Geology and Soil Mechanics
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Lecture - 53
Tutorial on Compaction

Good morning everyone. So, today we are going to continue our lecture on the on-tutorial classes on compaction after index properties of soils. Now you are going to use the index properties of soils the previous lecture that you have attended on the previous tutorial class that you have attended on this compaction. So, the first question that I am going to discuss on compaction is basically on a modified proctor test.

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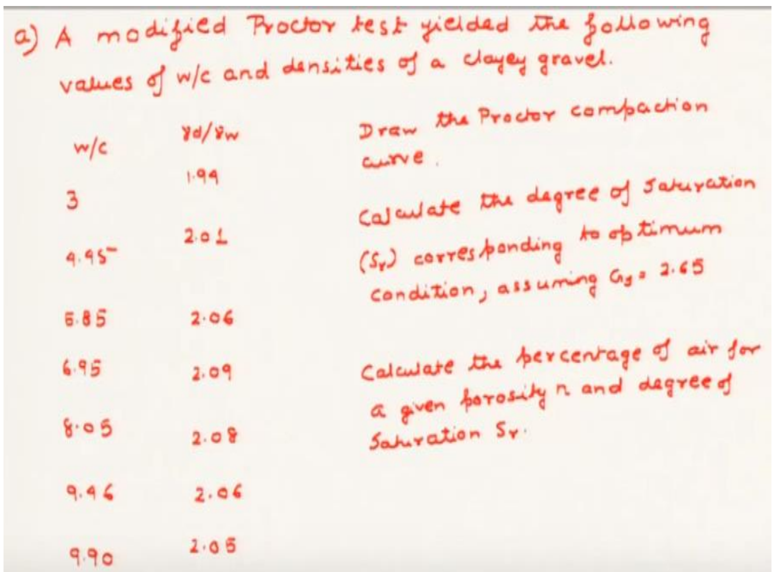

So, the question states that a modified proctor test yielded the following values of water content and densities of a clayey gravel. Now the values of water content is given as 3, 4.45, 5.85, 6.95, 8.05, 9.46, 9.90 and the corresponding gamma d by gamma w is given as 1.94, 2.01, 2.06, 2.09, 2.08, 2.06, and 2.05.

Now it is asked in the question to draw the proctor compaction curve and calculate the degree of saturation that is S r corresponding to optimum condition. Assuming that the specific gravity of soil solids that is G s is equal to 2.65. It is also asked that calculate the percentage of air for a given porosity n and degree of saturation S r. So, we are going to first do the first question that is the drawing the proctor compaction curve. Now drawing the proctor compaction curve, we will just plot them directly on the graph paper.

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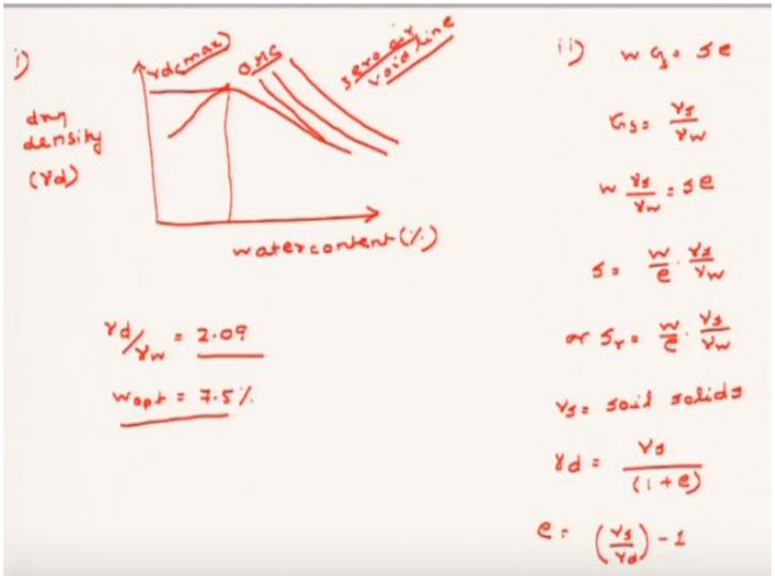

So, basically with the dry density so basically the graph looks somewhat like this. Now we have water content as the abscissa and dry density or gamma d as the ordinate. Now the cross now basically the graph looks somewhat like this as we have already seen in the lectures so this point the topmost point corresponds to the OMC or the optimal moisture content and this also correspond to the gamma d max the maximum dry density.

So, basically it is find out that the gamma d by gamma w is actually equivalent to 2.09 and the optimum moisture content or the OMC is found out to be 7.5%. So, the first question so after the first question we now move to the degree of saturation corresponding to the optimum condition. Now assuming G s equal to 2.65. Now how do you do that? Now we all know that W G equal to S e, W G s.

Now we can write G s in the form of gamma s by gamma w because we know that G s is the specific gravity of soil solids. So, we can write W into gamma s by gamma w is equal to S into e. From here we know that S is equal to W by e into gamma s by gamma w or S r equal to W by e into gamma s by gamma w. Again, gamma s generally corresponds to the soil solids. So, if it is a soil solid then basically it generally corresponds to the dry density. So, gamma d is equal to gamma s by 1 plus e. So, from here we can get that from here we get that e is equal to gamma s by gamma d minus 1.

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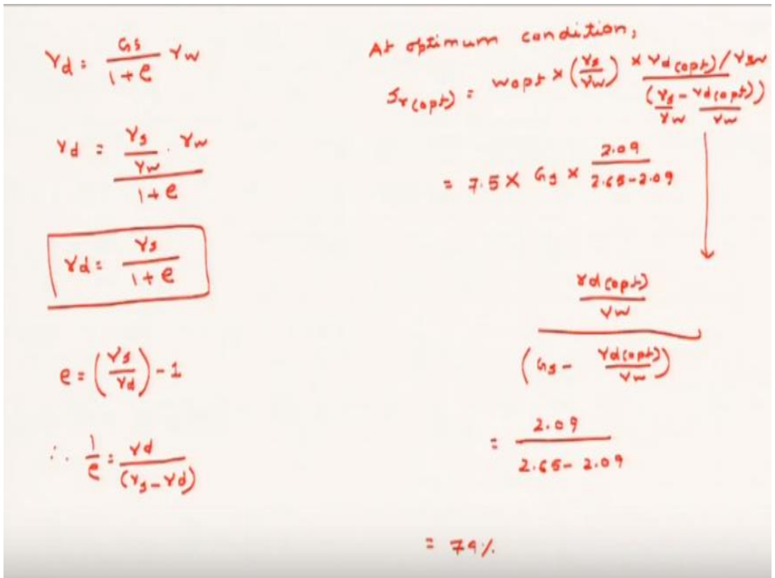

Now how do we get the expression gamma d is equal to gamma s by 1 + e this from the general relation that gamma d is equal to G by 1 + e so basically into gamma w. So, basically, we write that gamma d is equal to gamma s by gamma w into gamma w by 1 + e. So, gamma d is equal to gamma s by 1 + e. So, from here we obtain that e is equal to gamma s by gamma d - 1. So, we can also write 1 by e is equal to gamma d by gamma s - gamma d.

