Geology and Soil Mechanics
Prof. P. Ghosh
Department of Civil Engineering
Indian Institute of Technology Kanpur
Lecture - 05
Index Properties of Soil - C

Welcome to the course Geology and Soil Mechanics. So, in the last lecture as you have seen we took one problem and the problem was on this topic.

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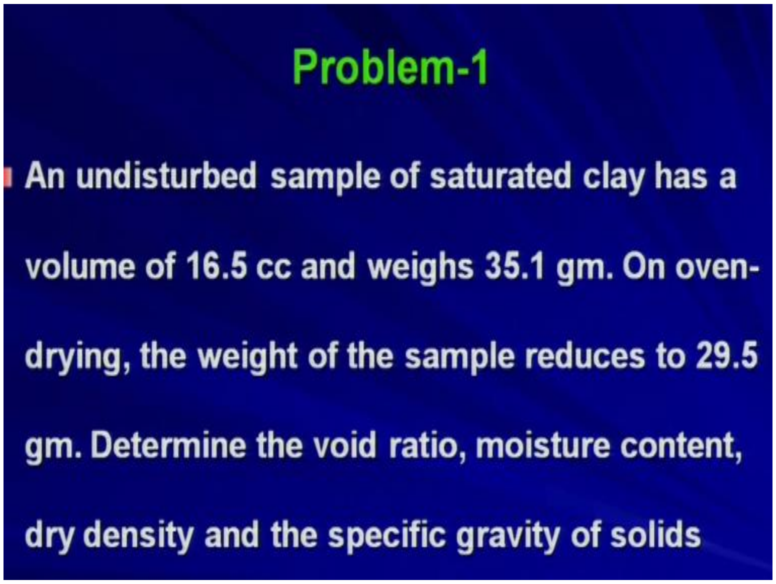

That an undisturbed sample of saturated clay has a volume of 16.5 cc and weighs 35.1 gm. On oven drying the weight of the sample reduces to 29.5 gm. Determine the void ratio, moisture content, dry density, and the specific gravity of solids. So, this problem was taken in the last lecture where we solved the problem by a method, method 1.

So, as we promised in the last lecture that we will be solving the same problem by some other method using the phase diagram whatever you have seen in the previous lectures and that is more fundamental coming from the basic so your understanding will be more better if you consider the phase diagram. So, let us see if you solve the problem by using your method 2.

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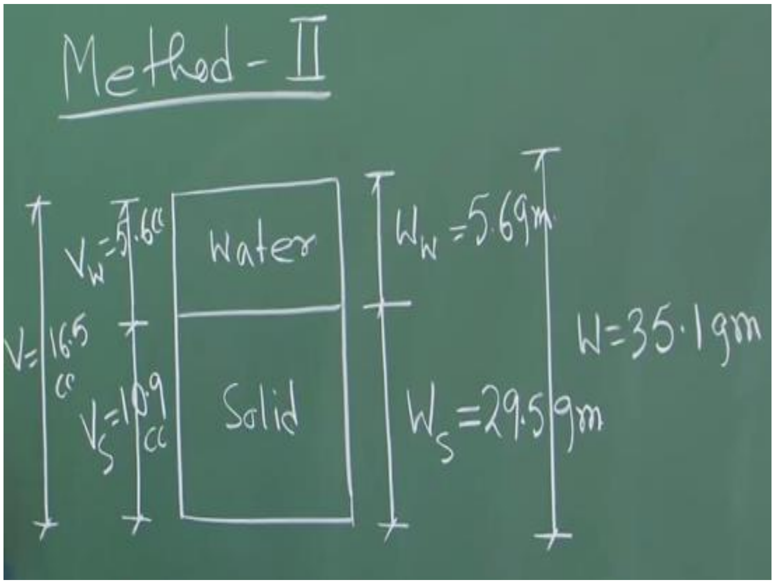

So basically, let us draw the phase diagram first for this kind of saturated soil. So, your, so as you know so this is a completely or fully saturated soil. So, your phase diagram, 3-phase diagram will be boiling down to the 2-phase diagram that means water and soil solids. So, you have water and solid and on this side, you have the wet scale. So, this is your weight of water and this is your weight of solid and on this side, you have the volume scale, volume of water and volume of solid and the total volume is say V which is equal to 16.5 cc. So that is given in the problem and the total weight if you look at the problem, the total weight is also given that is 35.1 gm okay.

