Ground Improvement

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Lecture No. 09

Application Problem

Hello, once again let me continue on ground improvement techniques. I have discussed different aspect of ground improvement that means the shallow densification where we can do, what equipment can be used, what equipment will be used for what type of soil and all those things we have discussed.

Now, while doing this sometimes you need to do some calculation for example, cutting and filling, suppose somewhere you have to make embankment, then you have to bring soil from some sources and that source called borrow area and the where we want to do the activity that is actually site worksite.

That means from borrow area when you try to bring soil then of course, there are different costs will be involved cost of borrow material, cost of transport, the other things that there and the quality of borrow soil type at borrow site will be different from the contracted side that we are finally you have to contract using the same soil by using some effort you have to achieve certain things. So, they are different.

So, because of that, sometimes we need to do some calculations suppose, are a particular embankment work suppose a few 1000 meter cube of work and we had to get that much of soil from somewhere and you can go and select borrow site and one site may not be enough you may see a number of one a number of sites and then from there based on number of sites sometimes which will be more suitable based on economy or based on suitability of the site size worksite we can select one or sometime because of the cost involved you may choose number of more than one sites.

So, because of that we need to do some calculation similar type of thing, then sometime you are while just collecting soil from a borrow area, the word moisture content or density something when you come back to the different moisture content or different density. So, how much water will be needed or whether water will degrade or not all those things actually you have to do calculation. So, for that purpose, I have taken two problems here in this module; try to see one by one.

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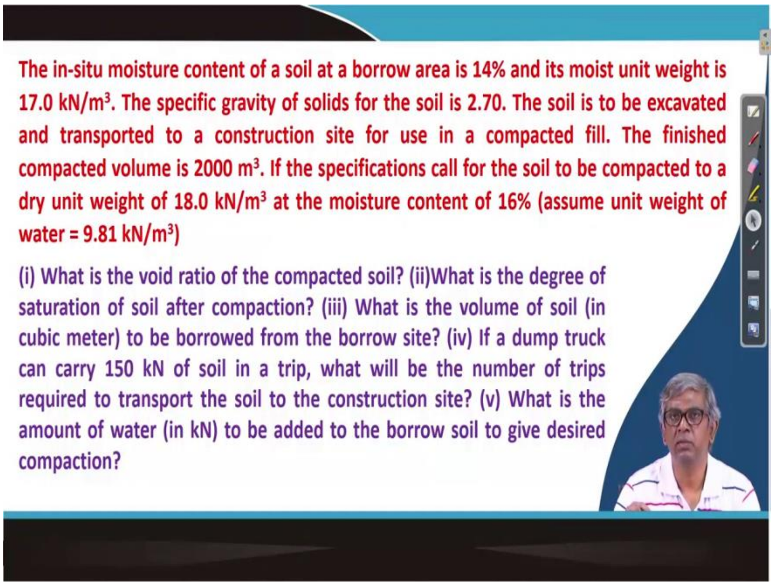

Yes, this is the first problem, you can see the in-situ moisture content of a soil at a borrower area is 14% borrow area from soil will be taken and its moist unit weight is 17 kN/m^3. The moist unit weight means bulk unit weight, as it is. So, everything 17 kN/m^3 γ-bulk is 17 and water content is 14w equal to 14%.

The specific gravity for the soil is 2.7 generally, either here to determine in the laboratory or if you cannot get out or if you do not have time or do not want to determine, then 2.65 to 2.75 something in between can we assume in most work actually is the most diverse type of soil with good soil which we are using construction site generally the specific gravity of that range.

So, assumption of 2.7 is generally good otherwise, actual value can be taken. The soil is to be excavated and transported to a construction site for use in a compacted field. The finished compacted volume is 2000-meter cube. So, that means how much volume of work you are to that is finished fixed.

If the specification calls for the soil to be compacted to a dry unit weight of 18 kN/m^3 dry unit weight γ_d is 18 here, actually bulk unit weight 17 but here to compact in such way, the dry unit weight become 18 it is quite heavy compaction will be required at the moisture content of 16 percent.

So, moisture content at the site borrow area was 14%. But we have to compact at 16 percent because you might have done some compaction test to achieve this much dry density you need to add 16% moisture content. So, that is that might have been checked and because of that it is recommended that you do need to add 18% and 18 kN/$m^3$and moisture content is 16%.

And for this of course, many when you do have calculation that unit weight of water will come in picture. So, generally in civil engineering many work we assume 10 but, for these soil mechanics or ground improvement work generally try to take the g value actual value of g that is 9.81 kN/m^3 this is the value will be used.

