Geotechnical Engineering II / Foundation Engineering
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Lecture – 02
Quick Review of Soil Mechanics (Contd.)

Let me continue with the same topic of classification and other things Quick Review of Soil Mechanics. And, in the previous lecture just I have concluded that when civil engineers, when civil engineer visit site then based on the site visit one has to assess the soil type, that is most of the time it is very essential.

And, how in the field without any instrument, without any formal testing, how can assess in the field that I have mentioned that assess means basically I had to classify where the soil contents sand or silt or clay or in between. In fact, if it is sand actually coarse sand very easy to identify by visual inspection, but when it is a fine sand and silt you will not be able to differentiate. So, because of that you need to carry out those test like dilatancy and filling or between the fingers, and then plasticity test all those things you have to carry out that based on that we can briefly can say that soil contents either sand or silt or clay or silt clay something like that. So, that will be enough for from the field whatever we expect.

But, after that for various engineering analysis we need to the further characterize the soil and for characterization of the soil the first step is of this is actually proper classification. And, proper classification means what actually what size particles and what quantity it is present and all, that is one thing and also as I have mentioned then originals you have to see first of all. Suppose it is from the site the one bag of soil has come and you have to classify the soil how will start, that is very important actually. Many times I ask this question to the student and they start actually is telling that will do sieve analysis.

But, it is not the case suppose your bag actually there is a big lump of soils, then lump how we can big lump of soil how we can see. So, that is what actually you have to see first. What type of soil it is? If, it is a very dark brown soil then; that means, the soil is actually and there is a some smell on it; that means, it is a organic soil and organic soil cannot be classified by sieve, there is some other classification method which we will discuss one by one.

Similarly, if you find that is a free flowing sand type of things then; obviously, you can go for sieve analysis, but if the soil is in between then big lump you have to break it, then you have to wash it if possible through particular sieve and then partly you have to do sieve analysis partly you have to do some other analysis and then based on that you have to come in conclusion the soil types. So, that is the things; that means, you have to learn that when the bag of soil this question when it is asked you cannot blindly say that I will do sieve analysis because you have to see the soil first; what it is, how it has come?

So, based on based first is the physical examination open the bag, see the soil and then afterwards take the decision what you have to do the next. So, like that if suppose the soil is free flowing and granular then; obviously, you can go for this sieve analysis.

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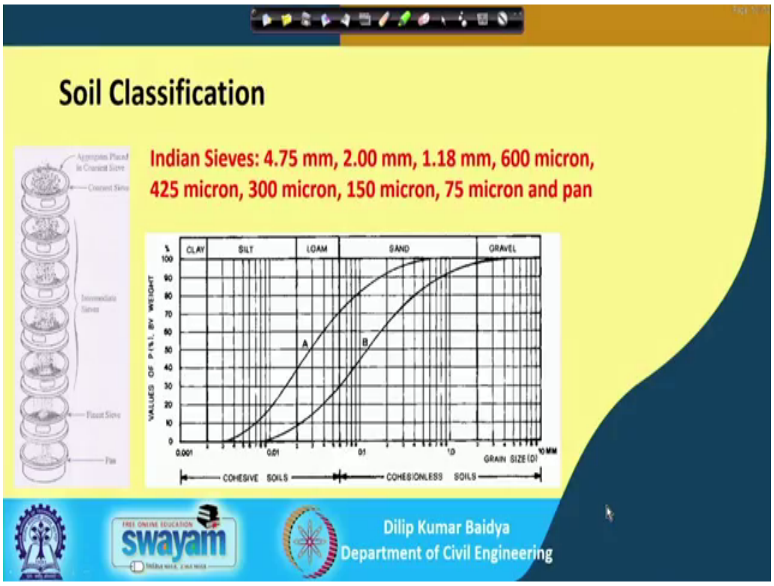

And for that you can see that I have shown here, that how we carry out sieve analysis; you can see that there are number of sieves are kept one after another and bottom most is the pan without opening, and this sieves are having different size of openings. And, as per Indian standard different country will have different standard as per our Indian standard, our sieve size ranges between top post with 4.75 millimetre and bottom most sieve will be 75 micron. Why is 75 micron is kept, below the 75 micron size actually we treat as a silt and silt cannot be classified based on sieve analysis.