So, at optimum condition we are asked to find out that what is the degree of saturation is. So, at optimum condition S r optimum is equal to W optimum into gamma s by gamma w into gamma d optimum by gamma s minus gamma d optimum. Now if you put all the values this is 7.5% because you have already seen that the w optimum is 7.5% into gamma s by gamma w which is nothing but the specific gravity of soil solids into gamma d optimum which we have found out to be 2.09.

So, 2.09 by gamma s which is 2.65 - 2.09 actually we divided by gamma s gamma d by gamma s sorry we divide by gamma w in all these cases. So, this came down to be gamma d optimum by gamma w divide by G s - gamma d optimum by gamma w which is nothing but 2.09 by 2.65 - 2.09. Now the S r optimum comes out to be 74% in this case. So, basically the degree of saturation corresponding to optimum condition comes out to be 74%. Now moving to the third question. The third question states that calculate the percentage of air for a given porosity n and degree of saturation S r. Now how are you going to solve this?

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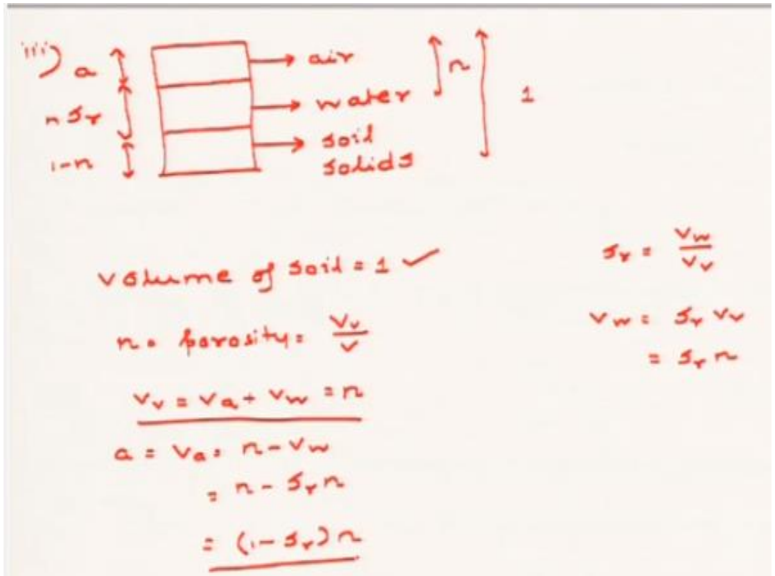

In this case let us first consider that the soil mass consists of air, water, and soil solids. Now the percentage of air is assumed to be a while the percentage of water is assumed to be n into S r and this is assumed to be 1 - n. So, the entire soil volume is assumed to be 1. So, basically the volume of soil is equivalent to 1 while if you remember the definition of porosity there it is equivalent to V v by V where V v is the volume of the voids and V is the total volume of the soil. So, the volume of voids which equals the volume of air plus volume of water that means this part actually equals n or the porosity of the soil because the total volume of the soil is 1.

So, from there we can find out what is the volume of air that is equivalent to n - V w. Now we also know that the degree of saturation can be written as the volume of water divide by volume of voids that is what the degree of saturation is. So, the volume of water can be written as S r into V v and we have already said that V v is equivalent to n. So, S r into n. So, n minus S r into n. So, this is equivalent to 1 minus S r into n. So, the volume of air is found out to be 1 - S r into n.

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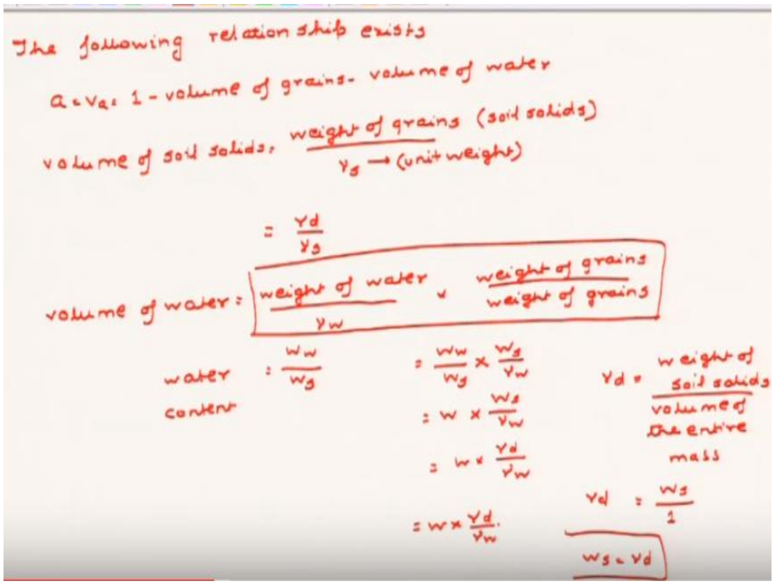

Now the following relationship exists that the volume of air can be written as 1 minus volume of grains means volume of soil solids minus volume of water. Now volume of soil grains or soil solids whatever you may call is equivalent to weight of soil grains by gamma s because the density is equivalent to weight because the specific unit weight is actually equivalent to weight by volume. So, the volume of soil solids will be equivalent to the weight of grains which basically is the soil solids divide by the density of the soil unit weight of the soil solids this is the unit weight of the soil solids.

Now the weight of the soil solids or the weight of the soil grains is again can be written in the form of gamma d by gamma s because gamma d is the dry density of the soil mass which basically consist of only the soil grains and nothing else except air. Similarly, the volume of water can be written as weight of water by gamma w. Here the same thing applies the unit weight of water is equivalent to the weight by volume.

