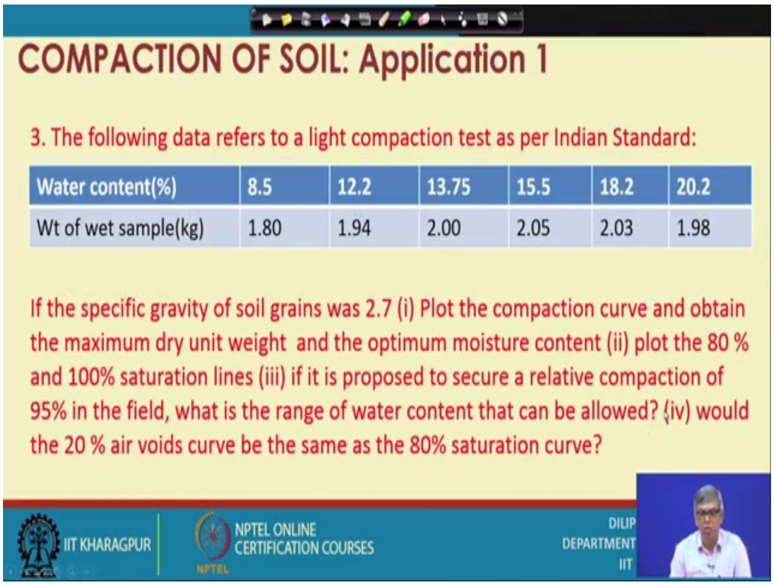
So, this since flow is passing through this there is no water table, but since water is passing through this, I can consider gamma saturated gamma saturated for the soil, that is actually G s minus G s plus e by 1 plus e, into gamma w. So, if I put 2.65 plus 0.67 divided, by 1 plus 0.67 into 9.81, this gives you a unit weight of 19.5, and sand suppose if the same property can be used, but you are putting (Refer Time: 10:54) you can assume the sand is dry suppose gamma d, gamma d G gamma G s gamma w by 1 plus e.

So, you can say 2.65 into 9.81 divided by 1 plus 0.67, this gives you a unit weight of 15.56. Now we have to how much weight is coming then, I suppose take this is height h now so, h into 15.56 that is weight is there plus gamma saturated 19.5 into how much 1.5, and how much water pressure is there, this is the 1.95 into gamma w is 9.81. So, this is actually disturbing; that means, causing the flow of sand along with water, and this is the resisting.

So, resisting by this this is supposed to be factor of safety which is 2.5, if I do this then by simplifying, this one, I can find out h equal to approximately 2.5 meter, or whatever may be it can be calculated and checked it may be 2.5 meter so; that means, around that much of soil if we put here dry sand, and even if I apply 1.95 of height upward head to flow water to through this soil, still you will have a factor of safety 2.5 against critical hydraulic gradient means what actually at that point.

Since I have not discuss the shear strength a. So, I am not able to use that, actually critical hydraulic gradient point actually, the soil lose shear strength actually become less, and because of that if you put any load on it, then it will not be able to support it. So, it will be like a flowing condition. So, that I will be discuss again later on. So, this is another application second application that is to achieve that factor of safety, we can do something so, that is the application I have shown here.

(Refer Slide Time: 13:27)



So, third application it is on compaction, and it is a very straight forward application, we can see that the following data refers to a light compaction test as per Indian standard, and the this is as I have told you that compaction test is done in the laboratory, which is having standard mould of 100- 1000 cc volume and standard focus test, if you consider then there will be hammer weight of 2.5 kg and height is 30 centimeter; that means, 13 centimeter height the hammer will be dropped on the soil, and this 1000 cc volume will be compacted in 3 layers, if you one third first filled up give 25 blows then, second one third then again 25 blows, third one third again 25 blows.

So, like that you have to compact the soil in a mould of 1000 cc, and then you have to find out the weight, if you know the weight and by finding out the you know the volume, then you find out the bulk unit weight, then after knowing the water content you can find out the dry unit weight.