So, up to the 75 micron soil we can do this sieve analysis. So, because of that we keep the bottom most pan as a pan without opening and we keep suppose 4.75 2 millimetre, 1.18 600 micron, 425 micron, 300 micron, 150 micron, 75. Sometime in between 1 or 2 sieve may not be there, but basically they will be arrange like the higher size will be here, and smaller size will be the here and this be without opening.

So, finally, we put a certain amount of soil at the in the sieve and then subsequent sieve will be in the below of that below to that, and then we will be putting you can shake it by hand like this, but otherwise we can put it in the shaker and we can put 8 to 10 minutes, 10 15 minutes, and then automatically if the soil particles is smaller than 4.75 then it will pass through, and it will come here. And, again further shaking if this is a smaller than 2 millimetre it will pass through that it will come here, and again if it is a smaller than 1.18 millimetre it will pass through retained it will come here.

Like that finally, if every sieve will retain some amount and pass some amount. And finally, from the 75 micron sieve will pass some amount and little bit retained here. So, those amount will be collected and finally, we will do some calculation that originally suppose I have taken a 500 gram of soil and each sieve retained some amount suppose x 1 gram, x 2 gram, x 3 gram, and then finally, retained on pan suppose x n gram, then summation of all together put together should be whatever soil I have taken. And most of the time we will see that whatever 500 gram we have taken I will not get 500 gram exactly, it will be maybe 1 gram or fraction of 1 gram will be less because of this while sieving some loss will be there.

But, we understand there will be loss, but if this loss is too much suppose 4 to 500 gram and you have got 490 gram 10 gram loss that should is not acceptable. So, you have to very carefully conduct this, that if you have 500 gram. And finally, the soil collected from each sieve retained and that cumulative weight should be also close to very close to 500 gram. And, once you get that and then from that what you have to do you can again retained in the particular sieve and then percent retained another column you can prepare and then cumulative percent retained you prepare one.

And, then last column will be percent finer. Suppose a particular sieve cumulative retained is 20. Cumulative retained as level 1 point or 2 millimetre suppose 20; that means, 80 percent soil finer than 2 millimetre so, percent finer. So, that is the way we calculate and then based on that we plot the graph one side actually the grain size; that means, grain size is approximately same as whatever sieve size we take ok. And so, this is the sieve size in the particular sieve suppose 2 millimetre sieve the percent retained is 20 percent so; that means, cumulative percent retained that means, 80 percent is finer.

So, to I am go to the 2 millimetre suppose somewhere here 1 and then it will be 2 millimetre is here and cumulative percent is 20; that means, percent finer is 80. So, percent finer is here. So, I will find out the 80 here and point will be located here like that, corresponding to each sieve size what is the percent finer those points I will plot it a semi log (Refer Time: 08:45) paper. And, then finally, join them and I will get a curve and from that curve I will get the proper grain size distribution; that means, what size of particles and what quantity it is there in the particular mass that can be obtained. And this calculation is shown in the next slide, you can see whatever I have said in my previous one.

