Geology and Soil Mechanics
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Lecture - 03
Index Properties of Soil- A

Welcome to Geology and Soil Mechanics course. So, in the last lecture we have seen a few simple definitions which are really useful to define properties of soil and then we just started the index properties of soil.

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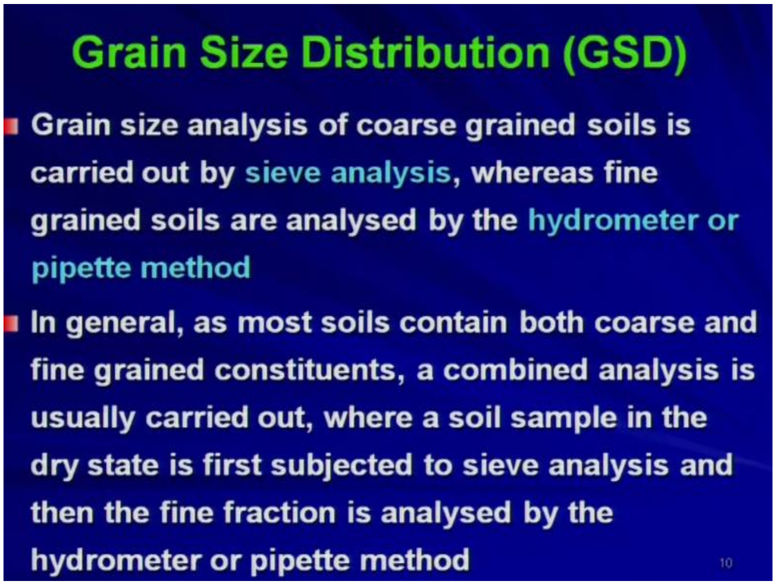

There we talked about the grain size distribution and grain size analysis of coarse grained soils is carried out by sieve analysis, which we discussed in the last class so just for continuity. So basically, if you have the coarse-grained soil then you will go for sieve analysis to get the grain size distribution of the soil whereas fine grained soils are analysed by the hydrometer or the pipette method. So, at this moment we are not very clear that or we have not covered really the what are the coarse-grained soils or what are the fine-grained soils.

However, I mean from your own experience you know that if you take sand so that will be considered sand or boulder or pebbles or cobbles, so these are these generally come under coarse grained category. Whereas clay, silt those things will be coming as fine-grained category. However, we will be discussing in more detail when we will be going to talk about the soil classification or other things that what exactly the coarse-grained soil and what exactly the fine-grained soil.

In general, as most soils contain both coarse and fine-grained constituents as you all know, a combined analysis is usually carried out where a soil sample in the dry state is first subjected to sieve analysis and then the fine fraction is analysed by the hydrometer or the pipette method. So, if you take any sample of the soil so basically that will be having both coarse grained as well as the fine-grained soil.

So now you need to get the complete grain size distribution you need both the method like sieve analysis and the hydrometer analysis. So, for sieve analysis first you do the sieve analysis and whatever we will be I mean we will be talking about that thing later on. So, whatever will be left out for a particular gradation so that will be going for our hydrometer analysis.

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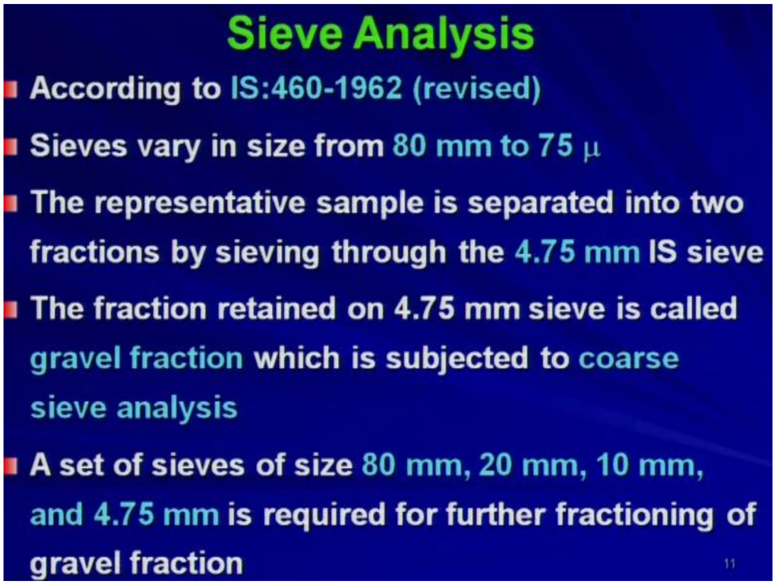

Now coming to the sieve analysis. So, it is it will be discussed as per IS:460-1962 (revised). The sieves vary in size from 80 mm to 75 micron. So, what exactly we do here, we will be having a number of sieves which will be stacked together and that and we will be putting the soil sample on top sieve and then we will shake the whole stack in the sieve shaker and then we will find out how much particle or how much amount of soil is retained on each sieve and based on that we do some calculation and ultimately, we will get the grain size distribution from the sieve analysis.