So, basically the gamma volume of water is equal to weight by the unit weight of water. So, now basically what we will do is that we will multiply the top and the bottom by weight of grains. So, we will multiply at the top with weight of grains and we will multiply the bottom by weight of grains. So, we all know that water content of a soil can be written as weight of water by weight of grains or the weight of the soil solids.

The weight of the soil solids and the grains are same so from this relation we can write W w by W s into W s by gamma w but this is nothing but the water content of the soil into W s by gamma w. Now W s or the weight of the soil solids as I have said previously is nothing is again gamma d gamma d by gamma w because the soil solids only is present in the is basically the soil solids because you consider the unit volume the volume of the soil solid to be 1 and if the volume of the soil solid is 1 then gamma d can be written as weight of soil solids by volume of the entire mass.

So, weight of soil solids to be considered to be W s the volume of the entire mass we have considered to be 1. So, W s by 1 is equal to gamma d. So, W s is equal to gamma d. So, that is why we have everywhere replaced the weight of the soil elements by gamma d. So, the volume of water we found out to be is equivalent to W into gamma d by gamma w. Now we have already found out the volume of water is also equivalent to 1 minus S r into n.

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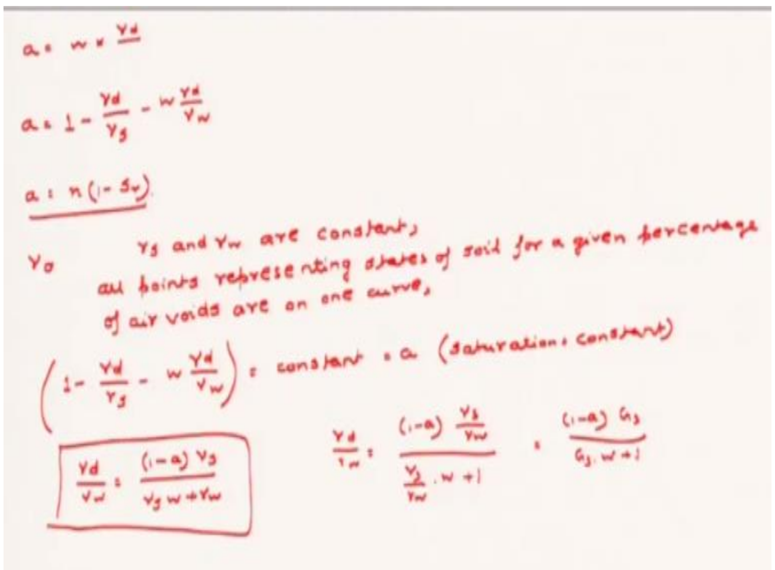

So, we can write a is equal to W into we have already found out that the volume of water we have already found out that the volume of air is actually equivalent to the volume of air is actually equivalent to 1 - S r into n. Now we are going to substitute in this relation that a is equal to 1 minus volume of grains minus volume of water. Now a is equal to 1 minus volume of soil grains. Now the volume of soil grains we have found out to be is equivalent to gamma d by gamma s.

So, 1 minus gamma d by gamma s minus the volume of water is W into gamma d by gamma w. So, W into gamma d by gamma w. We have also found out that basically a is equivalent to n into 1 - S r. Now for a particular soil we all know that gamma s and gamma w are constants because the specific gravity of soil solids is always constant it is a material property. So, for so basically whether the soil is at any moisture content whether the soil is at 1 point whether the soil is at 1.94 the soil is 3% moisture content or 4.95% moisture content or 6.95 moisture content wherever it is on this curve this proctor compaction curve it does not matter.

It is always since it is a material property so gamma s and gamma w are always constants. So, all points representing states of soil for a given percentage of air voids are on one curve and this is what you have to find out because it is said are on one curve because the percentage of air for a given porosity n and degree of saturation S r we have already found out. This is the percentage of this is the percentage of air voids for a degree of saturation n and porosity S r.

Now this curve that basically we said basically this curve that we basically said about is said to be the points that connect the equal degree of saturation. So, basically these are the points this all points (()) (18:07) of soil for a given percentage of air voids are on a curve that basically connects equal degree of saturation. So, the equal degree of saturation curve is basically has a equation which is given by 1 - gamma d by gamma s - w into gamma d by gamma w is equal to constant because the volume of air is considered to be constant in this case.

So, all these points are on equal degree of saturation that is saturation equal to constant because the volume of air is not changing and means the volume of air is not changing that means basically the points are on the same degree of saturation curve. So, we can write this in this way that gamma d by gamma w is actually equivalent to 1 - a into gamma s divide by gamma s into w by gamma w. Now this is a curve which basically is called as the it basically is called the saturation constants curve this has been already discussed in the slides.

These curves basically may represent 100% saturation may represent 90% saturation and may represent 80% saturation as well and it is always said that basically that 100% saturation line this often called as zero air void line as well. This zero-air void line is can theoretically never intersect with the compaction curve. So, zero air void line corresponds to the void line of 100% saturation.

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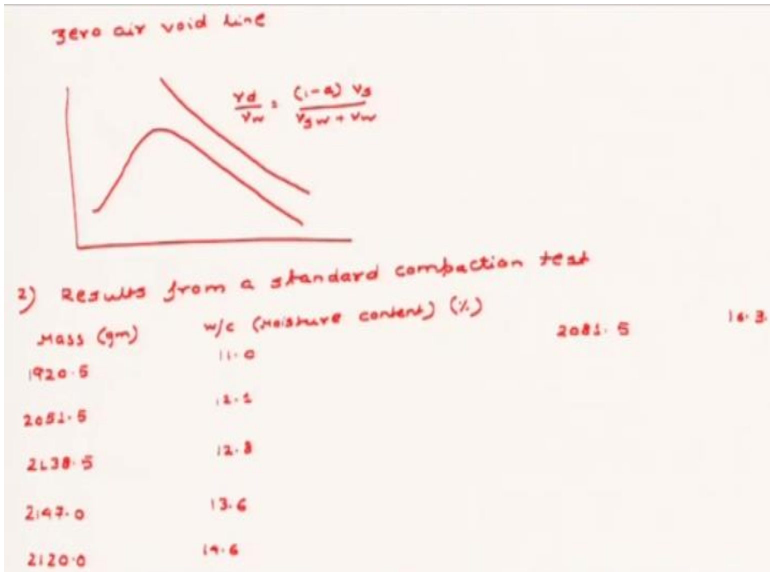

So, let us see the curve how does it look like. So, if this is the compaction curve then the zero-air void line come somewhere here which basically has the equation of gamma d by gamma w equal to 1 - a into gamma s by gamma s w + gamma w. So, on this line the saturation is always constant. This is the zero air void line so basically it is a 100% saturation line. Similarly, there may be 90% saturation line there may be 80% saturation line and accordingly in all those lines the saturation is said to be constant.