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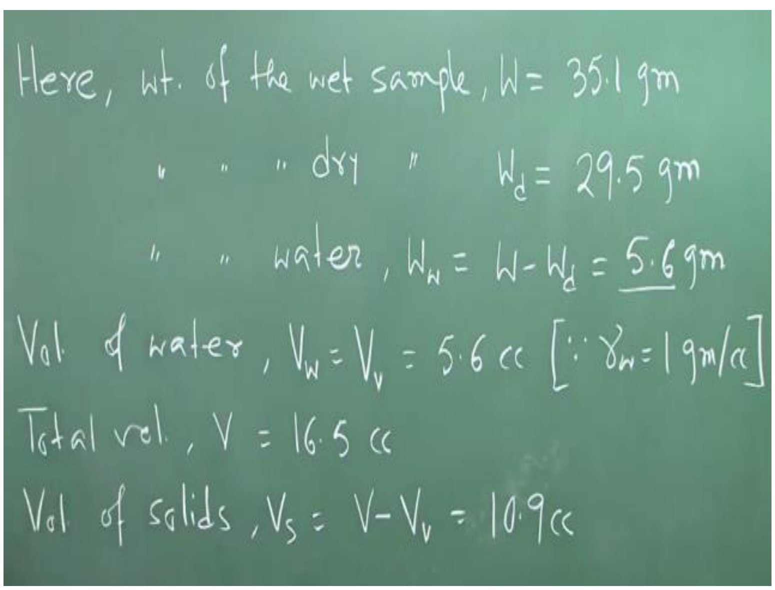

So here weight of the wet sample W is nothing but your 35.1 gm right. So, this is the total weight of the sample okay. Then weight of the dry sample which is nothing but W d is your 29.5 gm. As it is given in the problem itself if you see that on oven drying the weight of the sample reduces to 29.5 gm. That means whatever water was there in the sample so that has been evaporated and that has been removed from the sample and ultimately you have got the dry unit weight I am sorry dry weight of the sample W d is equal to 29.5 gm. So, weight of water which was present in the sample which was nothing but W w is 5.6 gm.

So, let us complete the phase diagram then. So, your now you have got W w is 5.6 gm and W s is 29.5 gm okay. Now what will be the volume of water then which was present in the sample? So, volume of water is nothing but your volume of voids. So, we can write because that is fully saturated, the all void spaces were occupied by the water.

So V w is equal to V v which is nothing but 5.6 cc because this is your weight and if we consider the unit weight of water is 1 gm per cc then you will be getting V w is nothing but equal to V v that is volume of voids is equal to 5.6 cc. So, I can write this is 5.6 cc. Then the total volume V so you can make a note here that your gamma w is 1 gm per cc and that is why your, if that is the assumption we are, not assumption, basically it depends on the temperature but we are considering gamma w is 1 gm per cc for my problem.

So ultimately you have got the volume of water like this. So, total volume V is given as 16.5 cc as you can see on the left-hand side of the phase diagram okay. So, your volume of solids therefore will be coming as V s is equal to V minus V v which is nothing but 10.9 cc. So now you complete this part 10.9 cc okay. So, you have got all the things, volume of water which is nothing but the volume of voids, you have got as 5.6 cc; volume of solids you have got 10.9 cc; and weight of water is 5.6 gm, whereas weight of solids is your 29.5 gm okay.

So, after getting that then what are things you need to find out? As before void ratio, moisture content, and what else dry density and the specific gravity. So, these 4 things you need to obtain. So, let us see how we can obtain those things from this I mean parameters.

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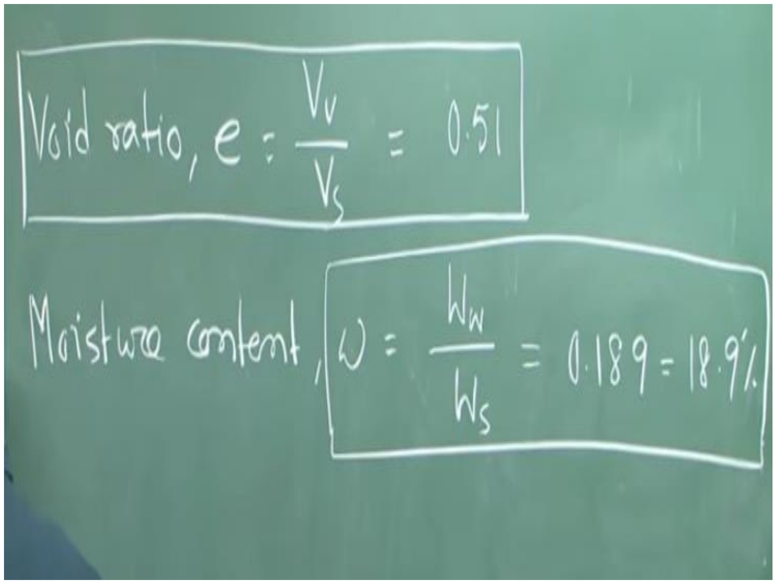