So, this is basically the laboratory experiment. However, in this course we will be talking about how to do or how to get this sieve analysis done. The representative sample is separated into 2 fractions by sieving through the 4.75 mm IS sieve. So basically, whatever representative sample you have in your hand so what you will do you will just sieve it through 4.75 mm IS sieve so whatever will be retaining on 4.75 mm and whatever will be passing through 4.75 mm so these 2 things will be separating out.

So, the fraction retained on 4.75 mm sieve is called gravel fraction so and which is subjected to coarse sieve analysis. So basically, we will be going for 2 different kind of sieve analysis. One is the coarse sieve analysis another one is the fine sieve analysis. So, coarse sieve analysis is basically associated with those sample whatever will be retained on 4.75 mm sieve.

A set of sieves of size 80 mm, 20 mm, 10 mm, and 4.75 mm is required for further fraction of gravel fraction. So, whatever has been retained on 4.75 mm that is the gravel fraction. Now this gravel fraction will be put on a stack of sieve and which will be consisting of different sieve sizes like 80 mm, 20 mm, 10 mm, and 4.75 mm and then we do the sieve analysis by putting the whole stack in the sieve shaker and then we basically get the gradation based on the retention on each sieve.

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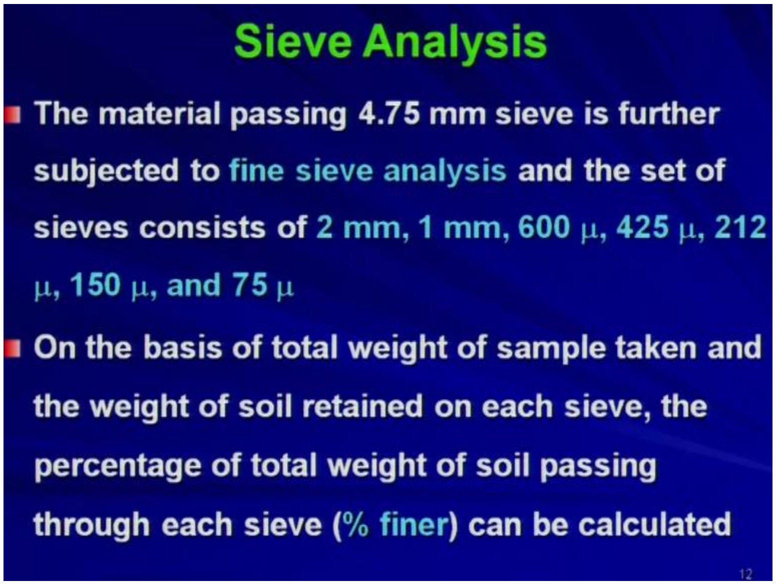

The material passing 4.75 mm sieve is further subjected to fine sieve analysis as we told just now and the set of sieves consists of 2 mm, 1 mm, 600 micron, 425 micron, 212 micron, 150 micron, and 75 micron. So, these many sieves will be stacked together and whatever has been passed through 4.75 mm sieve, that will be put on top of 2 mm sieve and then the whole stack will be shaken by the sieve shaker and you will be getting the gradation.

On the basis of total weight of sample taken and the weight of soil retained on each sieve, the percentage of total weight of soil passing through each sieve that is percentage finer can be calculated. Now basically to get the different say information from the grain size distribution we need to calculate some parameters that is those are coming like this.

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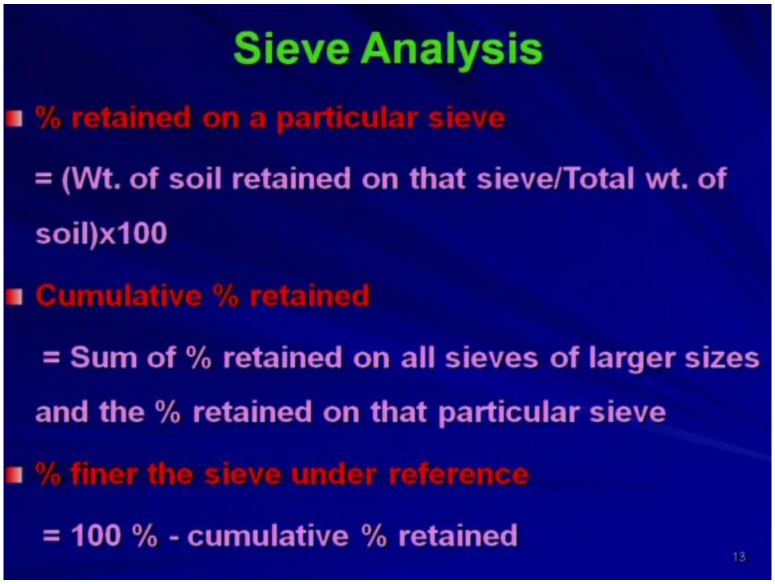