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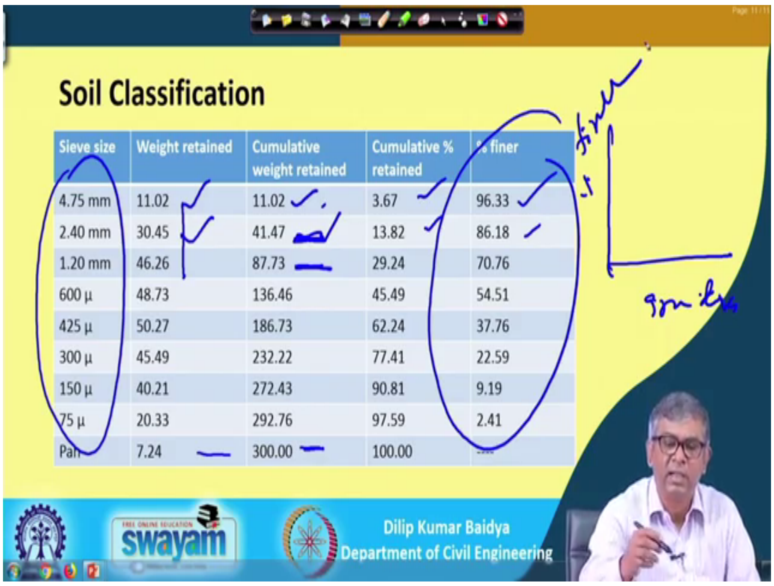

You can see here this, you can see that sieve size is given 4.75 millimetre, 2.4, 1 point this is actually this size actually based on some other it is not as per it is of course, 2.36 sometime we will write to 240, it was 1.18 now you can write 1.2, 600, 425, 300, 150 like that pan.

So, once such test actually suppose a 4.75 micron sieve the retained is this, 2.4 millimetres sieve retained is this, like that weight retaining this sieve is first collected.

That is the only thing we carry out during test and then rest of the things we will do calculation later on a cumulative weight retained. So, here there is no sieve above that. So, cumulative retained and retained same. So, and when we go to this at this level cumulative retained will be this plus this. So, this 2 together will have cumulative retain.

Similarly, when you go to this level your cumulative retained will be this all summation of these 3. Similarly, at this point if you reach then cumulative retained will be entire summation of this. And, when I will do cumulative retained, cumulative weight retained and cumulative percent retained so; that means, out of suppose 500 gram this much. So, what is the percent? Out of 500 this much is the what is the percent? So, like that this is a cumulative percent retained and after getting cumulative percent retained then finally, percent finer then 100 minus this that become 96 100 minus this. So, like that I get this the data and then I will plot finally, these versus this and x axis is the grain dia grain dia and y axis is the percent finer percent finer.

So, based on that I will plot and then I will get the joining those points, I will get the grain size distribution graph from there I can find out whether soil is fine or coarse or medium all those type of things information I can gather. And of course, when it is this type of classification can be used only when the soil is mostly sand ok. Maybe some amount of silt present and if it is not then of course, what you have to do we you need to watch the soil.

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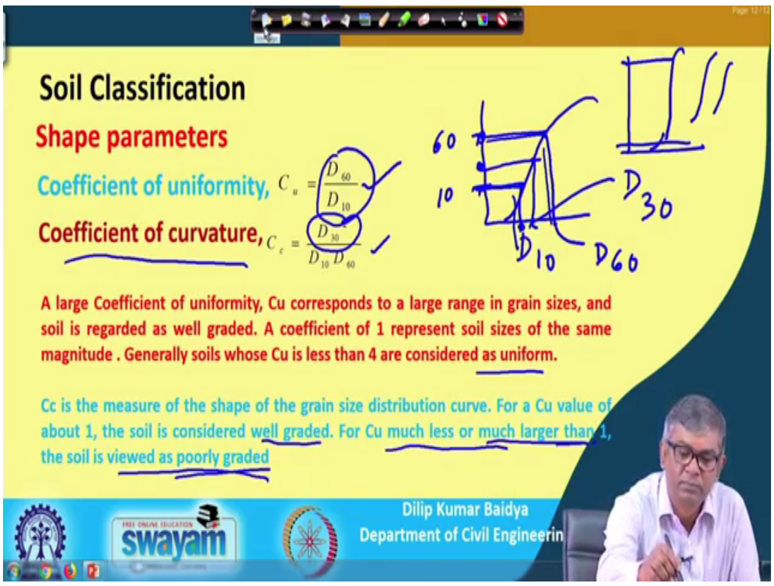

And, you have to through 75 micron sieve you have to wash and then I mean finer particle than 75 micron will pass through the 75 micron, and then from that washed portion whatever sediment I will get that to be dried and from that dried portion I can also some amount I can take and carry out the hydrometer analysis. The actually grain size distribution curve for fine soil sometime can be done hydrometer analysis, and if you do this wash method then what you have to do by the retained 70 micron soil you will do grain size and past 75 micron you do hydrometer analysis then we combine them.