Now we will utilize this formula in our next problem. So, let us look to our next problem. Now here also there are some results from a standard compaction test. Now we will see here basically it is given in terms of mass of compacted soil and the water content or the moisture content. So, the mass of the soil in terms of grams is given as 1920.5, 2051.5, 2138.5, 2147.0, 2120.0, and 2081.5. The corresponding moisture content or water content at 11%, 12.1% this is in percentage, 12.8%, 13.6%, 14.6%, and 16.3%.

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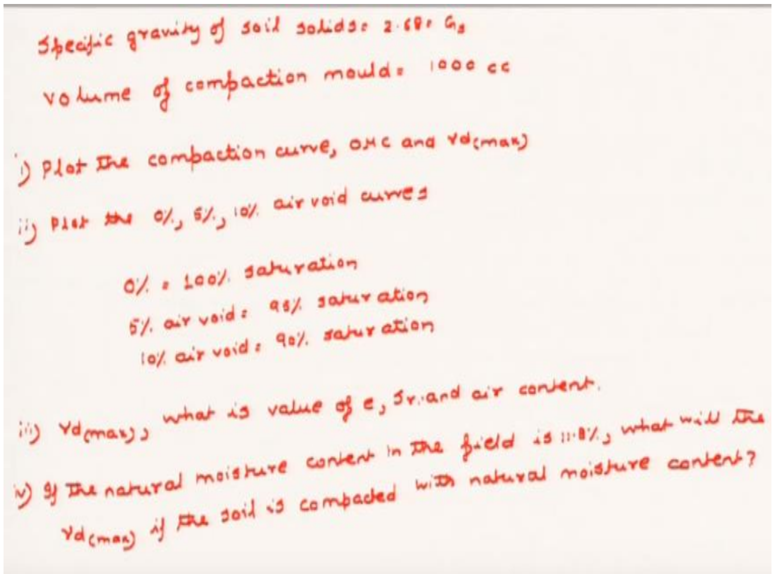

Now here the specific gravity of soil solids is equivalent to 2.68 that is this is equivalent to G s and the volume of compaction mould is equivalent to 1000 cc. So, here the first question is again asked to plot the compaction curve and find out the OMC and gamma d max, the optimum moisture content, and the maximum dry density. Similarly, here in the second part it is asked that plot the 0%, 5%, 10% air void curves.

Now this is the thing that we have covered in the previous question. These are all the this air void comes as the equation of gamma d by gamma w 1 - a into gamma s by gamma s w + gamma w. So, we are going to utilize this formula in the next problem. Now this 0 percent curve means 0% air void curves means basically it is a 100% saturation line that means basically here the saturation is 100%.

So, the saturation is constant and is equivalent to 100% saturation. Similarly, for 5% air voids it is equivalent to 95% saturation line and for 10% air voids it is equivalent to 90% saturation line. It is also asked to find out that at gamma d max what is the value of e or the void ratio, the S r or the degree of saturation, and air content. In the fourth part it is asked that if the natural moisture content in the field is 11.8% then what will be the gamma d max if the soil is compacted with natural moisture content that means with 11.8%.

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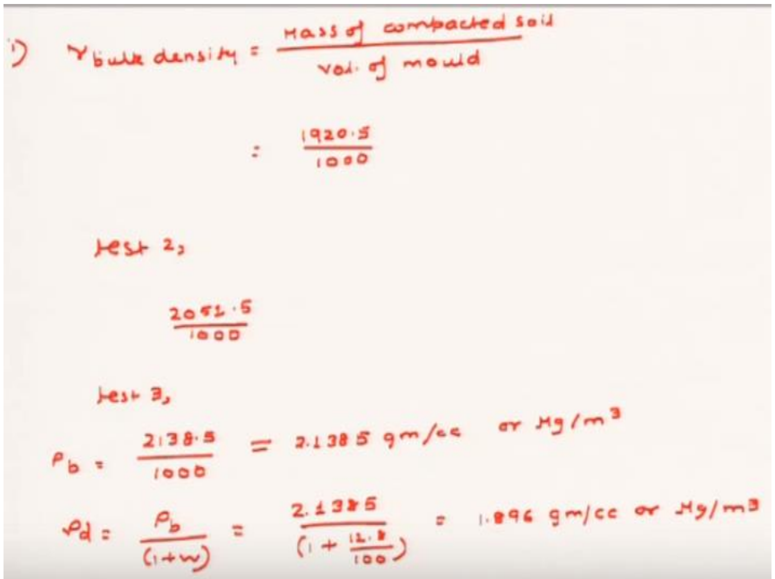

So, we are going to solve the first part. Now the first part is pretty easy because the mass of the compacted soil is given. So, basically you have to only divide it by the volume. So, once you divide it by the volume then basically you will get a figure then basically you are supposed to get a figure but basically remember that this is gamma whatever mass of the compacted soil when you divide it by volume you are going to get the bulk density you are not going to get the dry density.

So, basically you have to convert the bulk density to the dry density. So, gamma bulk density is nothing but mass of compacted soil by volume of mould. So, here it will be for the first case it will be 1920.5 divide by 1000. Now similarly for the similarly if you consider test 2 it will be 2051.5 by 12.1 by sorry by 1000. For test 3 it will be 2138.5 by 1000. All these numbers come from here 1920.5, 2051.5, 2138.5 and it is given that the volume of the compaction mould is 1000 cc.

So, we will consider test 3 right now. So, now you will have rho b or the bulk density of the soil as 2.1385 gm/cc. This is the unit that you are going to proceed or there is one more unit which basically is equivalent to gram per cc which is milligram per meter cube megagram per meter cube. Now as I have said that this is the bulk density of the soil. So, from the bulk density now you have to find out what is the dry density because the proctor compaction curve is a plot of dry density versus the moisture content.