So, first one is the percentage retained on a particular sieve. Now this is nothing but equal to the weight of soil retained on that particular sieve by the total weight of soil into 100. So that means if you consider any particular sieve whatever material or whatever I mean fraction of that sample will be retained on that particular sieve and if you take the percentage with respect to the total weight of the sample taken so that is nothing but your percentage retained on a particular sieve.

Similarly, you need to calculate the cumulative percentage retained. Now what does it mean? It is the sum of percentage retained on all sieves of larger sizes and the percentage retained on that particular sieve. Now if you consider any particular sieve, on top of that there are several sieves, now when I am going to calculate or determine the cumulative percentage retained basically I will be considering whatever retained on that particular sieve plus the whatever is retained on the sieves which are on top of that particular sieve. So, total cumulative percentage can be calculated based on the, based on the stacked sieve retention.

Then percentage finer the sieve under reference. So, this is nothing but total is 100% of course, 100% minus cumulative percentage retained is nothing but the percentage finer. That means it is the fraction of that sample which is passing through that particular sieve. So, these 3 parameters we need to calculate or we need to determine which will be giving me lot of information. Later on, we will see that and for your grain size distribution curve if you want to plot so these informations are required.

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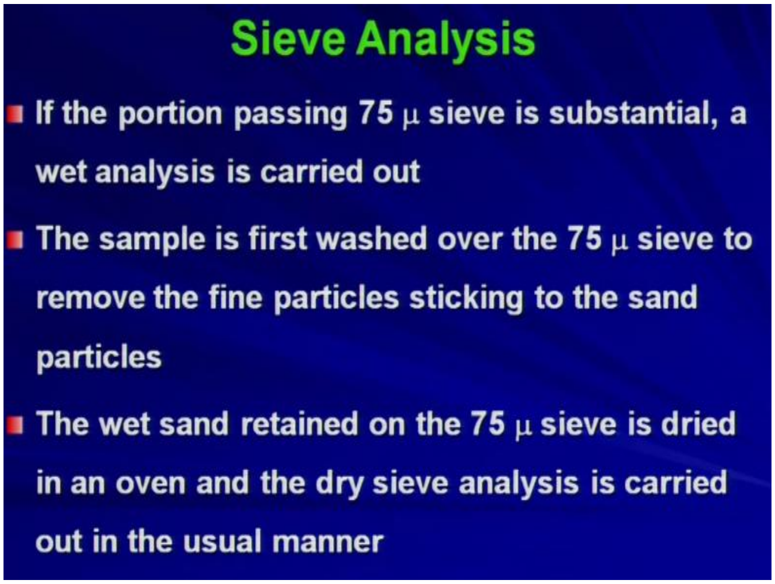

If the portion passing 75-micron sieve is substantial, a wet analysis is carried out. Now you may get the sample in such a way that you have this 75-micron passing portion is very significant. So, in that situation you will be doing wet sieve analysis. Now what does it mean?

The sample is first washed over the 75-micron sieve to remove the fine particles sticking to the sand particles so that you will getting only the coarse fraction and then the wet sand retained on the 75-micron sieve is dried in an oven and the dry sieve analysis is carried out in the usual manner as we discussed just now. So that is why it is known as wet analysis because you first you wash the sample and then you take the sample whatever is retained on 75-micron sieve and then you make it oven dried and then you take that sample to do the regular sieve analysis.

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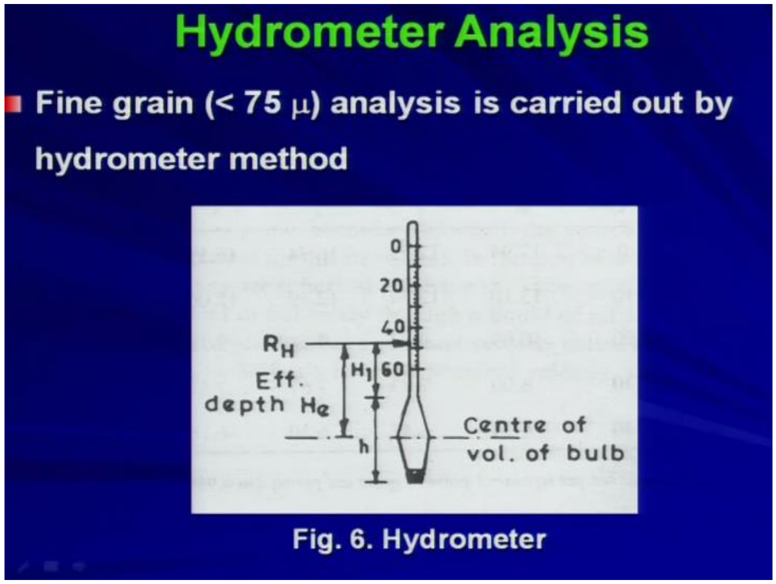