So, if it is not given you can use or assume 9.81 or 10 and he had to mention that and if it is given that is fine. So, this is the problem now that main set of borrow site soil is described and at the finish site, what is the requirement that is also mentioned. So, based on these the question is asked actually what is the void ratio of the compacted soil?

That is the first question that means when you compact at 18 kN/$m^3$of dry unit weight so, that means the void ratio will be reasonably less. So, what is that that is the first question. Second question is what is the degree of saturation of the file after compaction, degree of saturation that means, will have mentioned that that we do not get maximum density at full saturation, it will be less than the 100%saturation.

And that problem also I will take one more problem I will take where I will be explaining that. So, the saturation level actually you need to that is the second question how close to 100 or how away from 100 that you have to check or you have to find out and what is the volume of soil in cubic meter to be borrowed from the water site.

So, we know the finished volume compacted finished volume 2000m^3, but for that how much quantity of soil to be excavated from the borrow site that to be determined that is a third question and fourth question is if a dump truck can carry 150 kN of soil in trip what will be the number of trips required to transport the soil to the construction site?

So, this is the third question or fourth question and fifth question what is the amount of water included to be added to the water soil to give desired compaction? So, these are the different aspects of the problem. So, let me try to solve this problem. So, first question is what is the void ratio of the compacted soil?

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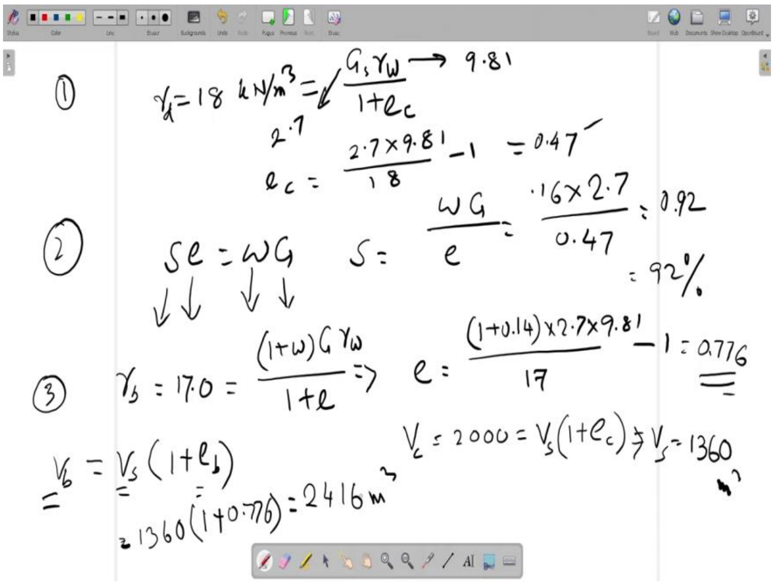

So, let me create a board in here and you can see that borrow site, you borrow site actually your dried unit weight is given γ_d not borrow site, it is compacted γ_d is 18 kN/m^3. And γ_d expression is generally as $\gamma_d = \frac{G_s\gamma_w}{1+e_c}$. And since it is a construction site, I will say it is e_c and this γ_w is 9.81 and this G_s is 2.7. So, from here I can find out e_c value will be equal to G_s is 2.7, γ_w is 9.81 divided by 18 minus 1. So, this is the value or I can calculate and find out.

$$e_c = \frac{G_s\gamma_w}{\gamma_d} - 1$$

$$e_c = \frac{2.7\times 9.81}{18} - 1$$

$$e_c = 0.47$$

So, this value if you calculate, then you may find a value e equal to, so, if I do that, let me see here. This is 2.7 multiply 9.81 divided by 18 minus 1 that is actually going 0.47 and then this is the first part, you can say. The second part was asked your that is what is the degree of saturation and we know that one relationship is into e equal to w into G. This is the degree of saturation, this is the void ratio, this is the water content and this is the specific gravity.

$$Se = wG$$

$$S = \frac{wG}{e}$$

$$S = \frac{16 \times 2.7}{0.47} = 0.92 = 92\%$$

$$\gamma_b = \frac{(1+w)G\gamma_w}{1+e}$$

$$e = \frac{(1+0.14)2.7 \times 9.81}{17} - 1$$

$$e = 0.776$$

$$V_b = V_s(1+e_b)$$

$$V_b = 1306(1+0.776) = 2416m^3$$

$$V_c = V_s(1+e_c)$$

$$V_c = 2000(1+0.47) = 1360m^3$$

So, you can see now, the water content is 16% e is known, S will become w into G divided by e. It will be 0.16 multiplied by 2.7 divided by 0.47. This value will be how much you can see 0.16 multiplied by 2.7 divided by 0.47. So, that gives you 0.92 so that way it is 92%. That will this 18 dry unit weight we are getting at a 92% saturation.

