Geology and Soil Mechanics
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Lecture - 04
Index Properties of Soil- B

Okay welcome back, welcome back to the course Geology and Soil Mechanics. So, in the last class we have seen the sieve analysis, grain size distribution and hydrometer analysis so and then we just started the consistency of clay with an Atterberg limits.

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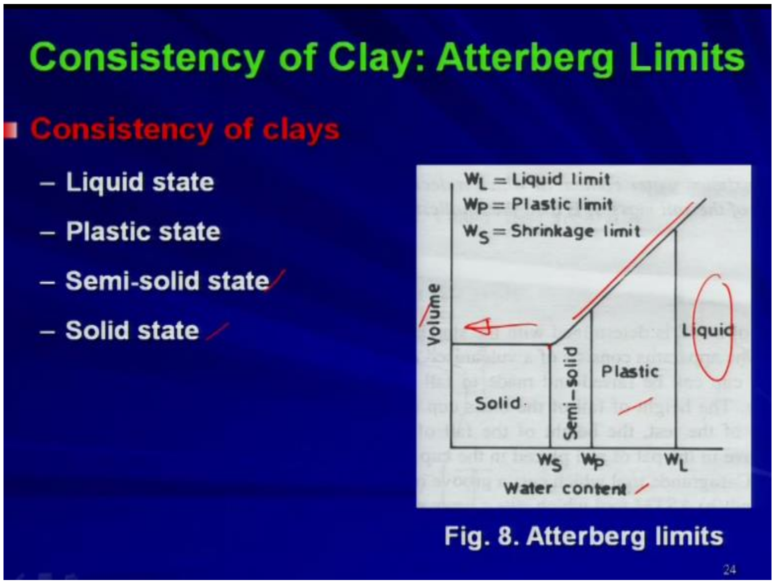

So basically, the consistency of clays is defined or is categorized by 4 state. First one is the liquid state and then plastic state and then semi-solid state and solid state. So, there are 4 state by I mean if you vary the water content or the moisture content of the soil or the clayey soil then you will be getting 4 different states and those states are defined or associated with consistency of clays.

Now basically how you define this 4 state. One, first one is the liquid. As I told you liquid state, plastic state, semi-solid state, and solid state. Now if you come back to this figure, so basically you add water to a particular clayey sample and you make a slurry. So, this is something like your liquid form if you get it. So basically, that comes under this zone. So, this is your liquid state so and then you reduce the water content from the sample and then slowly from the liquid state the soil sample will be entering the plastic state okay.

So, when basically you can deform the material. So, in the liquid state you do not have the option to deform it rather it will flow it will lose its strength, so it will be a complete fluid kind of thing. When you reduce the water from this liquid state basically slowly or gradually you will be entering the phase or the state which will be defined as plastic state. So, in the plastic state basically you can deform the soil.

Suppose if you want to make a ball of the soil sample or if you really want to do the clay modeling, so basically you need to have the state which belongs to plastic state. Then from plastic state basically if you further reduce the water content or the I mean moisture from the soil then basically you will be entering the semi-solid state.

So, as you see this plot is basically volume versus water content. So, as you reduce the water content basically you are also getting the reduction in volume. So, you your volume is getting reduced and so in the liquid state it will be having the maximum volume and slowly it will be reducing to the plastic state and then semi-solid state. So then basically in the semi-solid state once you reach at this point then if you further reduce the water content suppose in this direction you are reducing the water content but you are not getting any change in volume and that is known as solid state.

So, your in your solid state whatever no matter whatever water content you are considering so you will not be getting any volume change. However, once you cross the solid state if you enter the semi-solid state or the plastic state or the liquid state basically your volume will be increasing gradually from semi-solids to plastic and plastic to liquid by increasing the water content. So, this is by and large a clear picture about the consistency of clay.

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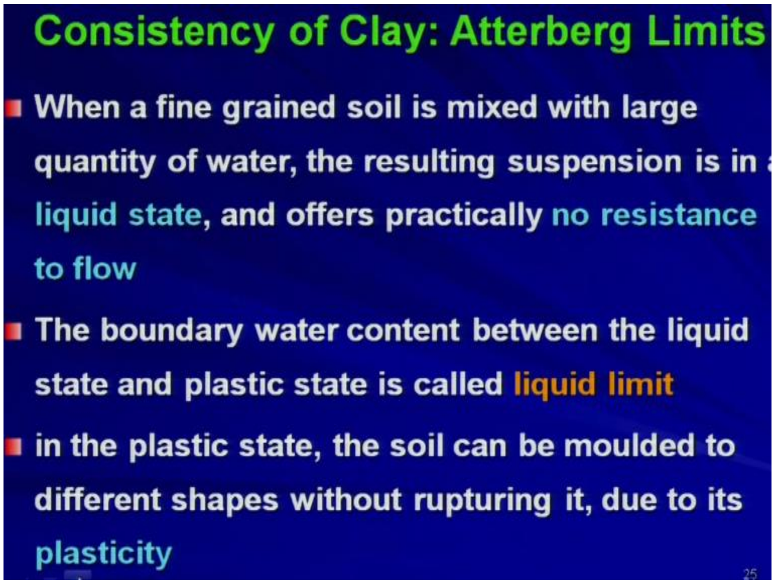