Now coming to the hydrometer analysis this is associated as I as I told you just now so this is associated with fine grained soil like clay, silt and all which is basically passing through 75 micron so that cannot be seen for by your bare eye so this thing you cannot do the gradation by using your use your sieve analysis rather you have to use some other method like hydrometer or the pipette method by which you can get the information about that fraction.

So, fine grain which is less than 75-micron analysis is carried out by hydrometer method. Now what is this? So, if you look at so this is my hydrometer, hydrometer is nothing but one glass tube which is having a bulb kind of enlarged bottom at the end and this the stem of the hydrometer, this is known as the stem of the hydrometer.

The stem of the hydrometer is graduated and this is the bulb, this is the center of the bulb and R H that is now what we do basically we take the soil sample which is passing through 75 micron and then we mix that thing in water and we keep that thing in a jar and so the jar would be having the soil water mix that is something like your turbid water and then we put the hydrometer inside that solution.

So what the main mechanism is that basically the soil particles depending on based on different time, based on different size of the particles the particles will settle down and the hydrometer it the hydrometer will be immersed in the jar so basically this hydrometer reading will be getting changed because as the soil particles will be settling down at the bottom and the water level will be rising and based on that you will be getting different reading of hydrometer and based on that you do some calculation and get the information about the what diameter has been settled at what time and what percentage finer you are getting.

So, this is the overall again this is the laboratory experiment we can do that thing in our regular geotechnical laboratory. However, we need to understand the theory first and let us see how we can find out the information about our fine-grained soil gradation.

So, this is our hydrometer. So, this R H is nothing but the hydrometer reading that means the I mean you can see that much credit graduation or the I mean your marks on the stem of the hydrometer and this H e is nothing but the effective depth which is nothing but the distance between the center of the bulb and the hydrometer reading.

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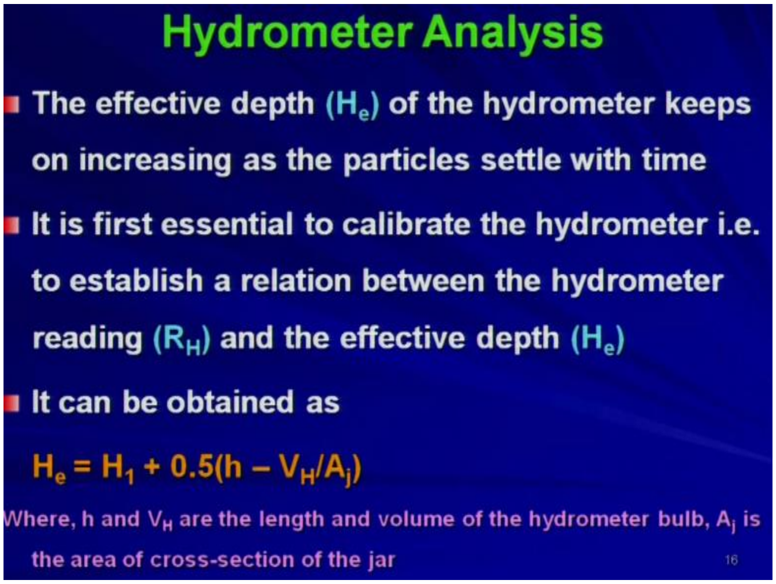

The effective depth that is H e of the hydrometer keeps on increasing as the particles settle with time. It is quite obvious right. So, you have the turbid water which is mixed with the soil sample and now the soil different soil particles are settling down at different time so as time increases the soil particles will be settling down and because of that you will be getting increase in the effective depth of the reading.

It is first essential to calibrate the hydrometer that is to establish a relation between the hydrometer reading and the effective depth. That means so if I, I mean from this calibration chart I will be getting the idea that okay if this is the hydrometer reading what should be the effective depth and from based on the effective depth we have some equation or the expression by which we can calculate the diameter of the particle which has been settled down at that particular time or the percentage finer of that particular size.

So, this calibration plot is very important. So before starting the experiment you need to establish the calibration chart. So, it can be obtained as H e that is nothing but the effective depth is equal to H 1 that we have just seen H 1 plus half of the I mean depth of your bulb that is 0.5 into h minus 0.5 into V H by A j so that is coming because of your as the particle settles down you will be getting the water level I mean this is something like your coming from the buoyancy.