So, now, third question was asked that how much the quantity of soil to be taken from the borrow area, is it okay? So, for that I can find out the void ratio of the borrow area first. So, if I say the moisture content the bulk, γ_b was given. So, third part γ_b is given actually 17 kN/m^3, that is actually I can expression is 1 plus w G_s gamma w divided by 1 plus e.

So, if I fought this way, then your e become your e become 1 plus w is at the borrow site 14 percent and G is 2.7 and gamma w 9.81 and divided by 17 minus 1 because I take 1 plus e there and I send 17 here and then finally e will be entire quantity minus was 1. So, if I do this you can see how much it comes 1.14 multiplied by 2.7 multiplied by 9.81 divided by 17 minus 1. So, you can see that this is 0.776 is the void ratio.

So, you can see that, that borrow area void ratio was 0.776 and compacted site void ratio is 0.7 that means that much void ratio reaction was required that is also that how would this compact we are not going to that. So, what is your reduced to these two, this value and now, if I know these, so, volume suppose volume of borrow area will be equal to volume of solid multiplied by 1 plus e borrow area, is it not?

So, volume of borrow area I can find out if I know volume of solid and already, I know void ratio. So, actually you can see total volume is required actually volume of solid and volume of voids. So, that from there I can get if I take this volume of solid you take out then it will become 1 plus volume of bytes volume of solid that is nothing but void ratio.

So, this equation we are getting. So, I have to somehow know the volume of solid. So, now I will take another relationship I know at the, at the site at the finished site total volume is actually that is some of the construction which is actually nothing but 2000meter cube and this is again I can say same soil will be used. So, solid portion will be same. Only void ratio has changed but solid part is remained one solid part remain unchanged.

So, here also same Vs will be used. Vs multiplied by 1, 1 plus e construction site, is it okay? So, that means, so volume of solid multiplied plus volume of voids. So, here actually volume void of the site or by volume voids at the borrow site. So, that voids of course, it will be more because void ratio is more. So, this this relation if I use, then from here I get Vs will be equal to, Vs will be equal to 2000 divided by e_c construction site is point so, it will be 2000 divided by 1.47.

So, it be 1360, so Vs comes actually 1360m^3. So, volume of solid only out of 2000m^3 of finished file compacted soil only 1360 is your volume of solid. So, now, this amount of solid will be same it will you have to collect from the borrow site. So, if I put this volume of site here that if I multiply that one that means, the actual we call to 1360 multiplied by one plus e b actually 0.776.

So, that gives you 1.776 multiplied by 1.776. So, this gives you total volume equal to 2416 m^3. So, this is your that means, the third person was asked that amount of soil to be collected from the borrow area that is 2416m^3 though our finished volume of compacted site is only 2000. So, that 400 more actually more you have to bring. So, that after compaction is become 2000.

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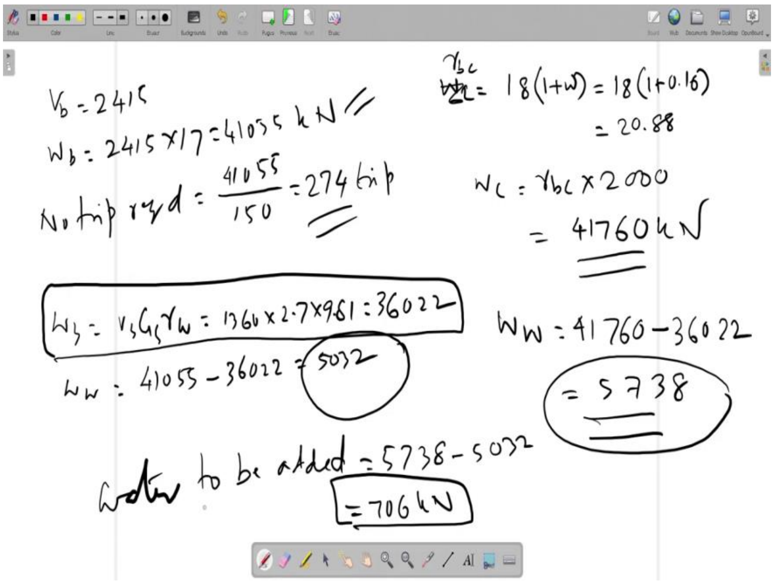

So, let me create another page and then go back to the problem. So, this one so, here actually that your fourth problem was if a dump truck can carry 150 kilo Newton of soil in the trip, what will be the number of trips required to transport the soil to the construction site. So, 150. I have to find out now, what is the total weight of the soil actually we are bringing from the borrow site.