Now when a fine-grained soil is mixed with large quantity of water the resulting suspension is in a liquid state as just now I have told and offers practically no resistance to flow. So, in the liquid state soil will not offer any resistance to flow so basically you will not be getting any kind of strength. It is a kind of soil water slurry.

So that is basically in the liquid state or I mean it will not be showing or it will not be giving you any say strength. So, if you want to construct anything on top of the soil which is on top of the this clayey soil which is basically under liquid state it will not carry or it will not give you any resistance or carry any load so that is basically your liquid state.

Then the boundary water content between the liquid state and plastic state is called liquid limit. So now we are defining different limits. So, the boundary water content between the liquid state and plastic state is called the liquid limit. Please try to understand, this is very important. So, based on these limits, basically you can get the property of the clayey soil.

In the plastic state, the soil can be moulded to different shapes without rupturing it due to its plasticity. As I told you so if you really if you are really interested in clay modeling so you should have the soil or the clay under plastic state.

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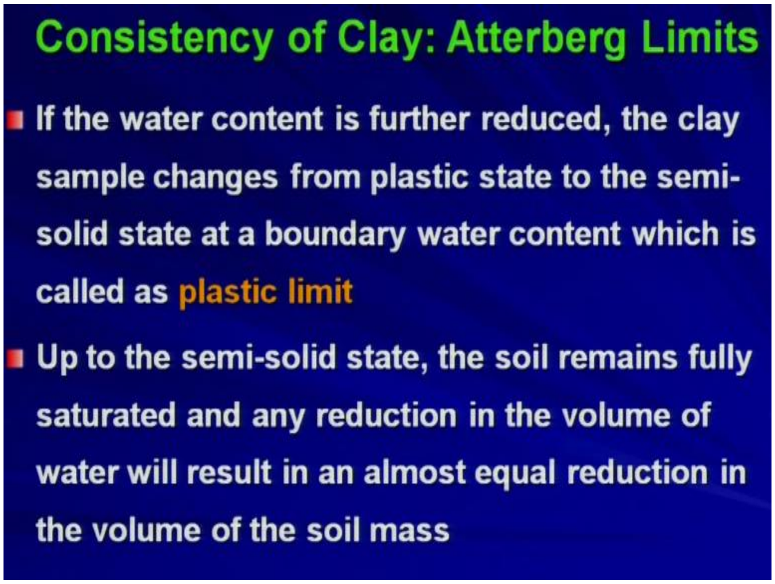

If the water content is further reduced, the clay sample changes from plastic state to the semi-solid state at a boundary water content which is called as plastic limit. So, this is the boundary of your plastic state and the semi-solid state. So that means from the plastic limit to liquid limit, the soil will be exhibiting the plasticity or the plastic state.

Up to the semi-solid state, the soil remains fully saturated and any reduction in the volume of water will result in an almost equal reduction in the volume of the soil mass.

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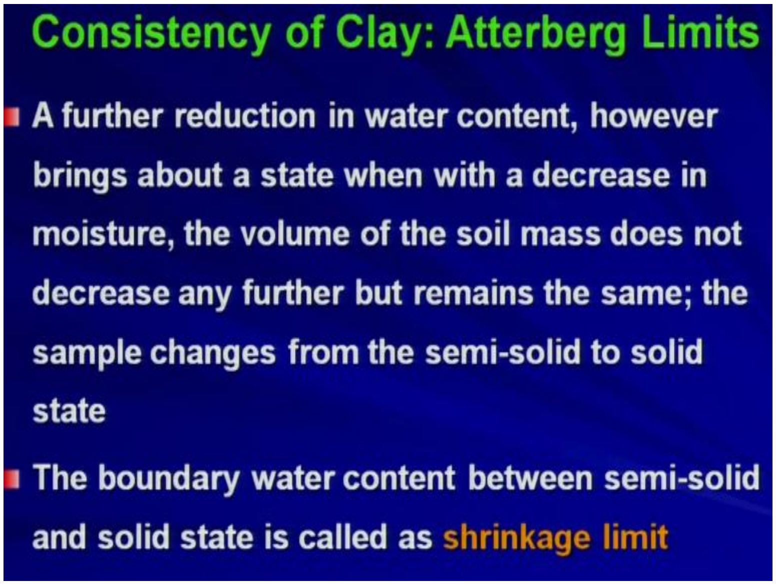