So, this idea is coming from the buoyancy where your small h and capital V H are the length and volume of the hydrometer bulb. A j is the area of cross-section of the jar. So that means you are putting the hydrometer inside the I mean soil water mixture and then you are calculating H e based on this equation.

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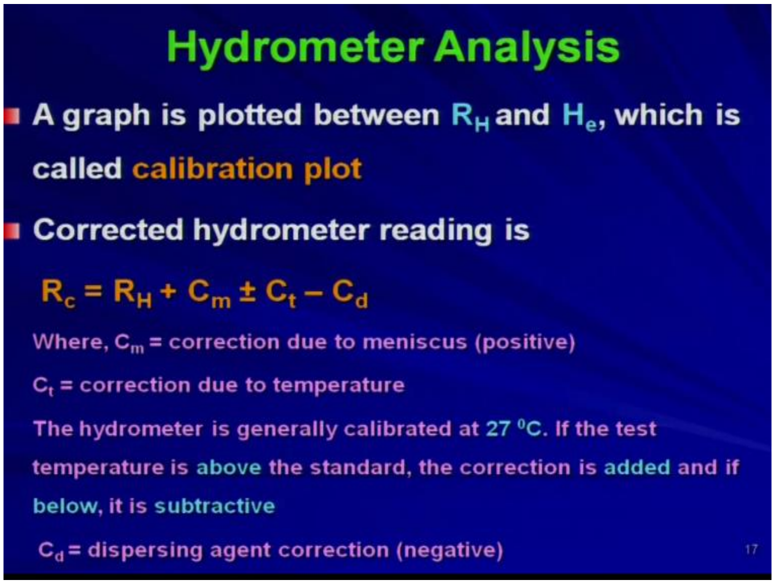

However, this is the theory. Now, basically we will be observing only the hydrometer reading and from the calibration once the calibration chart is ready with you then you simply go to the calibration chart to get the effective depth. So, a graph is plotted between R H and H e as we decided or discussed which is called as calibration plot.

But you need to correct the hydrometer reading. So, whatever R H you are getting you need to correct that based on some different parameters. Now R c that is nothing but your corrected hydrometer reading is equal to R H plus C m plus minus C t minus C d. Now where C m is the correction due to meniscus which is always positive. C t is the correction due to temperature. So, the hydrometer is generally calibrated as 27 degree centigrade.

If the test temperature is above the standard, the correction is added and if below it is subtracted. So that is why this plus minus sign is coming into the picture. Then C d it is dispersing agent correction that is always negative. So, dispersion agent is generally mixed in the soil water mixture so that some flocculation does not I mean some flocculation effect should be there.

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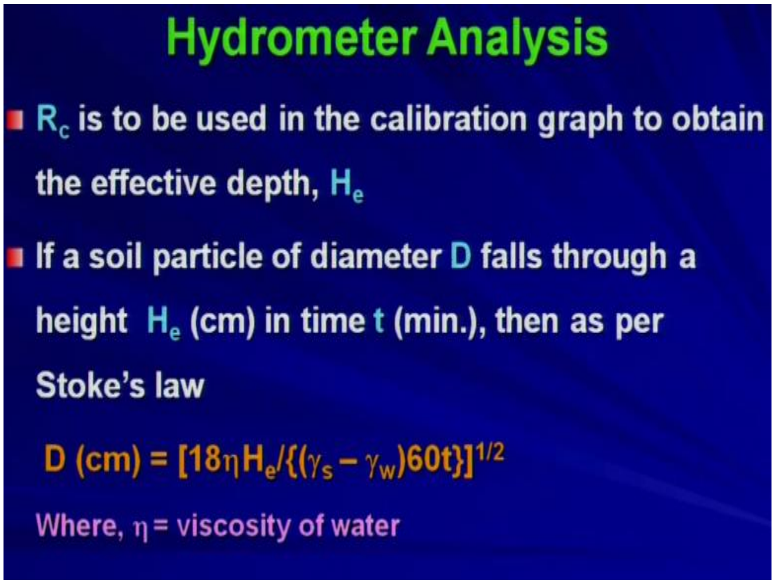

R c is to be used in the calibration graph to obtain the effective depth H e. So, what you do? So, you put you immerse the hydrometer and then you observe R c that is your hydrometer reading. First you observe R H then you correct that thing, you obtain R c and once you get R c you go to your calibration plot and obtain H e.

So once you get H e then you can calculate the diameter that is if a soil particle of diameter D falls through a height H e that is the effective depth, that is in centimeter, in time t in minute, then as per Stoke's law so D is equal to 18 into eta into H e by gamma s minus gamma w into 60 t whole root over half that means where eta is the viscosity of water.