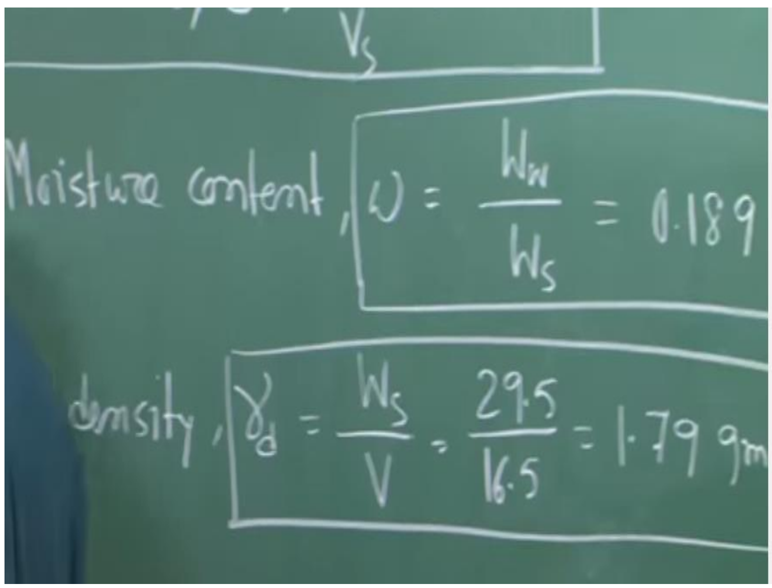

So, your void ratio e is given by, very simple, V v by V s so V v by V s. Now you know both the terms. So, what is your V v? V v is nothing but 5.6 cc. What is your V s? V s is nothing but 10.9 cc. So, if you put the value you will be getting void ratio e is equal to 0.51. So, you can match this value with your previously obtained value by using method 1 okay. So therefore, the moisture content is given by small w is equal to W w by W s, very simple.

So basically, in the method 2 you need not to remember the relation, whatever relation we have seen in the last lecture that you have established some relation of e or moisture content or something like that but you need not remember all those things for method 2 because you are coming from the basic, coming from the phase diagram. So, everything or if you need to know only the simple definitions or the fundamental definitions. So, your if you put now, what is your

W w that is 5.6 gram and what is your W s, 29.5 grams. So, if you put the value you will be getting 0.189 which is nothing but 18.9% okay. Now find out dry density. Gamma d is equal to W s by V, very simple. So, W s is the weight of solid by the total volume so that is nothing but your gamma d and if you put the values 29.5 by 16.5 it will be coming as 1.79 gram per cc. Now which one is left, the specific gravity. So, let us find out the specific gravity.

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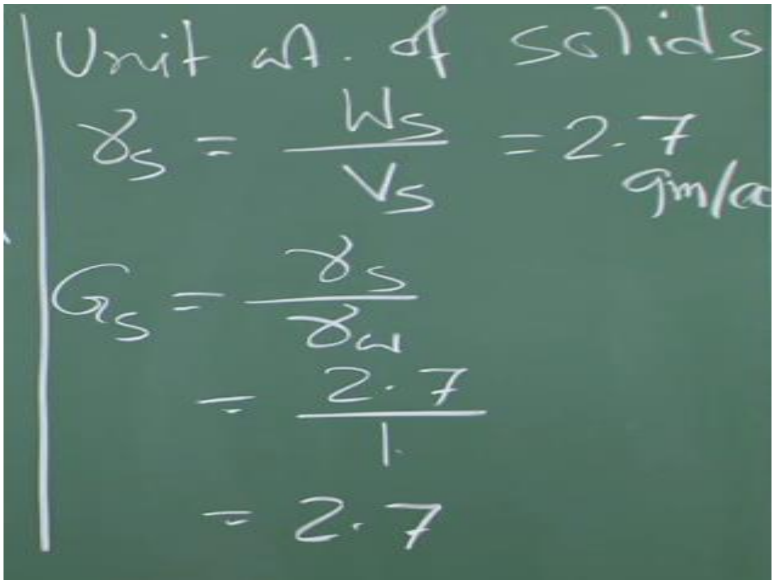

So, your unit weight of solids gamma s can be obtained by this definition, very simple right, W s by V s. So, if you put the values you will be getting this as 2.7 gram per cc. So therefore, specific gravity G s, what is G s that is gamma s by gamma w. So, gamma s is your 2.7 and gamma w we are considering 1. So, you will be getting 2.7 is your specific gravity. So, this is the whole problem.

The problem I mean whatever problem we have taken, the problem 1, so that problem has been solved by 2 different methods. In one method, in the first method basically you have seen some you need to establish or need to remember some relation among the parameters whereas the method 2 describes the problem starting from the basics which is nothing but your phase diagram okay. So, we will take the next problem.

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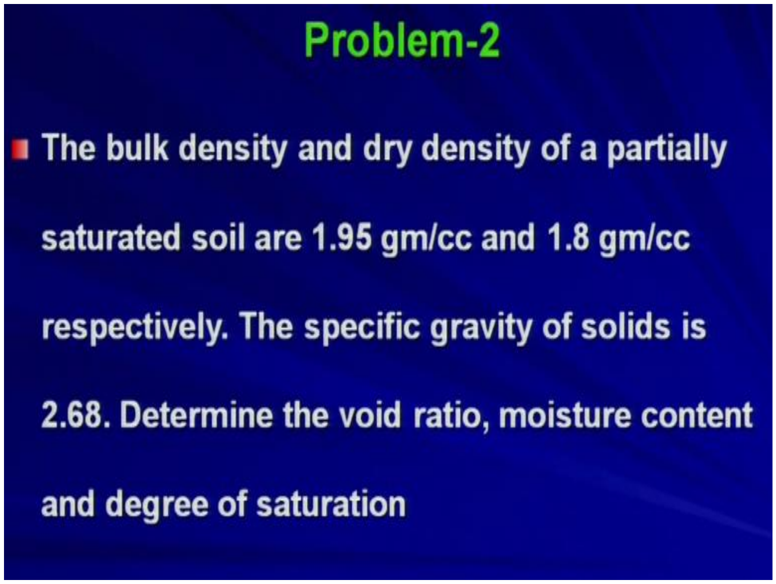