A further reduction in water content, however brings about a state when with a decrease in moisture, the volume of the soil mass does not decrease any further but remains the same; the sample changes from the semi-solid to solid state. As I told you in the solid state basically whatever moisture content or whatever water content you consider or if you reduce the water content, if you increase the water content in the solid state basically you will not be getting or observing any volume change in the soil matrix.

The boundary water content between semi-solid and solid state is called as shrinkage limit. So, this is the boundary between semi-solid and solid state. So that means from between shrinkage limit and plastic limit the soil will be behaving as the semi-solid state.

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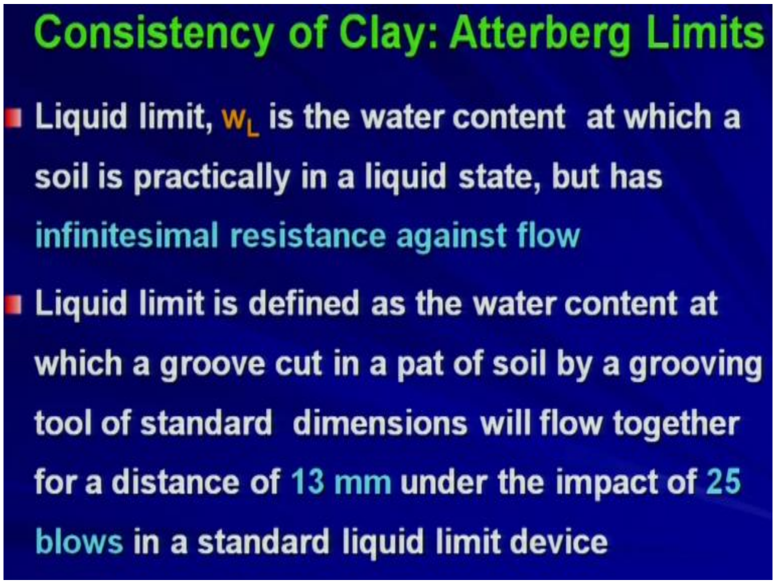

Now liquid limit can be defined. It is generally represented as W L and it is defined as the water content at which a soil is practically in a liquid state but has infinitesimally (()) (07:21) resistance against flow. So basically, you do not have any resistance to the flow. Liquid limit is defined as the water content at which a groove cut in a pat so this is again related to your laboratory experiment.

So basically you have some standard liquid limit device and there basically you have some small bowl and inside that you will be putting some soil by mixing with different moisture content and then you will be cutting the groove with a standard say cutter and then you will give the blows that means the that whole bowl will be going up and falling down and then at a I mean then slowly that whatever groove you have cut that groove will be touching each other and then based on that we can plot the flow curve and then that flow curve we can determine the liquid limit. So, this is the laboratory experiment device anyway.

So, the liquid limit is defined as the water content at which a groove cut in a pat of soil by a grooving tool of standard dimensions will flow together for a distance of 13 mm under the impact of 25 blows in a standard liquid limit device. So, this is basically the your laboratory experiment device. Now basically what you get here.

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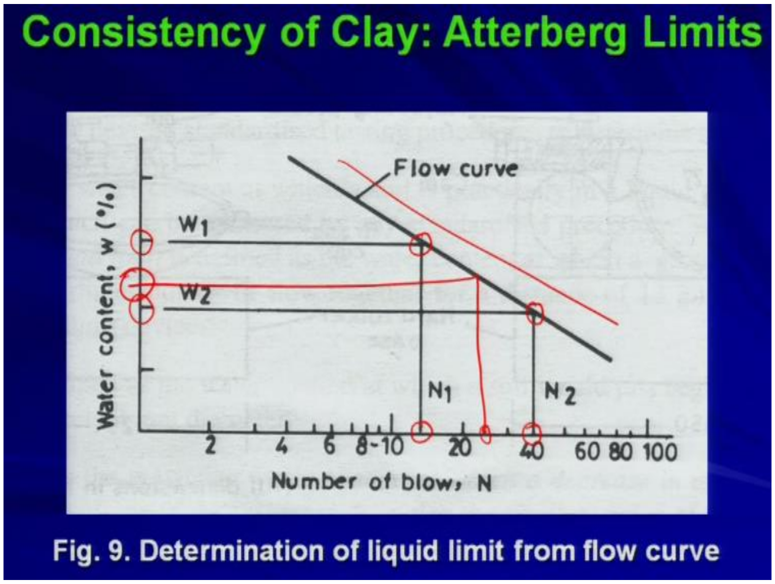

So, this is your I mean flow curve. So, you take some soil sample, you mix I mean or if you mix different say amount of water and that means you are varying water content and then basically you are putting that sample in the standard liquid limit device and then you cut the groove with the standard tool and then you give the blows and then you observe that the flow of the groove. That means the groove is touching each other.