So, if you use this equation so you know what is your viscosity of water at that particular temperature you just you have got H e from your calibration plot you know gamma s and gamma w and you observe the time at which time you are you want to get the which diameter is settling down and from this expression you will be getting the diameter of the particle which is settling down at that particular time.

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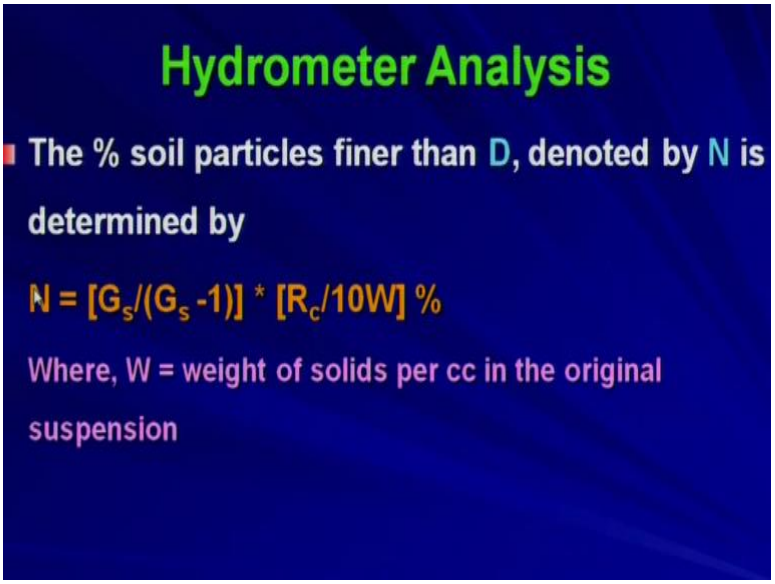

So, the percentage of soil particles finer than capital D as we did for our sieve analysis, similar thing we are also doing here that is the percentage finer. So, percentage of soil particles finer than capital D whatever we have just calculated denoted by say N is determined by this expression. So, if you use this expression everything is known to you.

So, G s is known to you, you can find out and R c of course is known to you and where W is the weight of solids per cc in the original suspension. So that we know from our starting point of our experiment. So, if from this expression basically we can calculate N. So, from the sieve analysis we have got similar thing that is percentage finer than a particular sieve or particular diameter and then from the hydrometer analysis we have got N that is also percentage finer than a particular diameter and then we combine these together and then we plot it then we will get the grain size distribution curve of soil.

So, after doing this exercise, after combining these 2 results obtained from your sieve analysis and from your hydrometer analysis now if we if we combine this percentage finer then we will be getting the grain size distribution curve which will look like this.

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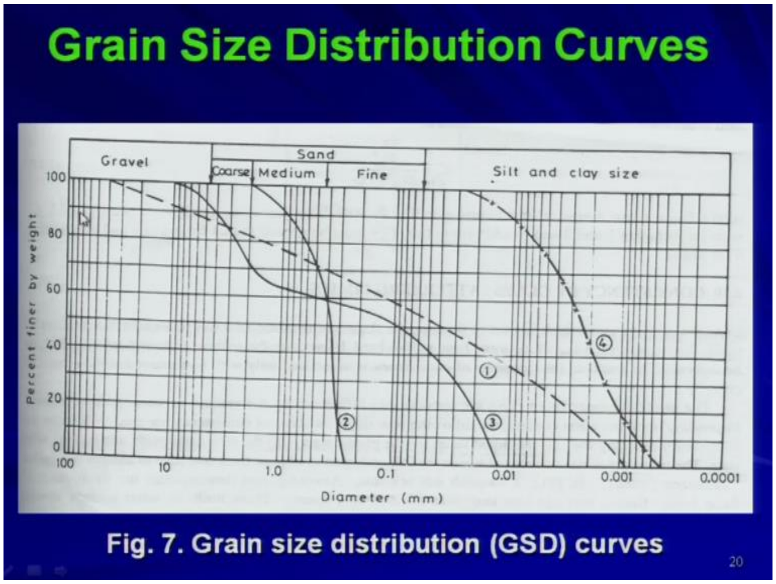

So, this plot is basically semi log plot. So, this is the normal axis, I mean this is the percentage finer by weight along y axis and along x axis you have the diameter which is along which is basically the logarithmic scale. So now basically what we are observing here say if you look at this curve say this curve 1, this curve 1 now it is starting from here and it is ending at here. That means this is the diameter okay, this is the diameter, 100% is finer than that diameter.

So, this is the largest diameter available in the soil that sample. So, 100% material, 100% sample is finer than that particular diameter. Whereas if you if you take any one say this is your 20% finer so if this line so this is the diameter, this is the diameter which will give you the idea or the it is corresponding to the 20% finer representative sample. That means your 20% sample is finer than this diameter. So, based on that we can determine or we can say few things.