So, the dry density now you can find out as rho d equivalent to rho b by 1 + w. So, this will be equivalent to 2.1385 divide by 1 plus now the corresponding moisture content is 12.8. So, 1 + 12.8 by 100. So, this is equivalent to 1.896 gm/cc or Mg/m cube. Now this is done.

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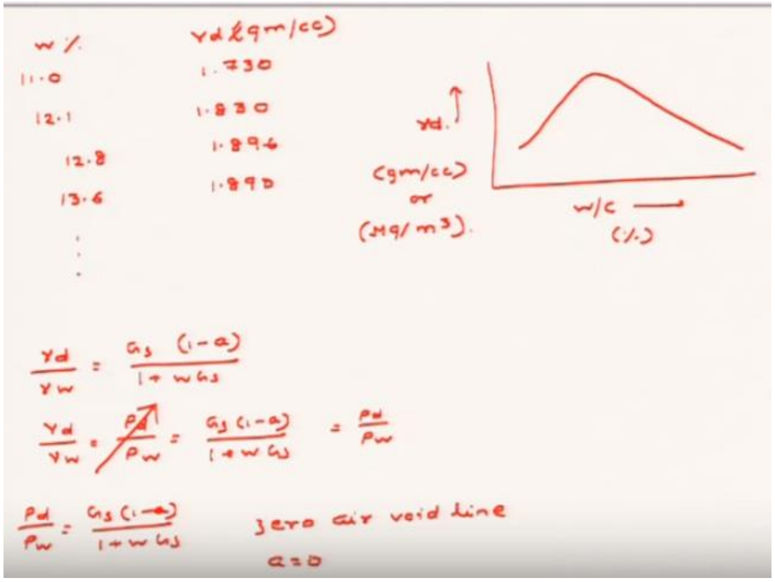

Now you have to plot the plot of water content versus the dry density. So, you will get a list of water content like let us say for the dry density from 11 let us start with the moisture content of 11 because 11 is the starting moisture content here. So, for 11 you will get the dry density of 1.730. Similarly, for 12.1 you will get 1.830. For 12.8 we have already got the moisture content as 1.896 this is in gram per cc. Similarly, for 13.6 this is 1.890 and like that.

So, if you plot the proctor compaction curve it is going to show a curve like this where this is going to be the gamma d and this is going to be the water content. This is going to be in percentage while this is going to be in gram per cc or megagram per meter cube. Now in the next question we are asked to plot the 0%, 5%, and 10% air void curves.

Now using this 0%, 5%, 10% air void curves we are going to utilize the formula that you have derived gamma d by gamma w is equal to 1 - a into gamma s by gamma s into w + gamma w. So, gamma d by gamma w is equal to G s into 1 - a divide by 1 + w into G s.

It is similar to this formula except that I have divided it by gamma w in every case because if you divide it by gamma w in every case then it comes out to be 1 - a into gamma s by gamma w by gamma s by gamma w into w + 1 which is equivalent to 1 - a into G s by G s into w + 1 and that is the same formula that I have written here. So, this is so a corresponds to the percentage as we have said that a is nothing but the volume of air, a is nothing but the volume of air V a.

So, it is similar it is already told that what is the volume of air for 100% saturation line the volume of air is going to be 0. So, gamma d by gamma w or basically you can write it in the format of rho d by rho w is equal to G s into 1 - a into 1 + w G s this I will cut off because gamma d will precede with gamma d by gamma w or you can write it in the format of rho d by rho w that is rho d by rho w is equivalent to G s by 1 - a into 1 + w into G s. Now for 0 air void line a is equivalent to 0.

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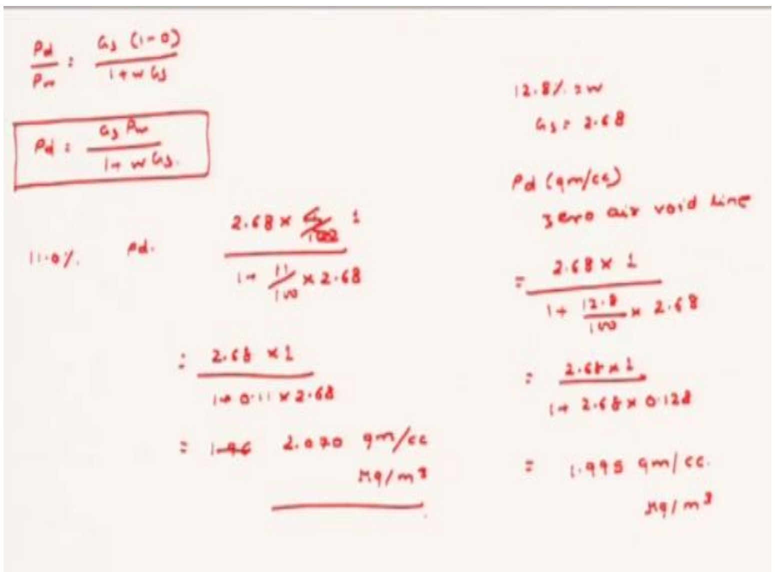

So, we get rho d by rho is equal to G s to 1 - 0 by 1 + w into G s. That is rho d is equal to G s into rho w by 1 + w into G s. So, this is the formula for zero air void curve. Now here the saturation is always 100 percent and this is equation for the 100 percent saturation line. So, for different so now for different water content let us say that basically if your water content is 11%.

Then in that case for zero air void line you will get rho d as G s is already said to be 2.68 so 2.68 into rho w is 11%. So, 11 by 100 divide by 1 plus sorry this is not 11 by 100 this is rho w rho w is if it is in gram per cc because we are all writing in terms of gram per cc so 2.68 into 1 to 1 + 11 by 100 into 2.68. Now this comes out to be 2.68 into 1 divide by 1 + 0.11 into 2.68 which comes out to be 1.96 sorry 2.070 gm/cc or Mg/m cube.

Similarly, if it is like 3% air if it is like 12.8% moisture content so I will show with another calculation like 12.8% is the w. G s is again given to be 2.68. Then rho d in terms of gram per cc for zero air void line would be equivalent to 2.68 into 1 because the density of water is 1 gm/cc divide by 1 + 12.8 by 100 into 2.68 which is nothing but 2.68 into 1 by 1 + 2.68 into 0.128 which is equivalent to for the 12.8% is equivalent to 1.995 gm/cc or Mg/m cube unit, so w for you. So, this is for the zero air void line.