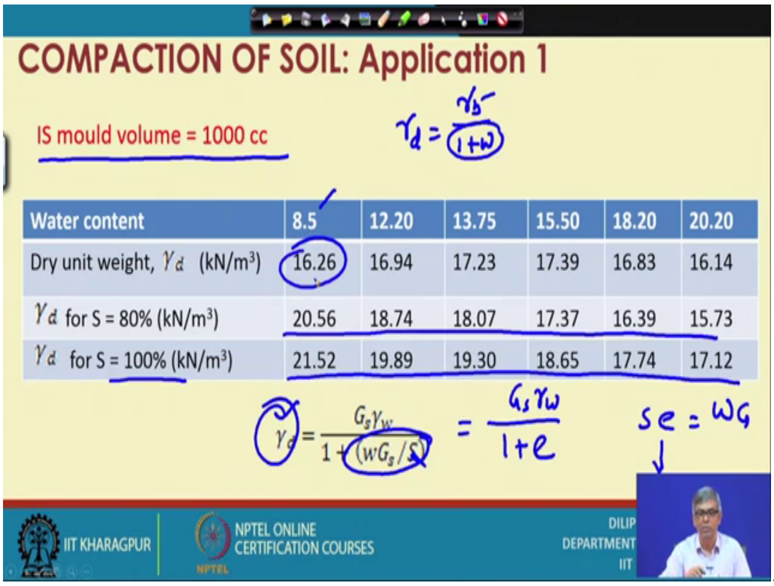
So, water content corresponding to dry unit weight get from the compaction. So, I have mentioned that we generally do 5 trials 1 to 2 to 3 will be dry side and 2 to 3 will be wet side, then optimum is there either exactly we may not get point at 0.1 optimum may be 2,3 will be before optimum, and 2,3 before after optimum from there you will get the trend you get the curve.

So, that is what it is given here pipe test given water content and corresponding weight of wet sample; that means, for a volume of 1000 cc 8.5 and 1.8 kgs, when the 12.2 percent and it is 1.94, 13.75 it is 2, 15.5 like that (Refer Time: 15:20) So now, and what you have to do, if the specific gravity of soil grains was 2.7, plot the compaction curve and obtain the maximum dry unit weight, and the optimum moisture content, then plot the 80 percent and 100 percent saturation lines.

If it is proposed to secure a relative compaction of 95 percent in the field, what is the range of water content that can be allowed, which I have shown that if you have a compaction curve which has a dry density, but if I want to know 95 percent of that suppose if you have got 1, 95 percent of 1 means 0.95, then I will draw a line horizontal line on 0.95. So, 9.0, 0.95 dry density with both sides are optimum.

So, that range you will get, and you would the 20 percent air void curve be the same as the 80 percent saturation, this is the point this is the question asked. So now, for this we need to some do calculation, those calculation I would like this we have to prepare the term.

(Refer Slide Time: 16:19)



We have to prepare the sample, we can see this I s mould is the volume is 1000 cc, and generally your gamma d, will be equal to gamma bulk, divided by 1 plus w. So, this is the one thing you can do use. And so, using this table you can see 8.5 percent of water content, then you can find out gamma d.

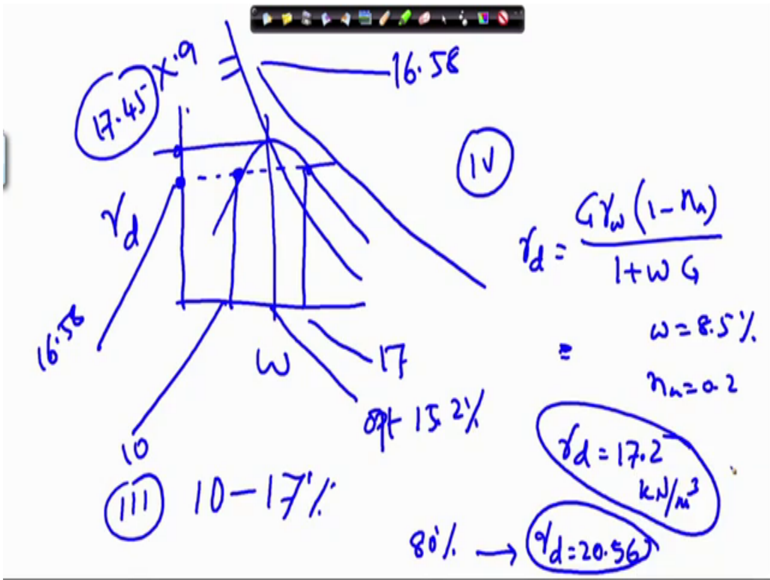
First you can find out the gamma from the original weight by volume we get bulk unit weight, then bulk divided by 1 plus 0.085 if you do then you will get this one, the 8.5 percent this is the dry unit weight, 12.2 this is the dry unit weight, 13.75 this is the dry unit weight, 15.5 water and this is the dry unit weight, 18.2 percent this is the dry unit weight, 20.2 percent this is the dry weight.