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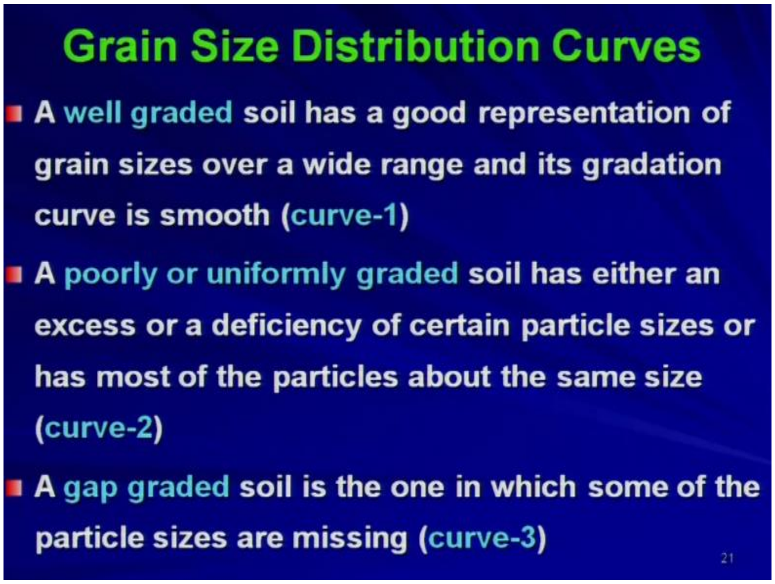

A well graded soil has a good representation of grain sizes over a wide range and its gradation curve is smooth. Now if you look at this gradation curve, GSD curve, then basically this line curve 1 is known as or is basically representing the well graded sample. Why it is well graded? That means you have most of most of the diameters or most of the material or the particles are present in the sample. So that is why it is well graded sample.

So well graded sample has a good representation of grain sizes over a wide range and its gradation curve is smooth. So that already we have observed and this is denoted by curve 1. Similarly, a poorly or uniformly graded soil has either an excess or a deficiency of certain particle sizes or has most of the particles about the same size.

So, if you look at this curve, gradation curve 2, you see it is very it is poorly graded. You do not have the proper representation of all the samples, rather it is starting from here ending at this point. So, it will be having the particles only within this range. So, it is not covering the whole range. So that is why it is known as uniformly graded or the poorly graded curve.

Then a gap graded soil is the one which some of the in which some of the particle sizes are missing. So, if you look at this curve, curve 3 basically this is known as gap graded. So, some of the particles are missing. So, you are doing you are doing the gradation or the grain size distribution you are plotting that and then you are observing that some particles are missing and some deficiency is there in the gradation. So that is why it is known as gap graded.

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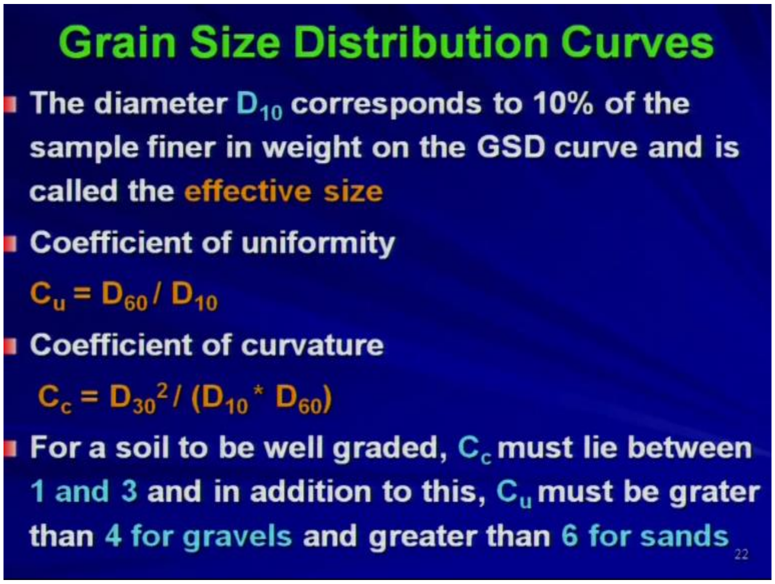

Now the diameter D 10 so this is generally we represent that thing by D 10. So D10 corresponds to 10% of the sample finer in weight on the GSD curve and is called the effective size. So, if anyone is asking you what is the effective size of this sample then immediately you have to report the D 10 of that particular sample. Now what is D 10? So, I mean this is the general definition of what exactly it means from the GSD.