So, we have got 2415 m^3 of soil and you know the bulk you need to add is 17. So, I can go back to this one. So, that is actually you know 24, we have got 2415 that is V_b actually 2415. So, the W_b will be equal to 2415 multiplied by 17. So, it will become 410, 41055 kN. So, number of trips required will be equal to 41055 divided by 150. So, for this will be around 274 trips approximately I have written because it is coming faction. So, I have to take a higher one.

And then if I see the go back and you can see the last question that, what is the amount of water to be added to the borrow site to give desired compaction. So, that the amount of water actually you have to find out now, and for these what I can do, I can do borrow soil, that is W_s will be equal to W_s will be $V_s G_s \gamma_w$

So, if I do that, that went 1316 Multiplied by 2.7 multiple by 9.81 that gives you 3602 and that means W_w will be equal to I have got this total weight 41055 minus 36022 So, that water was 5032 kN. So, this much water was there initially and w c construction site, what is the water, what is the weight of the file W_c?

You can see 18 kilo newton per meter cube actually dry unit weight that means bulk unit weight you have to multiply by 1 plus w. So, that means, it will be 18 multiplied by 1 plus

0.16. So, these if you do 18 into 1.16. So, 18 multiplied by 1.16 this gives you 2088 this one that means, that is not Wc this is actually gamma bulk at construction site. So, W_c will become gamma V_c multiplied by volume actually 2000 so this will become multiplied by 2000. So, that it is your 41760, 41760 kN.

So, that means and 41760 so, that means Ww will be 41760 minus Ws is constant w solid weight is constant this one, see if I multiply subtract 36022 so that become how much 5738. So, that mean the compacted soil final finish compacted soil amount of amount of water is this much, but in the when you are collecting the soil from the borrow site amount of water present this much for water to be added will be equal to 5738 28 actually 57738 minus 5032 equal to so that means 5738 minus 5032.

So, that gives you 706. So, 706 kilo newton of water and if you assume 10 kilo newton per meter cube unit out of water so, that means it is 70m^3 approximately 70 m^3 of water or 706 kN of water to be added then only it can achieve that much compaction. So, this is the problem the first problem entire thing is done.

$$V_b = 2415$$
$$W_b = 2415 \times 17 = 41055 kN$$
$$W_b = \frac{41055}{150} = 274 trip$$
$$W_s = V_s G_s \gamma_w = 1360 \times 2.7 \times 9.81 = 36022$$
$$W_w = 41055 - 36022 = 5032$$

$$\gamma_{bc} = 18(1+w) = 18(1+0.16) = 20.88$$
$$W_c = \gamma_{bc} \times 2000 = 41760 kN$$
$$W_w = 41760 - 36022 = 5738$$
$$\text{water to be added} = 5738 - 5032 = 706 kN$$

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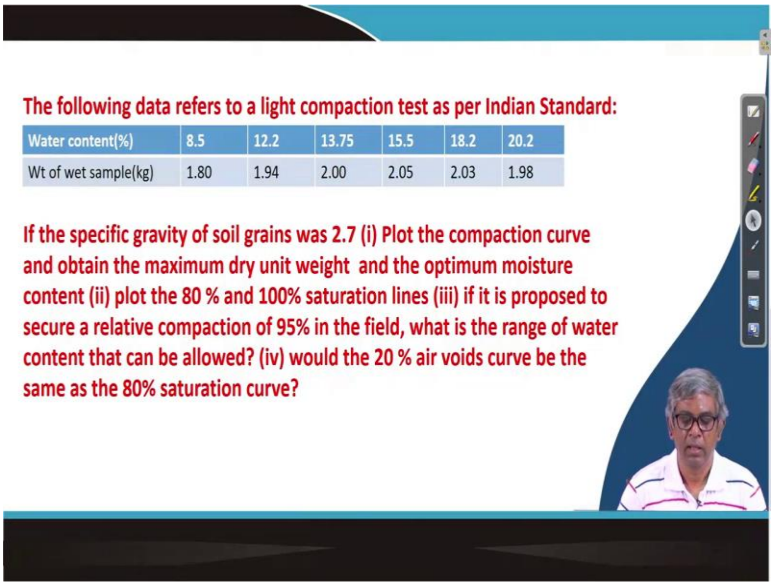

Now, let me go to the next box problem. So, this is the second problem here. We can see this is the problem we have also critically and we have discussed that when you do compaction test in the proctor compaction or modified compaction, there is a mold and that mold will be compacted in a particular standard way and then the weight will be taken and weight of the weight sample that means a compactor mold and what is the water present that data will be collected occasionally in a particular test.