Now, gamma d with. So now, if you plot this one, water content versus dry unit weight, then we will get a curve that I will come later on together. And now I have to find out gamma d for s is equal to 80 percent gamma d for s is equal to 100 percent. So, gamma d expression is like this is the gamma d, and gamma d will be equal to G s gamma W by 1 plus e, and e s into e equal to W into G.

So, e can be substituted W G by s. So, that is thing by you done, now in this 80 percent saturation means, I will take s is equal to 0.8 and water content is same and G s is same and everything is un unchanged, and instead of e I am using now, this expression and there are once I will use 0.8 another I will use 1. So, when I use 0.8 these are the results for dependent water content, and when I use s are equal to 1 and for different content these are the results.

So, moisture content versus dry density as it is in the lab with 100 percent saturation and 80 percent saturation, 3 data set we have got, and this will be plotted now if you plot this.

(Refer Slide Time: 18:54)



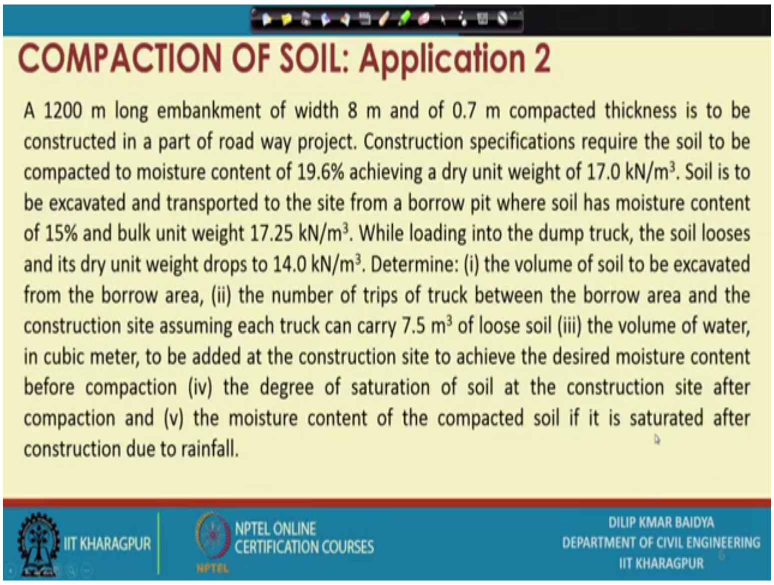
Suppose this is a gamma d and this is moisture content. So, typical curve will be something like this, and we may get a moisture content. So, this gamma d, if you do you will get 17.45, if you plot in a particular curve 17.45, and this moister content you will have got optimum, actually 15.2 percent, and now as I have mentioned that 95 percent of that.

So, 95 percent of that if you do into 0.9, if I do that gives you a value 16.58, and that 16.58 suppose this one and if I draw a horizontal line then you are getting 2 moisture content this and this. So, this moisture content actually is 10, this is around 10 and this is around 17 so; that means, your second part or third part, answer to third person question it will be 10 to 17 percent water for water you have to add to achieve that was 19 percent of density. And second part actually is given plot 80 percent and 100 percent. So, 100 percent saturation line will get something like this, whatever table previous table is there, water content versus dry unit weight if you plot them you will get a curve like, this and 80 percent if you plot you will get a curve like this.

Now, the next part is 4th part is mentioned whether 80 percent saturation line and 80 percent (Refer Time: 20:40) lines are same. So, I will take gamma d equation in condense of air content, there is a expression I have derived once gamma w 1 minus n a, divided by 1 plus W into G suppose I will take first set of data that is 8.5 percent water, water content is 8.5 percent and n a is equal to suppose 20 percent 20 percent air voids. So, in that case if I put all those things in this expression, then you get gamma d equal to 17.2 kilometer per meter cube, and whereas s 80 percent from the table will get gamma d corresponding to 80 percent saturation, whatever is the calculation that is shown in the table from there are actually we get gamma d equal to 20.56.

So, 20 percent air content and 80 percent saturation they are not correct they are not same, that is what we want to mention here you are getting gamma d by this is a 20.52, and other case you are getting 17.2. So, this is the answer 2 the last part, whether 20, 80 percent saturation and 30 percent air content is the same or not this is not same, but you can also check with some other water content, second set of water content and they are suppose it is 12.2 w, and any again 0.2 if you use this expression, you will get another dry density and refer back to a table, and find out corresponding to that water content 12.2 percent, what is the dry density? And they will see that they are not the same. So, this is the one I wanted to point out here.