And finally, get the curve and based on that curve sieve sometime we can also assess the soil type; that means, just you have the mass, but you do not know what size of particles and what percentage it is present, but if you know the curve then we can say easily. And, if you know that then you will be able to assess the various characteristics of the soil.

So, like that when we will when we draw the grain size distribution curve and based on that distribution curve, we compute 2 coefficient; one is actually coefficient of uniformity, which is defined as D 60 by D 10. What is D 60? And, what is D 10? D 10 actually diameter corresponding to 10 percent finer, suppose there is a plot here and 10 percent finer is here and the curve is something like this I will produce on this 10 percent finer, then corresponding size that is actually D 10, this is D 10. So; that means, size corresponding to 10 percent finer. Similarly, if it is a 60 percent finer and I will produce on these and then I will come here this will be your D 60.

So, from the curve when I will get the grain size distribution curve from there actually I will find out D 10 and D 60. How to find out D 10 and D 60? A 10 percent finer you have locate, 60 percent finer you have locate, and that you produce on that grain size that you produce on the grain size this will give you D 10 and this will give you D 60.

And, there are 2 numbers and this ratio 2 numbers will get another number that that can be fraction of course, some number we will get. And, that is called coefficient of uniformity coefficient and based on that how we will classify I will come later on. And, then another coefficient that is called coefficient of curvature C c, there is D 10 and D 60 as it is there and there is another D 30; that means, in between there maybe 30 percent finer you locate, produced on the curve from their whatever we will get that is called D 30, that is about D 30. Then D 30 square divided by D 10 multiplied by D 60, that will give you another number and that number actually again give you some information about the soil type.

. So, coefficient of uniformity and coefficient of curvature this 2 and so, what we can learn you can see that, a large coefficient of uniformity; that means, Cu correspond to a large range in grain size; that means, Cu is large means the range of particles a large; that means, from small to big every particles are there. And, soil is regarded as well graded; that means, is the Cu is large; that means, small size of particles are presents; that means, small particles to big particle all particles then that is called well graded; that means, all size particles are present in the soil then this called well graded.

And, a coefficient of one represents soil size of the same magnitude; that means, the if the curve is something like this curve is something like this; that means, buy and large that is suppose 100 and that is suppose 1 and in between that is not curve is not no variation; that means, single size of particles present maximum quantity and if you calculate uniformity coefficient you may get close to one.

That means coefficient of one represent the soil size of the same magnitude; that means, all size particles are same (Refer Time: 16:21) all size are size are present same, then that is called uniform soil and generally soils whose Cu is less than 4 are considered as uniform. So, though actually if it is one that is perfectly uniform and when it is a less than 4, we treat them as a uniform soil though it is vertical there maybe little slanting line maybe like that. So, based on that we can get the value between 1 and 4 and if you get the value 1 and 4 then those soil will be treated as uniform. And, if it is a more than that then it is called well graded.

And, when soil mechanics actually most of the time many activities we expect uniformity. And, uniform it is a good in the sense it is a good parameter most of the cases, but in soil mechanics the uniform is not a good parameter. Soil when the soil is uniform; that means, bad actually they are not there will have more pores actually there porosity will be high.

So, the soil uniform means it is not a good one. In fact, we expect all are well graded, when it is well graded means what different size of particles are present; that means, smaller particles can be there in between bigger particles and this way the soil will be more compact state and it will be have more strength. So, all those things we will discuss we have already discussed in the soil mechanics and one second I will just highlighting that. So, well graded soil is better than the uniform soil.