So, we will take the next problem that is problem 2. The problem 2 says the bulk density and dry density of a partially saturated soil are 1.95 gm/cc and 1.8 gm/cc respectively okay that is bulk density and dry density okay. The specific gravity of solids is 2.68. Determine the void ratio, moisture content, and degree of saturation okay.

So basically, when we are talking about the bulk density and dry density and if I consider the bulk unit weight and dry unit weight they are related like the in terms of G as I told you, the acceleration due to gravity anyway. So basically, this problem says that is bulk unit weight is 1.9 gm/cc and dry unit weight is 1.8 gm/cc if you consider in the unit weight term, so anyway. So, let us solve this problem.

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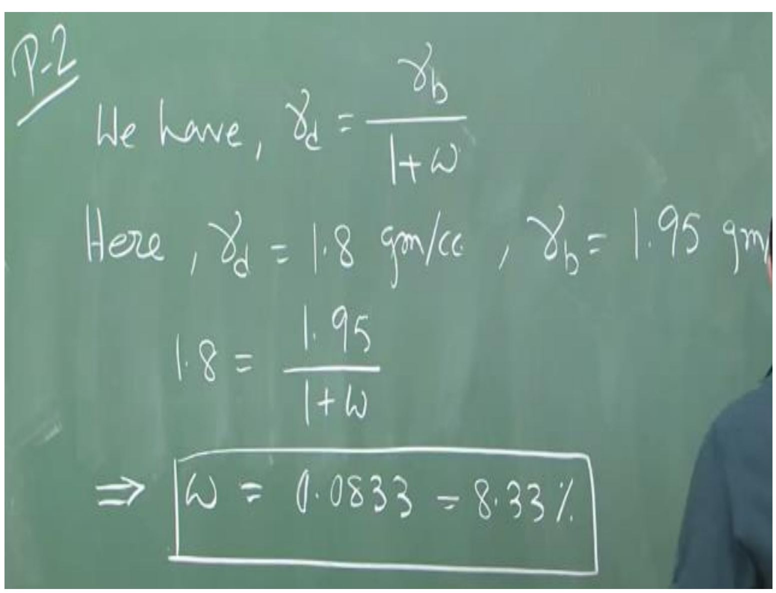

So, problem 2. We have gamma d that is the dry unit weight is nothing but bulk unit weight by 1 plus moisture content W right. So, this relation you can establish. So, it is not the new relation or it is not the empirical thing. Basically, from the basic definition of gamma d and gamma b as well as the moisture content you can establish this relation though I am not talking about those relations specifically, but any textbook or whatever textbook I have suggested from there you will be getting this relation and you can establish this relation okay.

So here gamma d is 1.8 gm/cc and gamma b is your 1.95 gm/cc. These things are given in the problem. So, if you look at the problem these 2 parameters or these 2-unit weight or the density value are given okay. So, if you put these values in this expression then basically from this expression you will be getting 1.8 is equal to 1.95 by 1 plus W that is the moisture content. So, from this you will be getting W is equal to which is nothing but 8.33% okay.

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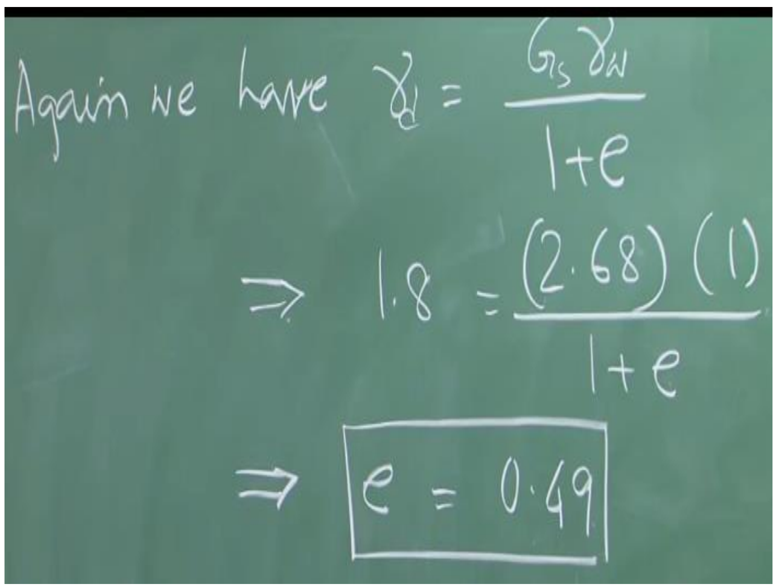