(Refer Slide Time: 22:42)



And now your last application, last application is here and another problem. This type of problem once I have taken, when I have done 3 phase diagram similar to that only little additional things are there, a 12 meter 1200 meter long impartment of width 8 meter, and 0.7 meter compacted thickness is to be constructed in a part of road way projects, that is a big project, but out of part of a project is 12 meter 1200 meter, 1.2 kilometer long and it is a width is 8 meter and height is 0.7 meter, construction specification require the soil to be compacted to moisture content of 19.6 percent, achieving a dry unit weight of 17.0 kilo newton per meter cube.

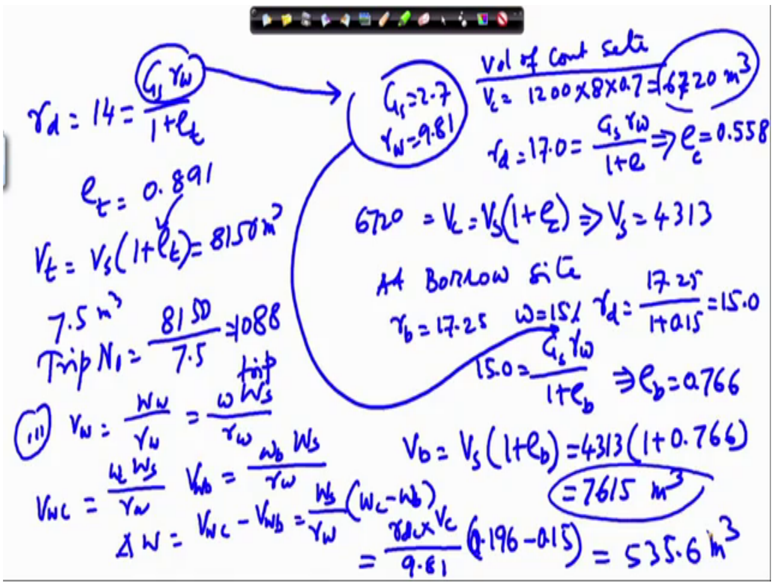
So, this is the requirement at the site. So, what are the things that known volume of the compacted work is known, and requirement what is the dry density unit, what is the moisture content is known, and soil is to be excavated and transported to the site from a borrow pit, where soil has moisture content of 15 percent and bulk unit weight of 17.2.

So, there actually bulk unit is given, water quantity is given, then I can find out dry unit weight from there actually I can again you can find out, what is the volume required from the bottom pit to get the that much volume of compacted volume. While loading into the dump truck, the soil loses and it is and it is dry unit weight drops to 14. So, when you excavate from the site; obviously, soil will be losing more volume will be occupied in the truck. So, that is what during that time it is approximately given that 14 kilometer per meter cube dry unit weight will get.

So, if that is the condition given the for that you have to find out the volume of soil to be excavated from the borrow area, the number of trips of truck between the borrow area, and the construction site assuming each truck can carry 7.5 meter cube of lose soil, then third the volume of water in cubic meter to be added at the construction site to achieve the desired moisture content before compaction see site actually water is 15 percent, but actual construction side we require 19.6 percent.

So, you have to add water. So, what is the amount of water that to be calculated. The degree of saturation of soil at the construction site after compaction, and the moisture content, when it is during flooding? When it is saturated? What is the moisture content? So, these are the various aspect we have to find out.

(Refer Slide Time: 25:35)



Now, I take one by one. So, volume of volume of constructed site. So, this will be 1200 that I suppose say V c, 1200 into 8 into 0.7 that will be that that will be equal to 6720-meter cube, and gamma d is given 17.0 kilo newton per meter cube, that is actually equal to G s into gamma w by 1 plus e. And if I take G s equal to 2.7 and gamma w equal to 9.81, then and this is known that this gives you e equal to 0.558, 0.55 sorry yes. So, this is the one then if I know this then, I can find out now V c will be equal to what is the in a V c actually compacted volume of soil, that will be solid and voids. So, I can imagine V s and V. So, if I we will back form if I write V s into 1 plus suppose this is a constructed side.

So, e c. So, this gives you V s equal to because e c can substitute here, and V c is known this one this is equal to 6720, and from there will get V s will be equal to 4313. So, V s you have got, now once you get the V s then at borrow site, we have got gamma b equal to 17.25, and water content is 15 percent.