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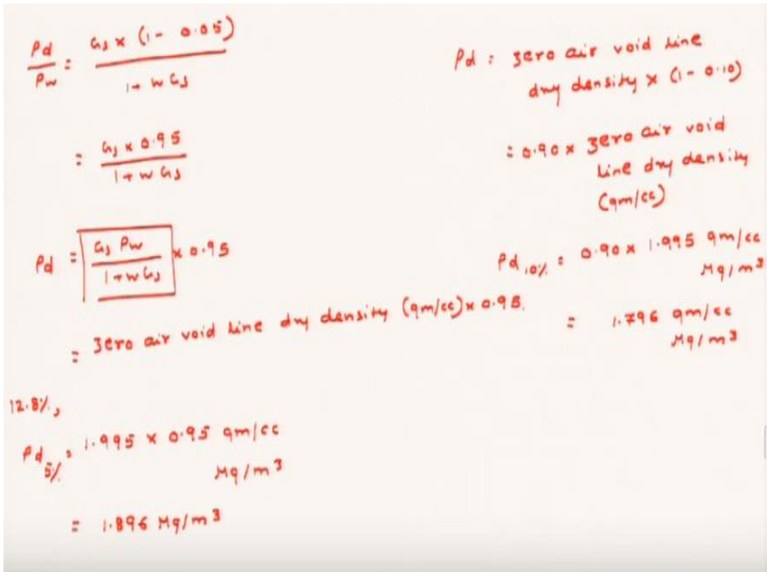

Similarly, for 5% air void line it will be equivalent to rho d by rho w is equal to G s into 1 - 0.05 because the volume of air now is 5% so it is equivalent to 1 - 0.05 1 + w into G s. So, G s into 0.95 into 1 + w G s. Now we already know that rho d into G s into rho w 1 + w into G s into 0.95. This term is actually equivalent to this term is equivalent to the zero-air void line. So, you can write it simply that zero air void line dry density unit in gram per cc multiplied by 0.95.

So, for let us say for 12.8% water content the third part it will be equivalent to 1.995 rho d. For 5% will be equivalent to 1.995 into 0.95 gm/cc or Mg/m meter cube whichever unit is again suitable to you it will come to 1.896 Mg/m cube. Now for the similarly for 10 percent it will be equivalent to rho d is equal to zero air void line dry density into 1 - 0.10 so it is equal to 0.90 into zero air void line dry density in gram per cc.

So, for the same 12.8% rho d, 10% will be equivalent to 0.90 into 1.995 gm/cc or Mg/m cube which is equivalent to 1.796 gm/cc or Mg/m cube. So, for every moisture content given here that is for 0%, 5%, and 10%, for 100% saturation, for 95% saturation, for 90% saturation you have to plot the dry density you have to plot the zero air you have to plot all these curves. Now the water content is given to you. It varies from 11 to 16.3. Corresponding to that the dry density has to be found out for all these cases, for 0% air void, for 5% air void, and for 10% air void curves. Now I have shown a sample calculation for 12.8% so for all these moisture contents if you find out what are the air void curves then they would look similar to this figure.

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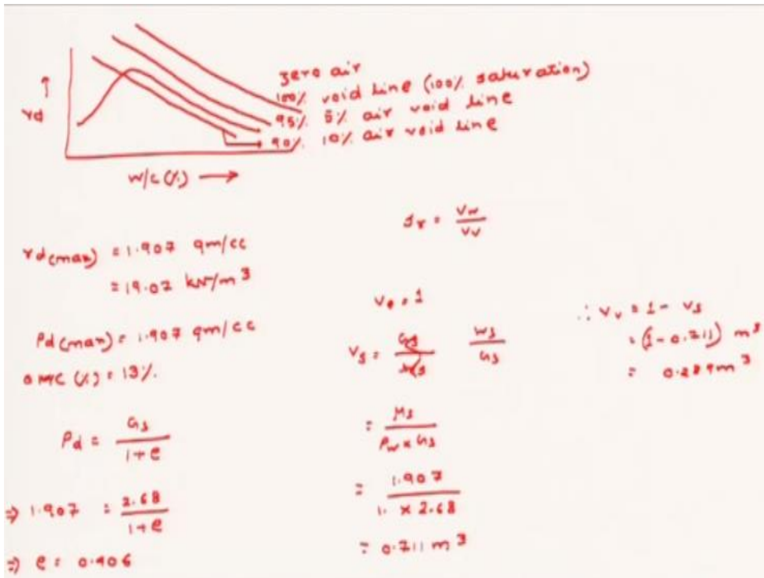

This is our compaction curve. So, this is where the zero-air void line lies as I have said that theoretically a zero-air void line can never touch a compaction curve. So, this is your zero-air void line which basically is a line of 100% saturation. This is water content in percentage while this is the dry density. Now this is our 90% saturation line or basically the 10% air void line and here lies the 95% saturation line or the 5% air void line.

So, this is how the figure looks like and all these points correspond to the water content that is given in the question that is 11, 12.1, 12.8, 13.6, 14.6, and 16.3 respectively. Now the third question that is asked is that what is at gamma d max what is the value of e, S r and the air content. So, we are going to discuss that. Now at moisture content now let us say that at what is your gamma d max.

The gamma d max is found out to be the gamma d max or the moisture content is found out to be 1.907 this is in gram per cc but actually this is unit weight so basically it will be 19.7 kN/m cube. So, since we have proceeded with gram per cc so we will proceed with rho d max. So, this is equivalent to 1.907 gm/cc. The corresponding optimum moisture content is found out to be or the OMC is found out to be 13%.

Now we know that rho d is actually equivalent to G s by 1 + e. So, G s is already given to you as 2.68. So, this is equivalent to 2.68 by 1 + e into 1.907. So, from here you can find out the value of e as 0.406. Similarly, if you go for the degree of saturation that is volume of water divide by volume of voids. Now how do you find out the volume of voids? Now for the volume of voids we already you can assume that the just like the previous class we have told that in the volume of voids you can assume the total volume to be 1 and then you can proceed.