Now again we have gamma d is equal to again this relation can be established by following the simple definition of these parameters. So, gamma d is equal to G s that is the specific gravity multiplied by gamma w by 1 plus e. So, in this expression if you put the values 1.8 is equal to 2.68 that is given in the problem and gamma w we are considering 1, 1 plus e. So, from this expression you will be getting e is equal to 0.49. So, the void ratio of the sample is 0.49. So, we have got 2 things, void ratio as well as moisture content we have determined. Now degree of saturation that is s. So, degree of saturation is basically related with this relation.

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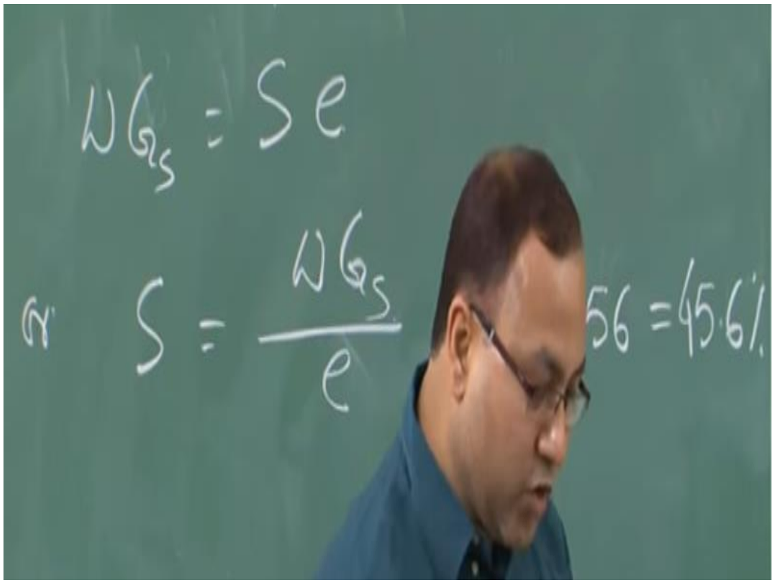

Again, you can establish that, moisture content multiplied by the specific gravity is equal to degree of saturation multiplied by e. So, I am not showing the derivation as I told you before it can be derivable and you can derive it by yourself if you know the definition of all those things. So, your degree of saturation is nothing but moisture content multiplied by the specific gravity by e. If you put all the values whatever you have obtained just now you will be getting 45.6%. So that means this is partially saturated soil and the degree of saturation is 45.6%.

So, having these 2 problems the problem 1 as well as the problem 2 will give you some background or give you some idea how to solve or how to find out different parameters which are really required to define the soil property okay. Now we will be taking another problem which are based on the index properties so let us see those problems. Another 2 problems we will be considering.

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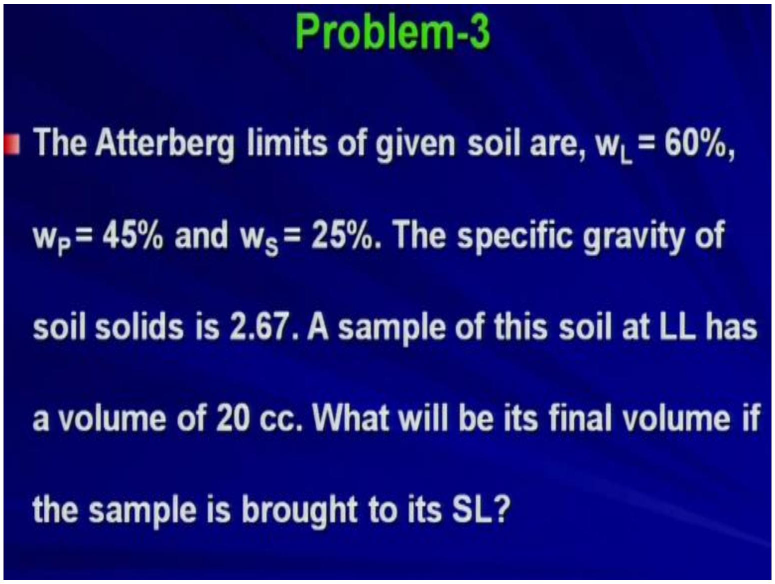

Okay, so next problem we will take and this on the index properties of soil that is the Atterberg limits of given soil are the liquid limit is 60%, plastic limit is 45%, and the shrinkage limit is 25%. So, these limits are known to you. Already you have covered these thing and you know the basic meaning of these limits, liquid limit, plastic limit, and shrinkage limit.

The specific gravity of soil solids is 2.67. A sample of this soil at liquid limit that is LL, now we will be defining liquid limit as LL plastic limit as PL and shrinkage limit as SL. So, a sample of this soil at liquid limit has a volume of 20 cc. So, in the liquid limit the sample is having the volume of 20 cc. What will be its final volume if the sample is brought to its shrinkage limit.