We have got these data suppose, at weight 8.5 water contains the weight of void sample in the mold, the mold volume is constant on all five tests, it was 1.8 kgs, and when water content was added to 12.2 percent, then the weight of which happened the same volume of mold 1.94 kg and when the water percent water content was 13.75 percent, then the weight of void sample was 2 kg and when it was 15.5 it was 2.05, when it was 18.2, then it becomes 2.03 and when it will become 20.2 will become 1.98.

So, this is the data is obtained if the specific gravity of the soil grains was 2.7 plot the compaction curve and obtain the maximum dry unit weight and the optimum moisture content. So, this is the one you have to do and so, that is one part second part is, if it is proposed to secure a secure relative compaction of 95 percent in the field what is the range of water content that can be allowed and fourth question is what 20 percent air voids can be the same as 80 percent saturation. These are the 4-5 questions and this while doing this problem you have to do calculation in the tabular form.

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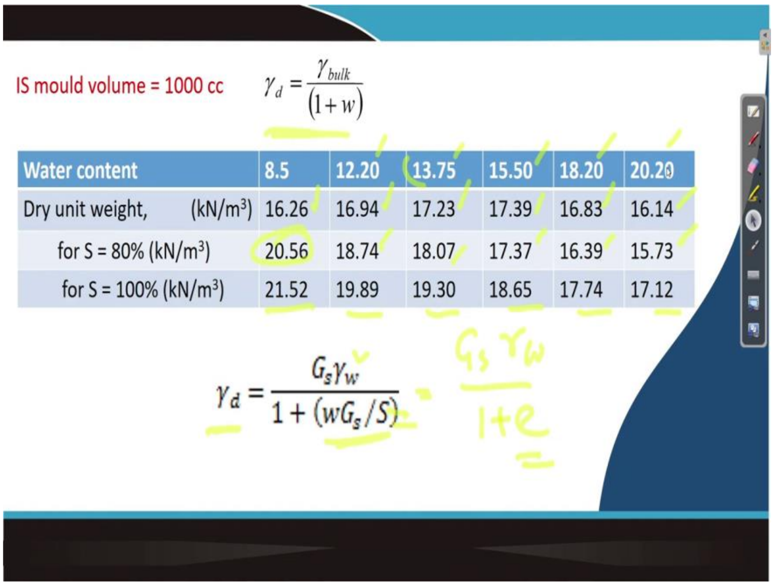

So, this table is prepared here actually you can see that when is the water content 8.5 percent what is the dry unit weight. So, dry unit weight actually the formula is given here that the dry unit weight formula is here, dry unit weight formula is here and you can see gamma bulk by 1 plus water content and you can see the gamma bulk was suppose you can see in the previous page.

So, it was, then again calculate the kg it got multiplied by 9.81 it becomes kilo newton and then divide by 1 plus w then it becomes it was 1000 cc so, it will become your it will become 16.6 dry unit weight and then when it is 16.94 when it is this one water content, this is the water content, this is the dry unit weight 15.5.

This is the dry unit weight when this is the dry unit weight and this is the water content this is our dry unit weight. Now, the while saturation is 80 percent that is another question asked so, when is the 80 percent saturation no then you have to find out another moisture content was dry unit weight, when is 100 percent saturation again you have to do. So, how this equation I can slightly modify gamma d will be their G s gamma w by 1 plus e it was equal to G s gamma w by 1 plus e actually, e can be substituted by this equation.

So, I can see now when 80 percent saturation I will use this 0.8 and w is water content this one and G s 2.7 then I can use 8.5 and then 0.8 and then I will do calculate then I will get this one, when I will use w this one and S is 0.8, I will get this one w this and S is 0.8 and I will get this when w is this S is 0.8 and I will get this when w is this and S is 0.8 I will get these when w is this and S is this then I will get dry unit weight this.