Similarly, when you calculate another parameter that is Cc the Cc is the measure of the shape of the grain size distribution curve. How it will be the you can see the I have shown the curve with a perfectly S type and for a Cu value of about 1, the soil is considered well graded. Close to one when we get that soil is be well graded. And, for Cu much less that mean much smaller than 1; that means, sum of 0.5 or 0.4 or much larger than 1; that means, maybe 3 4, then the soil is views as poorly graded; that means, it is a; that means, if you want to be well graded then it has to be between 1 and 3.

So, Cu much less or much larger than 1, the soil is views as poorly graded. Greater than 3 and less than 1, the soil is poorly graded. And to become well graded it should be between the it is range. So, well grades and poorly graded means one of the uniform soil also can be classified as poorly graded or sometime some soil there are large number of particle size are there, but 1 or 2 particles totally missing. So, they are also can be treated as poorly graded. So, like that based on Cu and Cc we can get this information and that will help actually to assess the other strain characteristics of the soil.

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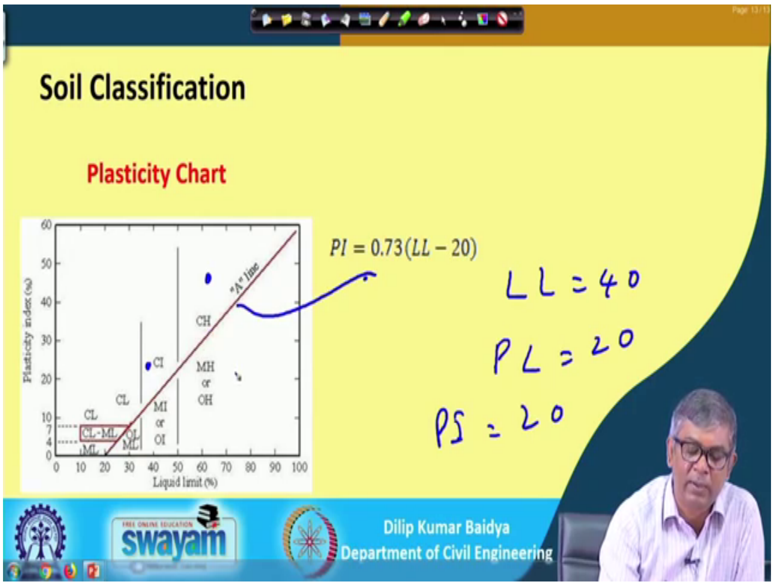

And, as I have mentioned that the beginning I have mentioned that, when the we get a bag of soil then you have to see and you have to take the action 1 by 1, and as I have told you when you get the sand and silt flow free flowing sand type of soil then we can do grain size silt present then you can pass through and carry out hydrometer analysis, but some time if you find more amount of silt and sand, then in that silt and clay in that case actually you can do classification by another means that is called plasticity chart.

And, what is that plasticity chart actually there are soil will have the plastic the fine grained soil will have plasticity characteristic like consistency limits like, liquid limit plasticity limit I will discuss that in the subsequent slide. And, based on the calculation of plastic liquid limit, we can find out the plasticity index and one side liquidity liquid limit. The actual this is the plasticity chart there is a line and it has a definite equation, this equation actually can be written in this form, there is a line and this axis is a liquid limit and this axis is a plasticity index. And, this lines are there and then there are vertical lines and if I carry out test on a particular soil and if I get a liquid limit suppose 40 L L suppose 40 and plastic limit suppose 20 then PI will be equal to 20.

So, PI 20 somewhere here and liquid limit 40 somewhere here then 40 on 20 the soil the point will come here, that mean the soil come here means the amount of particular amount of soil I have taken for a particular sample and carried out liquid limit and plastic limit test, and then I have got these value and then based on that value I have plotted that point of plastic limit versus, a plasticity index versus, liquid limit on this chart and the point came here. When point comes here we understand many thing what is that? The soil will be classified as CI; CI means what clay of high plasticity clay of intermediate plasticity.