So, in this case if we assume the total volume to be 1 then what is then how do you find out the volume of solids. Now volume of solids we already know is nothing but G s by the weight of the solids sorry W s by the G s. Now W s is again equivalent to M s rho w into G s. So, the mass of solids is 1.907 because at dry density we all know that it only consist of solids and air. So, the mass of the solids at that point the mass of the soil mass at that point is equivalent to the mass of the solids divide by 1 into G s is given as 2.68.

So, the volume of solids comes out to be 0.711meter cube. So, since the total volume is assumed to be 1 the total volume is assumed to be 1 so the volume of voids is assumed to be 1 minus volume of solids which basically is equal to 1 - 0.711meter cube which basically is equivalent to 0.289 meter cube. Now you can find out in this way or basically there is one more easier way. But basically, we will find out what is the bulk density first.

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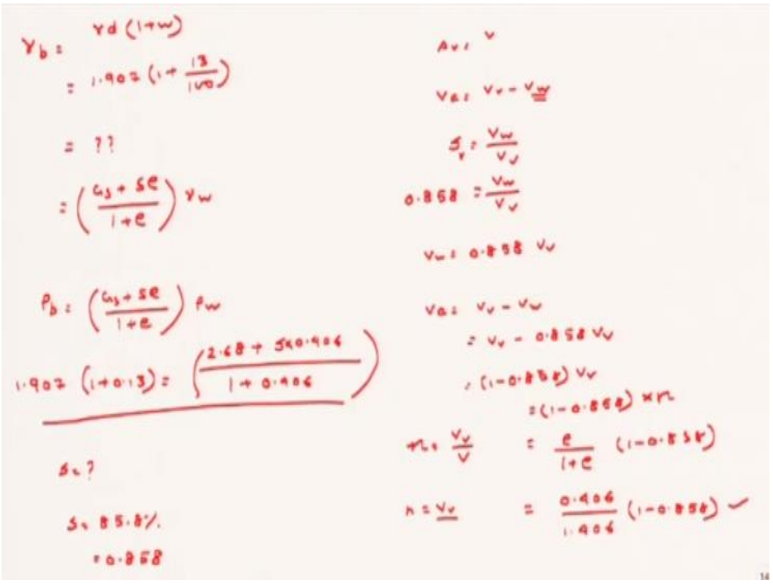

So, bulk density is equivalent to gamma d into 1 + w. Now we already know that gamma d or rho d is actually is for the maximum moisture content is actually 1.907 gm/cc and the optimum moisture content is 13. So, 1.907 into 1 + 13 by 100 is equivalent to now gamma bulk can be written as G s plus S e by 1 + e into gamma w or rho bulk can be written as G s + S e by 1 + e into rho w.

Now rho bulk is already known to us. Rho bulk is 1.907 into 1 + 0.13 and this G s is 2.68. So, 2.68 + S e is known at that point which we have calculated as 0.406. So, 0.406 1 + 0.406 and density of water is known to us as 1 gm/cc. So, this is how you find out the value of degree of saturation. Now the degree of saturation is known to us. Now the third question the last question that is asked to us is that the what is the volume of the air content.

Now if you know what is the volume of voids then obviously you can find out the volume of air content as well. Now the volume of air content can be found out as volume of the volume of air content is actually equivalent to volume of voids minus volume of water. Now if you know the volume of water as we have already calculated the volume of solids if you know what is the volume of water then basically from there you can find out what is the air content is or basically you can find out from the degree of saturation itself because degree of saturation is volume of water by volume of voids.

Now the degree of saturation from here if you find out which basically comes out to be 85.8% here the degree of saturation comes out to be 85.8% or 0.858. So, 0.858 into volume of water by volume of voids. Now volume of water is equal to 0.858 into volume of voids. So, volume of air is equal to volume of voids minus volume of water basically is equal to volume of voids minus 0.858 into volume of voids.

So, 1 - 0.858 into volume of voids. Now volume of voids you can find out from porosity itself where porosity itself says that porosity or basically from porosity itself where porosity says that it is equivalent to V v by V where you assume the volume total volume of the soil to be 1. Now the porosity itself is the volume of voids. So, this can be found out as 1 - 0.858 into 1 into n okay.

So, if you know the value of void ratio if you know the void ratio from there you can find out the porosity from the relation e by 1 + e. So, 1 - 0.858. So, the e is given as 0.406 so 0.406 into 1.406 into 1 - 0.858. So, this is what is the volume of air actually mean that the total volume of the soil is equivalent to 1 meter cube or 1 centimeter cube whatever but unit volume of the soil is taken.

So, we have discussed about how to plot the zero air void lines how to plot the compaction curves and basically, I have also discussed that how basically you can how the why the theoretical how the theoretical zero air void line does not match with the compaction curve. Now in the next part we are going to discuss a practical problem or a general practical problem that how are you going to apply the compaction in the field because many real-life situations actually require compaction.

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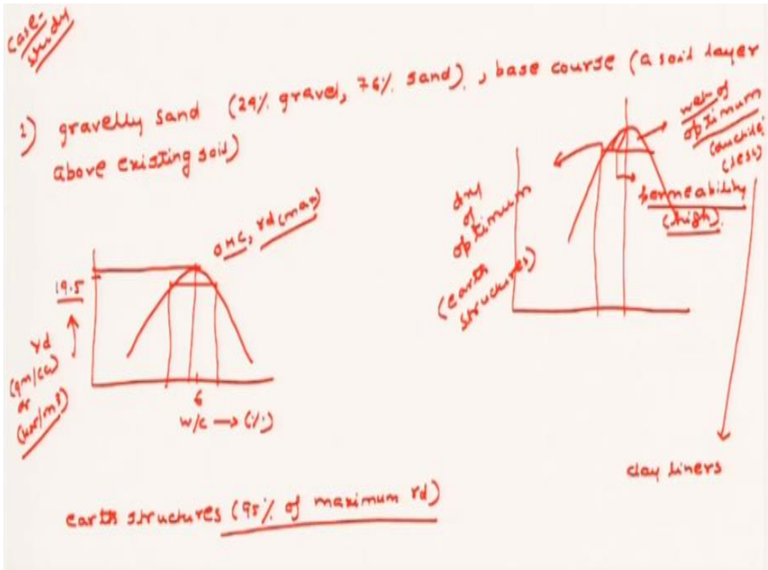

So, if basically a compaction curve is given to you then basically how do you actually consider a compaction curve and what type of compaction you are going to use. So, the type of compaction that you have so let us consider a compaction curve for a gravely sand. A compaction for the gravely sand is actually given to you that basically consist of 24% gravel and 76% sand. Now this is to be used as a base course.