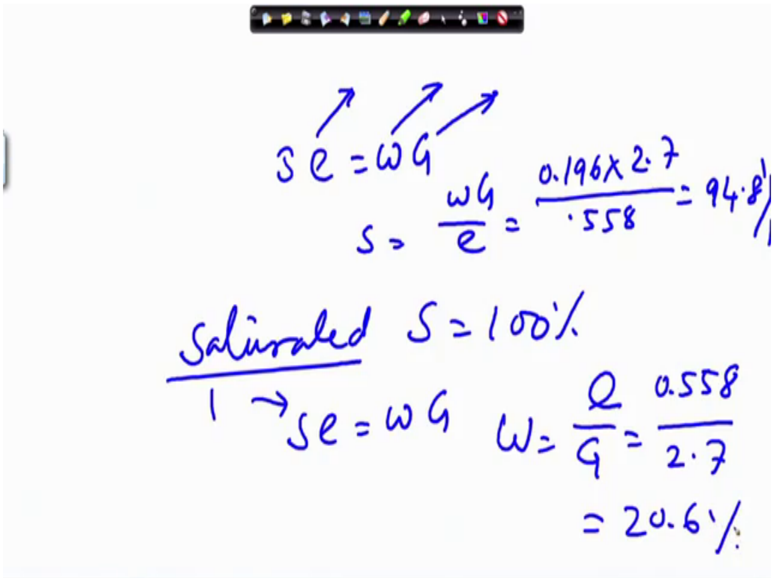
So, gamma d will be equal to 17.25 divided by 1 plus 0.15, that gives you 15.0. And so, 15.0 can be written as G s gamma w again 1 plus e borrow pit, from here actually if I take the same G s, if I take same here then I this gives you e b will be equal to 0.766. And once you got e b then I can V b, I can get volume at borrow pit, we can get that is actually V s 1 plus e b, and V s should be same amount of solid should be transferred soil. So, it will be 4313 into 1 plus 0.7666. So, that gives you V b equal to 7615-meter cube. So, it will be definitely whatever the actual cost compacted volume, borrow material has to be more than that. So, that is the thing you have got.

And now during filling or excavating your gamma d is 14, and that will be equal to again I can do G s gamma w by 1 plus, water content is given actually that one you know. So, 1 plus e suppose, and e it is not known. So, it is e transport, transportation time what is the void ratio. So, if I again this if I take same as this, then this gives you e transport time will be a value 0.891. So, V transport will be how much V s into 1 plus e transport. So, if I use this value here and V s already known if I use, then I will getting a volume equal to 8150-meter cube, and each truck take, each truck volume is 7.5. So, how many trip required, trip number will be equal to 8150 divided by 7.5 this gives you 1088 trip.

Now third part I have to find out, that is first second is what third part is, I know V w equal to W by gamma w, and that can be written as W into W s by gamma w. So, if I take now V w construction side, then it will be W c into W s by gamma w and V w at borrow, this will be equal to w borrow, into W s divide by gamma w, then delta w which is water required V w c minus, V w b and if I do this it then will be W s by gamma w, into W c minus W b, and W s nothing but gamma d c into V c, W d c into V c divided by, 9.81 is gamma w into W c is 9.0.196 minus W b is borrow site is 15 percent 0.15. So, if I do this calculation it gives you 535.6-meter cube.

So, this is actually; that means, how much water from a borrow site from the borrow site the amount of soil you are taking in that, soil we have to add this much meter cube of water to and then, compact then only you will get the desired thing. So, I will get this continuation of these; that means, 2 more parts they are quite small, and 4th part was what is the degree of saturation at compacted side, and for degree of saturation we know the equation that is s into e equal to W into G.

(Refer Slide Time: 32:37)



And you know the water content you know these 2.7 you know the e then if; that means, you will get s is equal to W G by e. So, that gives you all values if you put 0.196 into 2.7 divided by e is 0.558, it gives you 94.8 percent, and last question was when it is plotted and; that means, entire soil will be saturated then what is the water content, when it is plotted; that means, soil will be saturated. So, saturated means s is equal to 100 percent and in that case same equation is valid the s into e equal to W into G, and s equal to 1 and W equal to how much actually you have to find out.

So, W equal to (Refer Time: 33:40) e by G so; that means, e is 0.558 divided by 2.7, this gives you 20.6 percent. So, actually construction site we had water content of 19.6 because of the (Refer Time: 33:57) the water content will be slightly increase. So, 20.76 this is the, so various application on both hydraulic critical hydraulic gradient and the compaction.

So, these are the type of compaction equation calculation we have to do during compaction of course, in advanced level as I have mentioned, when we have to do dynamic compaction etcetera, we have to do some calculation for finding out the weight, height and the hydration level. So, that is of course, I am not including because it is generally not in the syllabus from the undergraduate level. So, with this I will just conclude the compaction may be next lecture onwards I will take some new topics.

Thank you.