Now if I look at this is my say curve 1. For this sample okay, this is your well graded sample, for this well graded sample what is my D 10. So, your D 10 is nothing but the diameter corresponding to the 10% finer. So, what is the 10% finer. So, this is the line for 10% finer. So, this is the diameter. If you draw a vertical from this point, so this is the diameter which will be known as D 10, which is nothing but the effective size of that particular sample.

Similarly, for your curve 2 that is your uniformly graded sample, your D 10 will be somewhere here. So, this is the diameter which will be known as your effective size of the D 10 of that particular sample. So similarly, we can define few things or few parameters by which we can get the idea of whether it is well graded or poorly graded sample.

Now those definitions are one first one is the coefficient of uniformity. So, C u is given by D 60 by D 10. Now what is D 60? D 60 corresponds to 60% of the sample finer in weight on GSD. So of course, this 60 will be always higher than your D 10. So, the ratio of D 60 and D 10 is nothing but your coefficient of uniformity.

Then another definition coefficient curvature which is nothing but C c is equal to D 30 square by D 10 into D 60. Now after calculating C u and C c we generally get the idea of this that for a soil to be well graded C c must lie between 1 and 3 and in addition to this C u must be greater than 4 for gravels and greater than 6 for sands. Now if I get one sample, soil sample, whose C c is say 2 and C u is say 4 for and if the soil is gravely soil then that gradation should be well graded and similarly for sand if the C u is 6 then that will be my well graded sample. Otherwise, the gradation will be uniformly or poorly graded.

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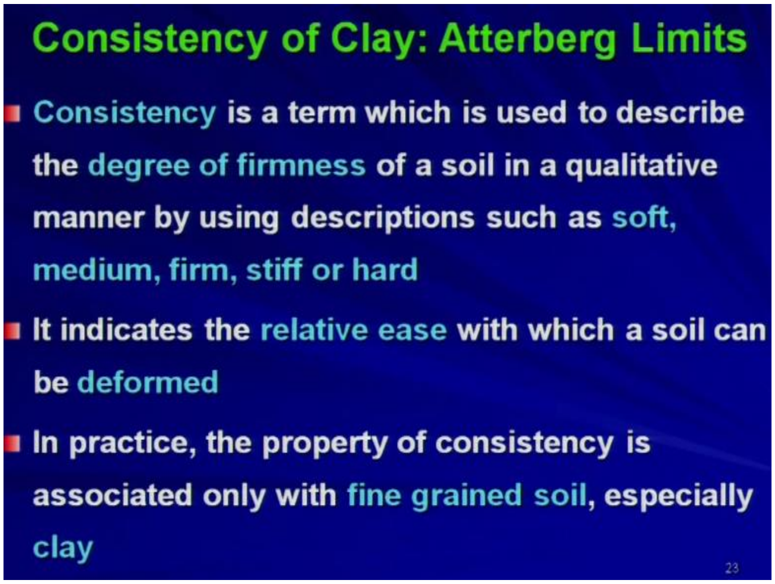

Now coming to the consistency of clay. So, when we are talking about the consistency of clay and then based on that different at about different limits are defined which are defined by scientist Atterberg, so based on that, Atterberg limits have come to the picture. So, what is consistency of clay. So, this is purely the property of clay. So please try to understand.

So, if you have the clayey type of soil then you need to calculate the consistency of clay so that you can particularly you can define the deformation criteria of that particular soil. So, what is consistency of clay? Consistency is a term which is used to describe the degree of firmness of a soil in a qualitative manner by using descriptions such as soft, medium, firm, stiff, or hard.

Now if you get a clay sample. Suppose I am giving you some clay sample and if I say what state the clay sample is, whether it is in the soft state, whether it is in the medium state, whether it is in the firm state, or stiff state, or the hard state. So, based on that basically your consistency of clay will be different and that is defined by different Atterberg limits. So that we will see in the subsequent lectures.

So, it indicates the relative ease with which a soil can be deformed. It is very simple. So basically, the soil that is the clayey soil will be having the property of deformable material right. So, the consistency will basically indicate that how ease I can deform the sample. Suppose in the childhood you might have used some clay say modeling or something like that. So there basically if you get very stiff clay, can you model it or can you go for the clay modeling, no.

So, for clay modeling you need some soft clay so that you can deform it for your say shape of interest. So that is basically based on your consistency of clay. So, this is known as your consistency. So, in practice, the property of consistency is associated only with fine grained soil, especially clay as we so if you take some sandy soil and if you try to deform it okay so basically you will be getting different grains of the sand.

You cannot make the modeling whatever you have done for clay modeling you cannot make a ball or make a different shape by using your sandy particle or the sandy soil. So, this consistency is purely based on or purely associated with fine grained soil, especially clay. So, I will stop here today. So, we will be seeing the rest of the things in the subsequent lectures. Thank you.