So basically, suppose my I am applying some water content W 1 okay and I am giving the blows and then at this number of blows say I am getting the groove is touching each other or the flowing of the groove so that means I am getting this point. Similarly, I am having again the water content of the same sample like this I am getting another point that is I mean this is the number of blows, say 40 number of blows which will be causing the groove to come closer where I am getting this point like this.

So, I will be getting in that way if I do the test for different water content I will be getting different number of blows to get the groove which is touching each other and ultimately, I will be getting this flow curve. So, this is my flow curve.

Now what I do at 25 number of blows, say 25 number of blows will be coming somewhere else I will be drawing one vertical line and I will be getting the water content, so this is my liquid limit. So, in that way basically we do in the laboratory. So, from the laboratory test we can determine the liquid limit by this method. So, this is my liquid limit.

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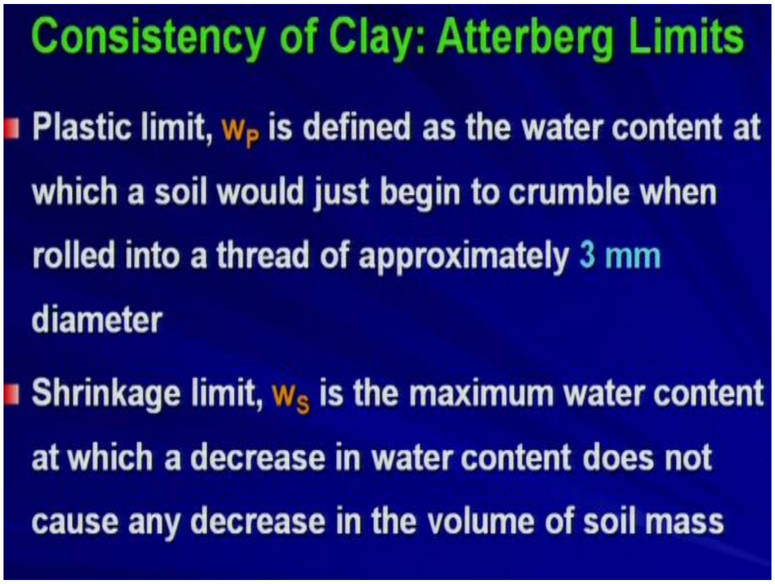

So, plastic limit that is W P is defined as the water content at which a soil would just begin to crumble when rolled into a thread of approximately 3 mm diameter. So basically, you in this plastic limit you take the sample out generally we do this thing in the in from the liquid limit device we take the soil sample because as we know the plastic limit is always lesser than your liquid limit.

So, whatever water content is there in the liquid limit test so that material if you take out and slowly or gradually if the water is getting out and we will be getting the plastic limit. So, what we do here, we take the soil sample, we roll it in a 3mm thread and 3mm diameter say soil sample and we roll it so when the soil is just begin to crumble so that at that time whatever moisture content is there so that is my plastic limit.

Now shrinkage limit is the maximum water content at which a decrease in water content does not cause any decrease in the volume of soil mass. So, this is the maximum water content at which a decrease in water content. So, if you if you further decrease the water content your volume of soil will not change.

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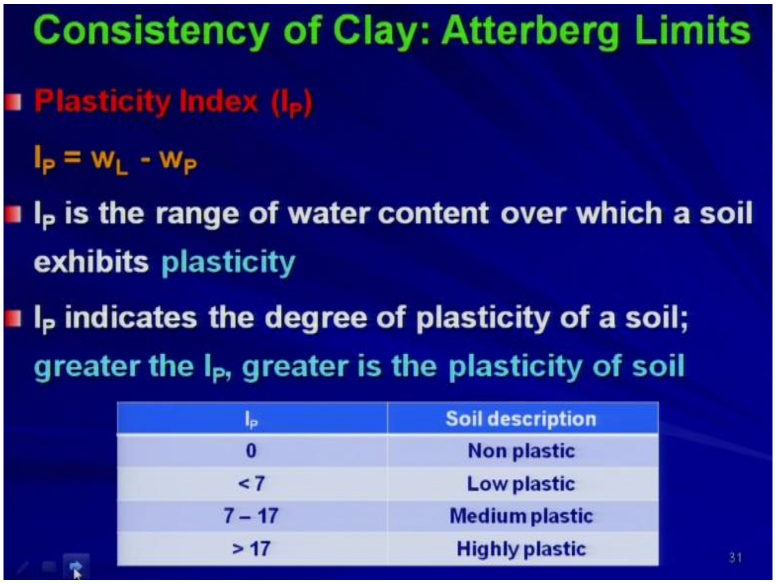