So, you know the different limits that is liquid limit, plastic limit, and shrinkage limit. Now you know the volume of the sample at liquid limit and now you are basically taking the sample to its shrinkage limit and you want to find out what is the final volume okay. So, let us start this problem. So basically, we will be solving this problem by using our basic definition that is the phase diagram. So, the problem 3, the 3-phase diagrams of the sample at its liquid limit and shrinkage limit are shown below okay let us draw that.

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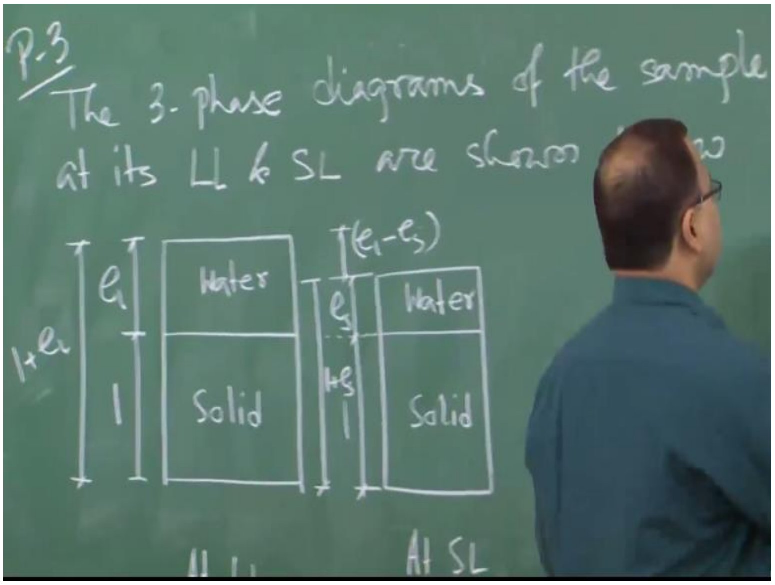

So, this is your phase diagram at liquid limit. We are considering unit volume of soil solid so 1 and the volume of water at liquid limit this is at liquid limit. So, the volume of water at liquid lime say e l so these are the things we need to find out. So, we are considering or we are assuming the soil solid volume is 1 unit, unit volume we are considering. So, your total volume will be 1 plus e l. There is no issue for that.

Similarly, if I try to draw the phase diagram in shrinkage limit, this is your solid, this is your water. So, your volume of your volume of soil solid will not change at all right, it will be remaining same. Because you are not, you are basically dealing with the same soil sample starting from the liquid limit you are coming to the shrinkage limit okay so but nowhere you are changing the soil particles.

So, the volume of soil particles will be remaining same and that is say unity okay. So, and we are considering the volume of water okay is e s at shrinkage limit. So, total volume at shrinkage limit will be 1 plus e s, very simple right. So, what is the reduction in the volume of water from your liquid limit to shrinkage limit that is nothing but e l minus e s okay. So, if you start from the phase diagram it will be very convenient to understand okay.

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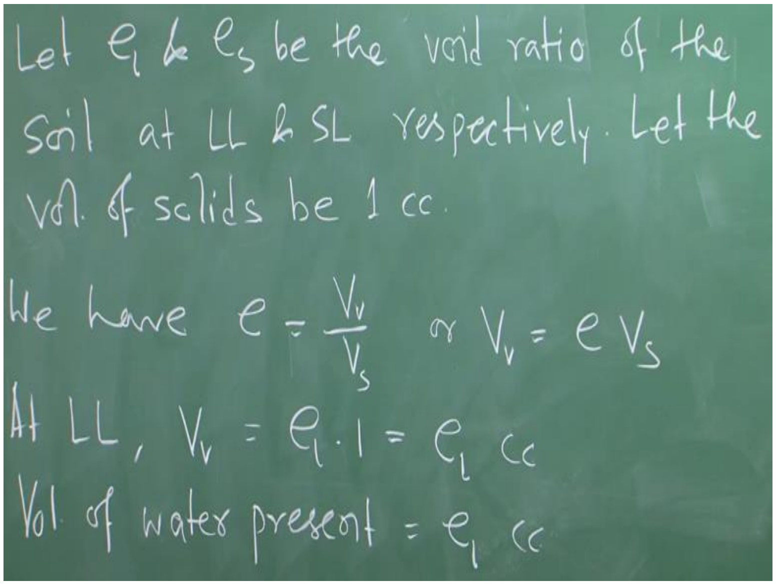

So now let us start this thing. Let e l and e s be the void ratio of the soil at liquid limit and shrinkage limit respectively and let the volume of solids be 1 cc. So, these are the things we are assuming. So, we are assuming the volume of solid is 1 cc and the void ratio at liquid limit is e l and void ratio at shrinkage limit is e s. Now you think about that.