Similarly, 100 percent saturate that means the S become one and same water content I will get this value this value this value this value and this value.

$$\gamma_d = \frac{\gamma_{bulk}}{(1+w)}$$

$$\gamma_d = \frac{G_s \gamma_w}{1+(wG_s/S)} = \frac{G_s \gamma_w}{1+e}$$

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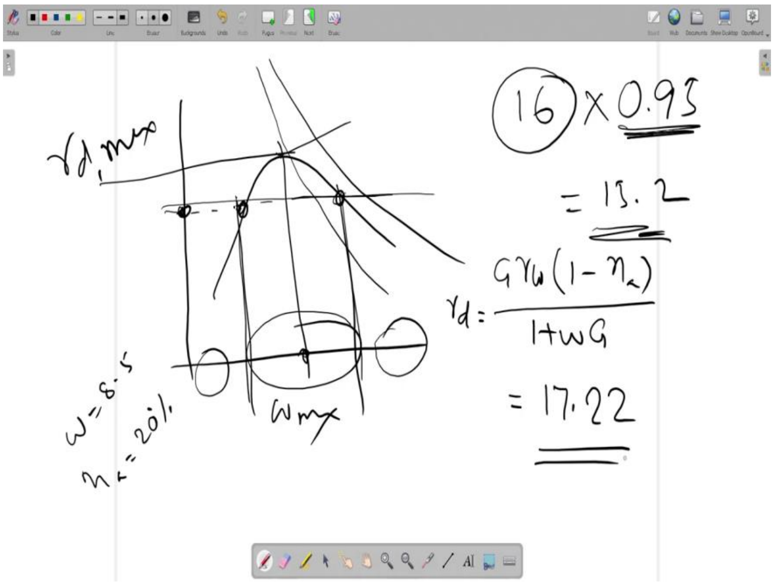

$$w = 8.5$$
$$n_a = 20\%$$

$$\gamma_d = \frac{G\gamma_w(1-n_a)}{1+wG} = 17.22$$

$$\gamma_{d\max} = 16 \times 0.95 = 13.2$$

So, with these it will plot generally we get a plot like this and this is optimum moisture content and this is gamma d max and this is w max. So, this is the way you can do and whatever data is shown here this one that we 8.5% and this is dry unit weight then 12.2 this is the dry unit weight at 13.3 this is the dry unit weight at 15.5 this is the dry unit weight 18.42 and this is the dry unit weight, 20.2 and this is the dry unit weight.

This thing if we plot typically, you will get one something like 80% so you will get a curve something like this. Similarly, 100% saturation curve that corresponding to eight water content and dry unit weight you will get a plot like this.

So, that the second problem is this one and then the last question was asked that is if you are dry unit weight if 95% that suppose you have got a dry unit weight, dry unit weight is 16.95 percent of that one is permitted in the site, so you have to file calculate this one 16 into 0.95, 16 multiplied by 0.95, this become actually 15.2 and so 15.2 suppose somewhere here, then I will draw a line from here, that means I will get one water content this one that means the range of water content for which you can do the compaction actually these two these.

So, this is the part actually I could not I could not plot in actual scale, this is a procedure I am telling you the table is prepared with this table, you can plot dry unit weight versus moisture content. And then for initial data, you will get this curve when 80% saturation data you are using with more different moisture content you will get this curve, when 100% saturation, saturation and different water content, you will get this curve.

So then, I found the initial curve I will get optimum moisture content and maximum dry unit weight and from that maximum gamma d into 0.95 I will get the these are dry unit weight actually the site that one I will mark in the scale then I will go to the horizontally and then I will get two points that different location that from corresponding water content that with this is the range of water content through which by which actually you must compact.

If you have water content this, then I will not get this value if I want if I have water content this and compact, I will not be able to achieve this value. So, this is the fourth question and fifth question was asked that whether 20% air void lines and 80% saturation lines are same or not.

So, that is actually it is different and mainly because there is equation for gamma d with different water content. So, this equation is G gamma w multiplied by 1 minus air content divided by 1 plus w into G. For example, if I take water content 80% w equal to 8.5% and then actually air content 20% and then it will be calculating this value and then you will get a different value other parameters are known and if you calculate then you will get a value of 17.22. So, gamma d 17.22 at 8.5% water content.

Whereas, if you see that 80% saturation actually this one and 8.5 is that your actual water actual dry unit weight is 20.56 whereas I am getting there 17.22. Similarly, for different water content you can find out that 80% saturation line and 20% air void line air void air content. The points are they are not same, they are different because it is giving different dry unit weight. So, with this perhaps I can stop this module. Thank you.