Now based on that we will be defining this index that is very important that is plasticity index based on that basically you will be classifying the soil, clay particularly. Later on, we will be seeing from the classification system. So, plasticity index is defined by the difference between liquid limit and plastic limit.

I P is the range of water content over which a soil exhibits plasticity. So basically, this is the range of water content, so if I say W L minus W P, as I told you this is the difference between liquid limit and plastic limit, within that range basically your soil will exhibit the plasticity right. The soil is in plastic state. I P indicates the degree of plasticity of a soil. Greater the I P, greater is the plasticity of soil.

So, if any soil particle if you consider, if you observe higher plasticity index then that means the soil will exhibit higher plasticity. Now this is the table which will give you some indication or the idea that how the soil consistency is dependent on plasticity index. So, if I P is 0 the soil description or soil is described as non-plastic soil. If it is less than 7, then low plastic soil. If it is 7 to 17 within that range, then it is medium plastic and then if it is greater than 17 then it is highly plastic soil.

So, based on that we can categorise whether it is non-plastic soil or low plastic soil or medium plastic or highly plastic. Now if you take or some sandy particle or a sandy soil and then if you try to find out the plasticity index, you will observe that I P is very close to 0. So that is non-plastic. So, sand is completely non-plastic and that is why you cannot model the sand modeling.

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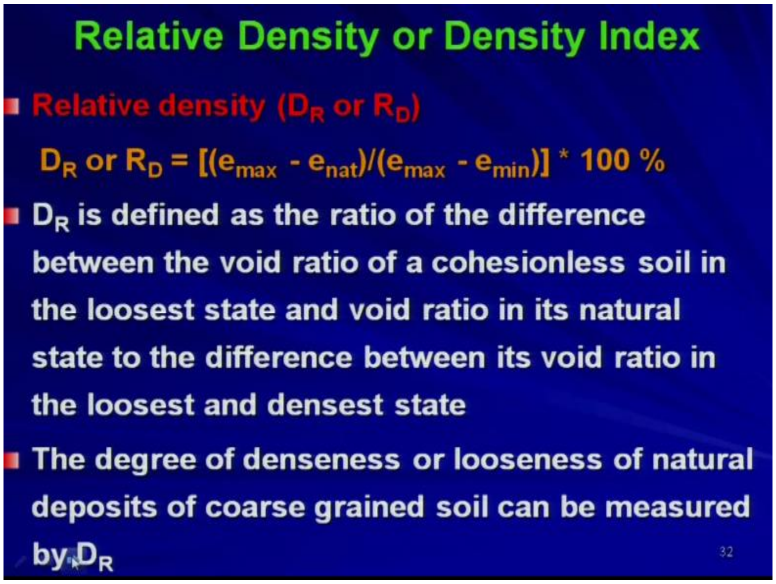

Now coming to the relative density, it is generally expressed as D R or R D in different books. Now this relative density is nothing but this is property of the sandy soil. So earlier we have seen the consistency of Atterberg limits, so they are basically associated with the clayey soil that is the fine-grained soil whereas to quantify or to get some idea whether the sand is very loose or state or the sand is very dense state so that kind of idea if we want to get it then we need to calculate the relative density.

So, relative density is purely associated with the sandy soil or the coarse-grained soil. So, D R or R D is equal to e max minus e natural by e max minus e min into 100%. So, it is generally expressed in percentage. Now what are this e max and e natural. So, e max is the void ratio in its loosest state. That means D R is defined as the ratio of the difference between the void ratio of a cohesionless soil in the loosest state, the void ratio of the cohesionless soil in the loosest state that means e max and the void ratio in its natural state.

So, whatever soil sample you are considering, that soil is having some natural void ratio that is e nat, e natural okay and e max is if you consider the soil sample in its loosest state that will give you the e max which is the maximum void ratio the soil sample can have to the difference between its void ratio in its loosest and densest state.