A base course means a soil layer above the existing soil basically it is used in case of pavements in case of highway embankments or pavements. So, I am going to write that here soil layer above existing soil. So, we have the compaction curve like this but basically the maximum moisture content this is 6% and this is 19.5%. So, the maximum moisture content is somewhere here.

This is the OMC. This is the water content in percentage and this is the gamma d in gram per cc or kilo newton per meter cube. But here it is in kilo newton per meter cube. So, this is the OMC the optimum moisture content and the corresponding gamma d max. Now the question is asked that basically what is the compaction criteria for the field that means what type of compaction you are going to use or which point you are going to use, are you going to compact it on OMC or basically are you going to compact it in the dry in on the left side of OMC or on the right side of OMC.

Now here you have to know that this left side and right side of OMC are very important because in most of the earth in most of the earth structures if you consider any earth structure like let us say embankment or any other case like embankments or basically let us say footings in those cases basically they generally go for a 95% of maximum gamma d. This is a common practice that is mostly used.

Now in other cases in other cases basically you can also go for dry optimum. Now this level of compaction this 95% of compaction as can you see from the compaction curve this 95% of compaction can be achieved in 2 points. One after the compaction while one while one after the OMC while one before the OMC. Now if you consider the point which is before the OMC this is called the dry side of optimum.

So, this is the 95% of compaction. So, this part is called the dry of optimum this part. While this part is termed as the weight of optimum. So, which 95% proctor compaction you are going to take, the dry of optimum or the weight of optimum. Now generally normal practice is that in most of the earth structures you are supposed to compact it at the dry of optimum because in dry of optimum it is dry of optimum there are many advantages like the first advantage is being the permeability of the soil is pretty high here.

While on the other hand if you conduct in the weight side of optimum then the material may be ductile but it is pretty the permeability is pretty less. So, that is why this weight of optimum is mostly used for clay liners mostly for low permeability soils like let us say swelling soils for wasteland covering for wasteland field so that the leached or the gas does not escape. In all those cases generally the weight of optimum side is used while dry of optimum is mostly applied for earth structures.

So, in this cases so in this cases basically since we are supposed to you are given a gravely sand you are given a gravely you are given a gravely sand so the first important part is that basically first important thing that you are going to say that which part which side of compaction you are going to use. Now as I have said there is a base course so basically you are going to use on the dry side of optimum.

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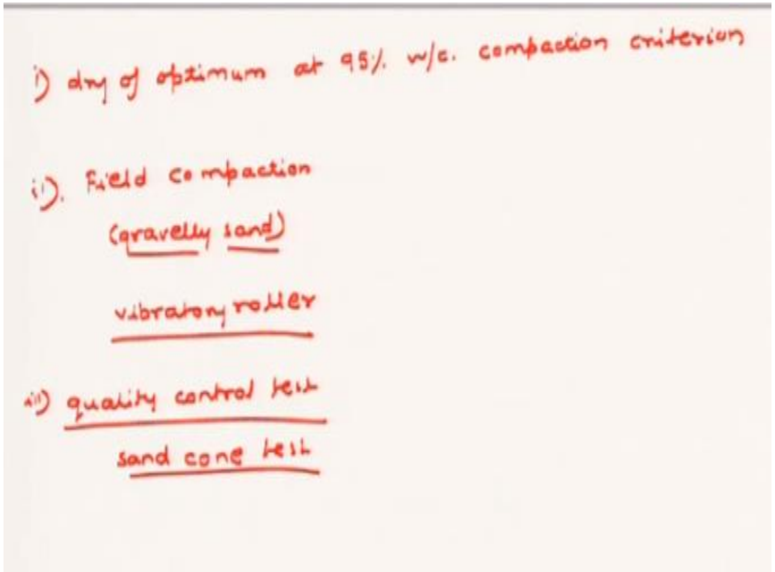

So, the first question is that on dry of optimum at 95% moisture content or 95% water content you are going to use the we are going to use we are going to use the compaction criteria. The second question is asked recommend field compaction equipment that now what is the they have asked the recommend field compaction equipment that would achieve the desired compaction.

So, they have asked about the field compaction equipment. Now what type of field compaction equipments are used. Now as you have already gone through the compactment you have gone through the compaction course you have already know that there are many types of rollers like vibratory rollers, slip rollers then basically the standard methods of compaction as well like deep dynamic compactions so which type of field compaction do you prefer.

Now again you have to remember here that it is a gravely sand. So, generally a sand type of thing is generally compacted by a vibratory roller. So, here also the most since it is a sand type of thing and gravely type of thing it is a coarse-grained soil so basically by adding water or basically by using tamping method will not work. So, here you are going to use a vibratory roller. The final part that is asked is basically specify an appropriate quality control test.

Now a quality control test means that basically you are supposed to use a density test. So, basically the most important type of density test that basically you are going to use here that basically will not that will require less labor is basically the sand cone test. Now a sand cone test has already been taught so I am not going to cover the details here. So, this is how basically in a case study you are going to solve a problem.

So, if a compaction curve is generally given to you and you are supposed to find out that what type of compaction you are going to offer this is how your judgment should be that basically depending on the type of soil first whether it is a coarse grained soil or a fine grained soil you are going to use the dry of optimum or the wet side of optimum whether it is a clay liner or basically its earth structure depending on that you are going to use the dry side of optimum or the wet side of optimum.

Here it is basically it is a gravely sand so basically, we have used the dry side of optimum here and generally it is always specified to use the 95% compaction 95% relative compaction. So, that is what I have also said here and next we are going to use that whether depending on the gravely sand whether you are going to use a depending on whether it is a coarse-grained soil or fine grained soil you are going to use whether it is a vibratory type of compaction or basically it is a tamping method.

So, basically since it is again a gravely sand we have used a vibratory roller here and generally a quality control test that basically is always mostly a sand cone test and sometimes different types of tests in nuclear densitometer is also done. So, today we have covered all the compaction part and in the next class basically we are going to discuss the permeability part along with a little compaction and other case studies. Thank you.