So, what is the definition of e l then V v by V s at liquid limit okay. So, what is the volume of solid at liquid limit 1 that is already assumed, that is unity and then what should be the volume of voids. Then V v should be equal to e l. So, this is the volume of voids okay. So that is why I have written e l right. Similarly, in case of shrinkage limit, if you see this is your unity the volume of solid is say unity so your V v by V s that is nothing but your V v by V s at shrinkage limit is equal to e s.

So, e s is nothing but equal to volume of voids at shrinkage limit, very simple. So that is why we have considered unity so that we will be getting the direct interpretation of your volume of voids okay. So, we have we know that as we discussed just now, so your V v that is the volume of voids for any sample is nothing but e into V s that is the void ratio multiplied by the volume of solid okay.

So, at liquid limit is nothing but e l multiplied by 1 whatever we just talked about so that we are writing here. So, e l cc okay. This is the volume of void at liquid limit and that is coming to e l okay. Now volume of water present is therefore e l cc because the void is completely occupied by the water. So, whatever volume of void is present in the soil sample at liquid limit so that is nothing but the volume of water. So, I will keep the phase diagram for my future reference.

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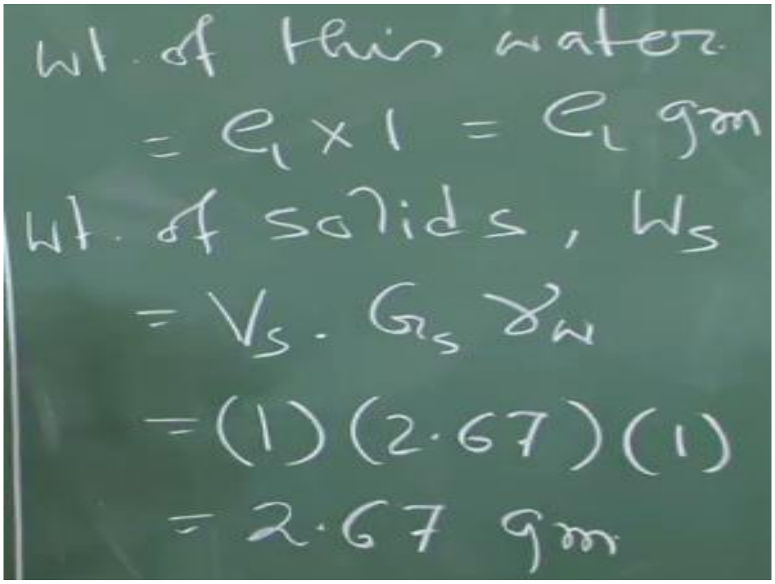

Therefore, weight of this water, whatever water is present in the voids at liquid limit is nothing but e l multiplied by 1, we are considering the unit weight of water is 1 gm/cc is equal to e l gm okay. Now weight of solids therefore is equal to V s that is the volume of solid multiplied by G s into gamma w. So, weight of solid say W s, agreed?

V s that is the volume multiplied by G s into gamma w that is nothing but your gamma s which will eventually give me the weight of solid. So, if you put the values, what is the value of solid, we have considered unity, so 1 multiplied by 2.67 multiplied by 1. So, 2.67 is the specific gravity as given in the problem. So, it is coming to 2.67 gm.

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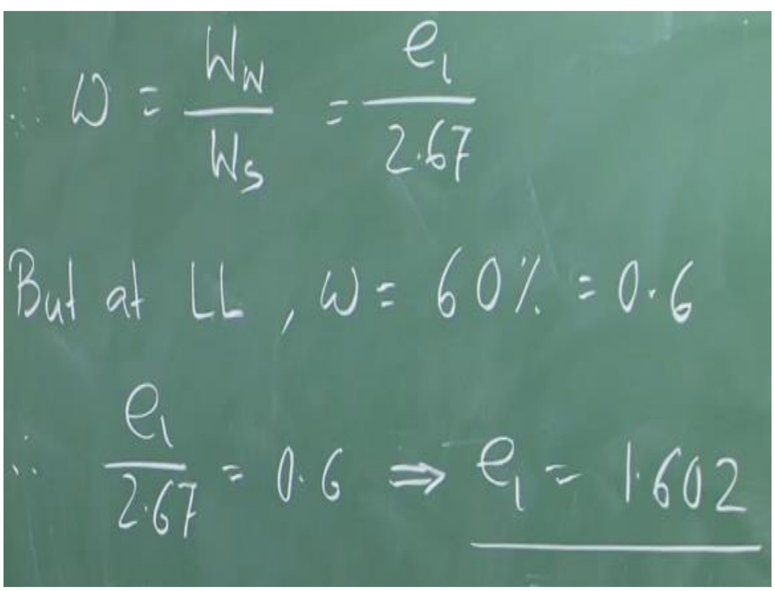

So, your water content W is given by W w by W s which is nothing but e l by 2.67 okay. But at liquid limit what was the water content? So, if you go back to the problem it says this is 60% that is nothing but 0.6 okay. So, at liquid limit this is the expression for water content and at liquid limit the water content is given in the problem as 0.6. So, we can equate these 2 e l therefore e l by 2.67 is equal to 0.6 from where I will get e l is equal to 1.602. That means the void ratio at liquid limit in the sample is 1.602. Similarly, we can find out the void ratio at shrinkage limit.