So, e min is nothing but the minimum void ratio the soil sample can have and that is at the densest state. So that will give me the relative density and it will give me the idea that based on the relative density I can say whether it is the dense soil or medium dense soil or the loose soil or the something like that. The degree of denseness or looseness of natural deposits of coarse grained soil can be measured by relative density.

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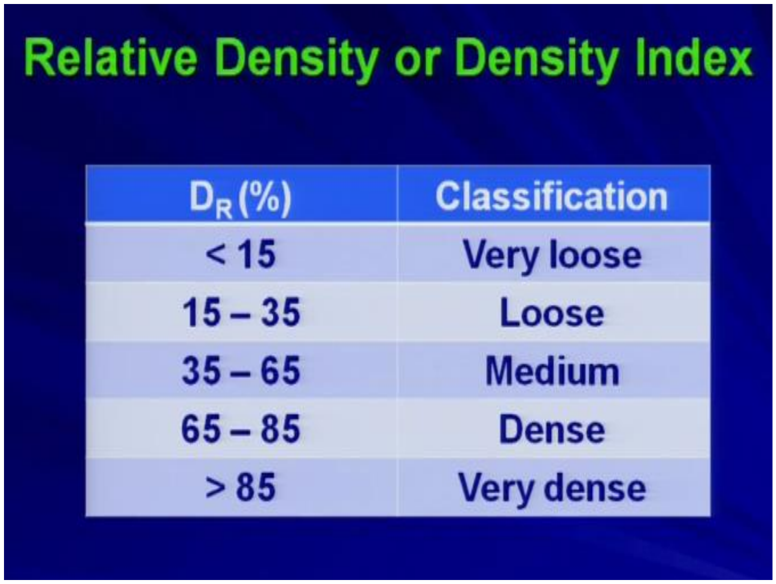

So, this table will give you the idea between your relative density and the classification of soil like if D R is less than 15% then it is very loose soil. So as D R increases it goes to the densified soil. So, 15 to 35 it is loose, 35 to 65 it is medium, 65 to 85 it is dense, and if it is greater than 85% then it is very dense soil okay.

So now we will be taking one problem of whatever we have seen or whatever we have defined some simple definitions we have come across. So, based on that we will be taking the first problem.

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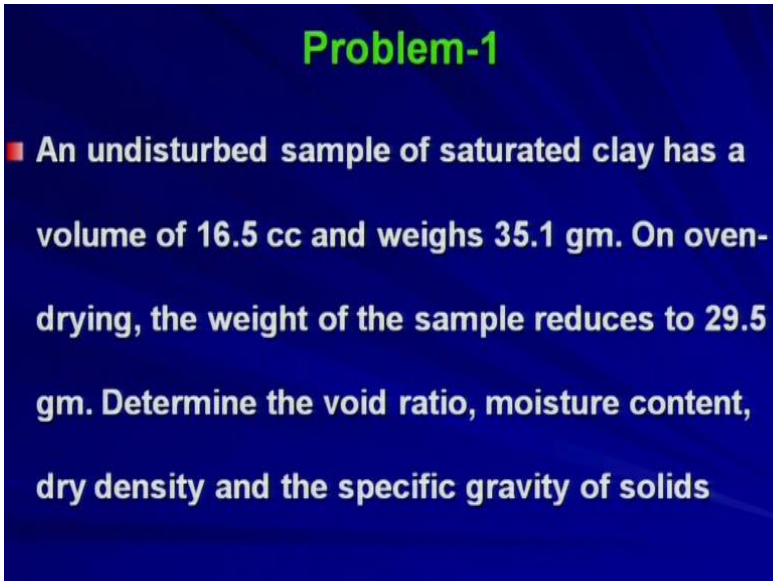

So, the problem says that undisturbed sample of saturated clay has a volume of 16.5 cc and weighs 35.1 gm and on oven drying, the weight of the sample reduces to 29.5 gm. Determine the void ratio, moisture content, dry density, and the specific gravity of solids.

So, as you have seen different definitions and these are the properties available with you, based on that you need to calculate or need to determine these parameters. So, let us solve this problem so that you will be getting some idea that how to crack this kind of problem and how to get different properties of the soil.

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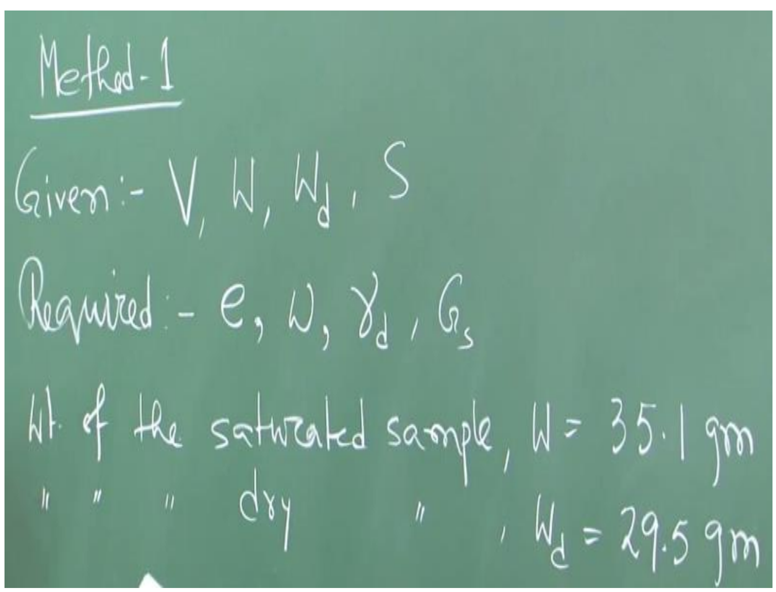

We will be solving this problem by 2 methods. First the method one. So, what are the things are given. You have volume, total volume, then total weight and then you have the dry weight of the sample or the weight of the dry sample and then degree of saturation that is S. So, these things already we have defined and already we have seen in our previous lectures and what are the things are required to determine, void ratio e, water content W, dry unit weight or the dry density whatever, and specific gravity.

So, these 4 things you need to calculate. If you know these 4 things, how to calculate or how to obtain this 4. So, let us see step by step so you will understand the steps. Now weight of the saturated sample is given as 35.1 gm okay. Similarly, weight of the dry sample is given by W d is equal to 29.5 gm.

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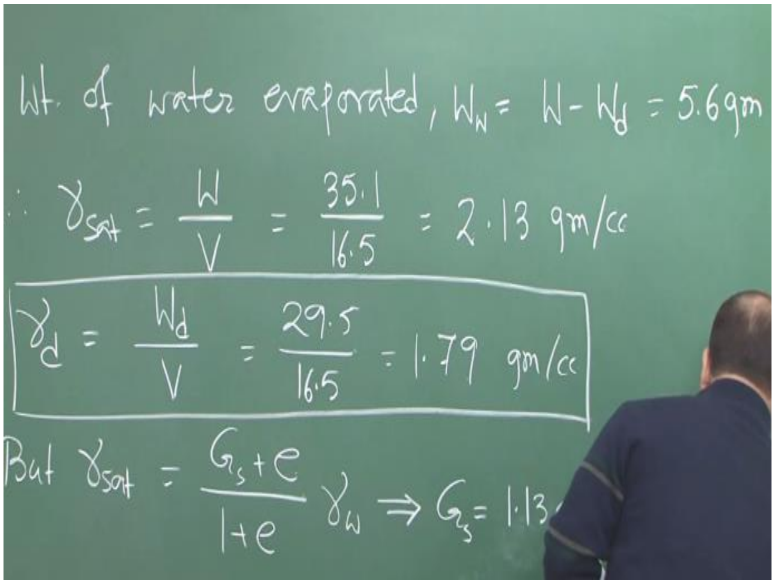

So, weight of water evaporated that is nothing but W W is given by, very simple, that is the total weight minus the weight of the dry sample. So that will give me the weight of water which was present in the sample. So that is nothing but 5.6 gm okay. Therefore, because the soil is saturated so I will be getting the bulk unit weight which is nothing but your saturated unit weight which is nothing but this, very simple as you have seen already.

So, these are the definitions already you have covered in our previous lectures. So, gamma sat is equal to W by V which will be 35.1 by 16.5 V is given and it is coming as 2.13. So, I am doing all the things in cgs units, anyway. So, this is gamma sat, so 2.13 gm per cc which you have just got it. So, once you have got gamma sat then you can calculate gamma d. Now what will be the expression for gamma d? Gamma d is nothing but the dry unit weight of the soil or the dry density of the soil.

So, unit weight and density basically the difference with respect to the g, small g okay acceleration due to gravity, anyway. So, the how to obtain gamma d? Gamma d is nothing but the weight of the dry sample W d by the total volume which is nothing but 29.5 by 16.5 is equal to 1.79 gm per cc. So, we have got it just now. So, this was our objective.

So, we have got gamma d. But gamma sat. So, these are the things I am not going in detailed derivation and all. You can find out that thing from the basic definitions. G plus e by 1 plus e into gamma W where G s is the specific gravity of the soil solids e is the void ratio and gamma w is the unit weight of the water. So, this expression can be derived so by from the basic definition. So that derivation I am not going in much detail. So that you can get from any other text book or from the basic definitions whatever we have covered from that you can calculate or you can determine that. So, the gamma saturated is given by this. So, what are the things you know from this. So, from this expression or from this thing you can write down G s is equal to 1.13 e plus 2.13 which is the equation 1.