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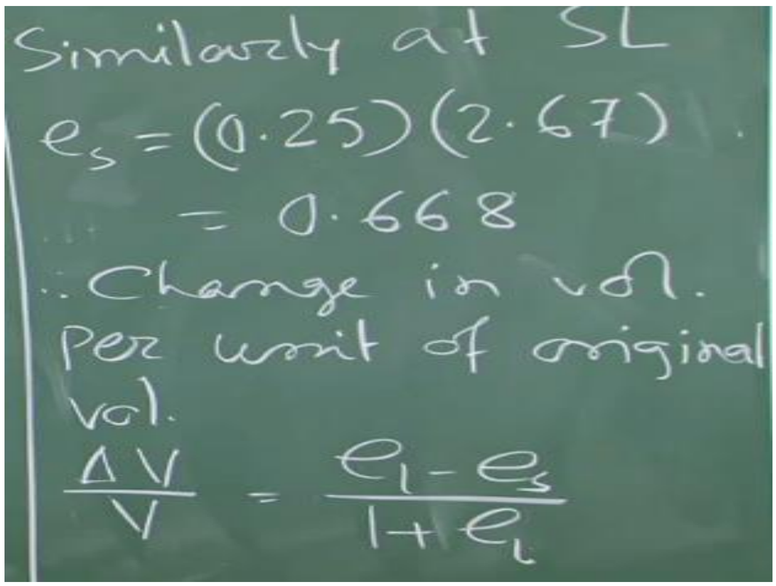

Similarly, at SL at shrinkage limit e s is equal to 0.25 that is 25% is given in the problem, that is the water content that is the shrinkage limit basically, that means the water content has shrinkage limit is equal 25% and from this we can find out the void ratio at shrinkage limit which comes to 0.668. Therefore, change in volume per unit of original volume is nothing but delta V by V which is nothing but e l minus e s by 1 plus e l. So, what is your delta V, that is the change in volume.

So, what is the magnitude of or what is the expressional change in volume? This much is your change in volume because this was the phase diagram at liquid limit or after drying cycle you are getting the phase diagram like this at shrinkage limit. So, this much is your change in volume, the reduction is volume and that is due to the evaporation of water or removal of water, but whereas your volume of solids will be remaining same, there is no change in that. So, the total volume is 1 plus e l earlier, original value original volume of the sample at liquid limit 1 plus e l, that comes here and e l minus e s is your volume of change or sorry change in volume.

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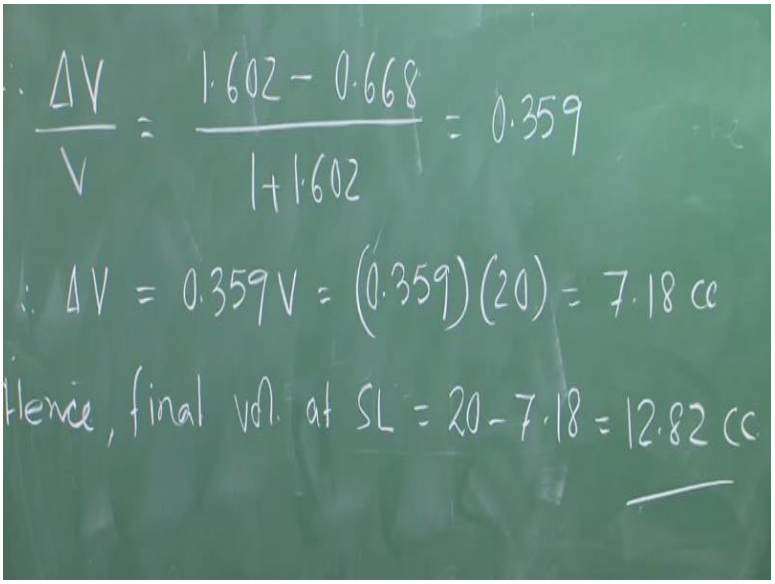

So, from this we can write down delta V by V is equal to 1.602, that is e l minus e s just now we have obtained these 2 values, divided by 1 plus 1.602 this comes to 0.359. Therefore, your change in volume is 0.359 into V and what is the volume is given at liquid limit, if you look back the problem a sample of the soil at liquid limit has a volume of 20 cc. So, this V is your 20 cc which comes to ultimately 7.18 cc.

So, this is the change in volume. Hence final volume at shrinkage limit is equal to 20 minus 7.18 which comes to 12.82. So, this is the final answer. That means the final volume at shrinkage limit okay. So now if you look at this problem, basically this problem is started with the condition what was present in the soil sample at liquid limit and from that liquid limit we come to shrinkage limit after deduction or after removal of some water and the volume earlier at liquid limit was 20 cc and at shrinkage limit it comes to 12.82 cc.

Thank you.