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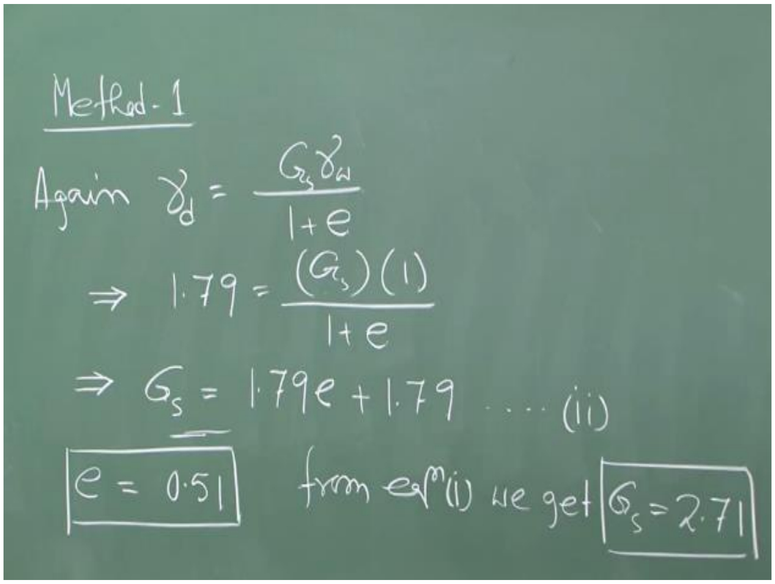

Again, gamma d is equal to again this can be derived again I am not showing you the complete derivation. That you can see or you can find out from your simple definitions whatever we have covered. So, gamma d can be expressed in terms of this G s into gamma w by 1 plus e. Now if we put all the values, so gamma d already we have calculated 1.79 is equal to G s into 1 by 1 plus e and from this we can calculate G s 1.79 e plus 1.79 say equation 2.

Now by solving these 2 equations, equation 1 and equation 2 we can find out e is equal to 0.51. So, your void ratio is 51% okay. So, you have got e. Now from equation 1 or equation 2 whatever you feel better you can calculate G s is equal to 2.71. So, we have got out of 4 parameters, unknown parameters we have got gamma d, e, and G s. Now water content is left out. So, we can calculate water content.

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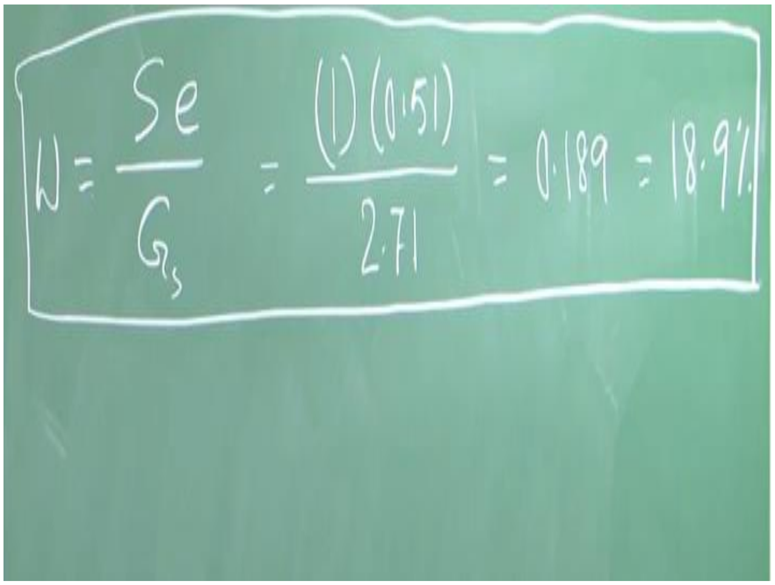

So, water content W is given by S e by G s. Now what is the value of S that is the degree of saturation in this particular problem, completely saturated soil. So that means S is 1. So, 1 and your void ratio is 0.51 divided by 2.71 is coming as 0.189 that is 18.9%. So, we have got all the 4 unknown parameters by knowing those 4 parameters whatever we started with.

Now this is by method 1. So, we have calculated because these equations we have put. Now in the next lecture we will see by solving this same problem okay by using some different method, method 2 which is based on your phase system, whatever phase system we have understood or we have seen in the last lecture. Thank you very much.