Similarly, if another situation if come suppose somewhere here, then what I understand the it is about the soil it is CH. What is the meaning of CH; the clay of high plasticity? Similarly I have another sample and based on the test and I get a point somewhere here ; that means, what will understand about the soil the soil is either MH, that may silt of high plasticity or OH; that means, organic of high plasticity. Suppose, I get another soil sample and based on the test whatever I get the point comes here, then what I will understand about the soil which is of silt of intermediate plasticity or organic of intermediate plasticity.

Similarly, it can come here it can anywhere it can go and based on this chart I can classify the fine grained soil, whether it is CH, CI, MH, OH, MI, OI, like this. And, once we I can classify this; that means, the soil of Ca is; that means, clay of high plasticity means it is a problematic soil generally and you have to take care while designing the foundation system. So, that is the thing we have to understand through soil mechanics.

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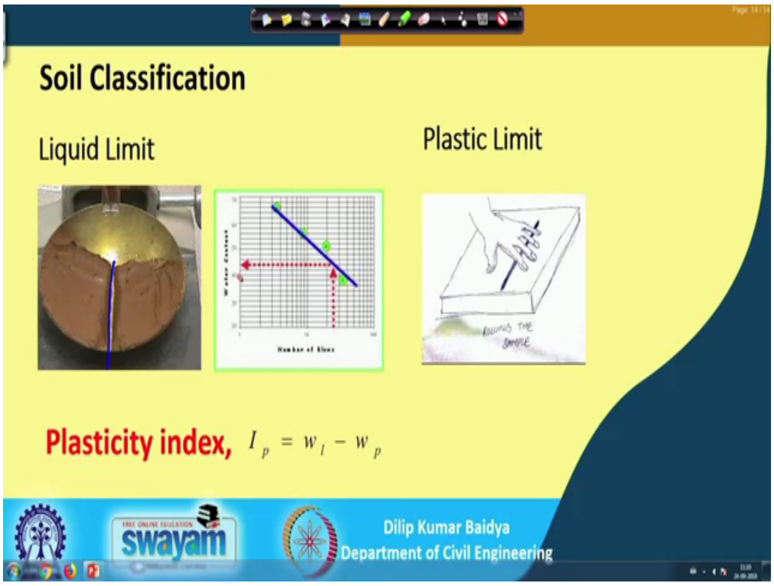

And of course, whatever I have mentioned about the plastic limit liquid limit there we in soil mechanics they have discuss this, and you can see the procedure for plastic limit test, that actually we have to soil paste you have to make and there is a casagrande apparatus, and on that casagrande apparatus you have to cut a group and then you have to give the number of blows, and the water content corresponding to that actual liquid limit is nothing, but water content at particular stage. And, that particular stage actually when water content is such in this while you require only 25 blows to cut the groups that is the definition.

And, so, by single travel it is difficult to do because of that we mix with different percent of water and then we carry out test and see water content version number of blows and finally, plot number of blows versus water content. And finally, 25 blows corresponding 2 point water content corresponding to 25 blows by get from this curve and that will be defined as liquid limit. And, similarly plastic limit test also we generally make a soil paste and we generally roll on the glass plate by our pump with light pressure, and we try to make a thread wire like and when will be able to make 3 millimetre diameter of wire like material and it will not just about to crack.

That is the stage and that water content is actually plastic means very looks like very simple, but it is very difficult to carry out this test generally need lot of experience and you have to do again and again and based on that finally, you will get the plastic limit. So, the plastic limit was actually it is also water content at a particular stage, how to do? We will make a soil lump with water and then roll over the glass plate with light pressure, and we will try to make a wire like of 3 millimetre thing, and then when you will see that when about to make 3 millimetre of wire and it is just trying to crumble; that means, that is the that is the plastic limit ok.

So, that that is the plastic limit so, that plastic limit and liquid limit if you know and based on that I can finding out plasticity index I P, which is actually used one of the axis in the plasticity chart. And, other axis actually liquid limit and this 2 actually to be calculated and based on that I can find out the classification of the soil type.

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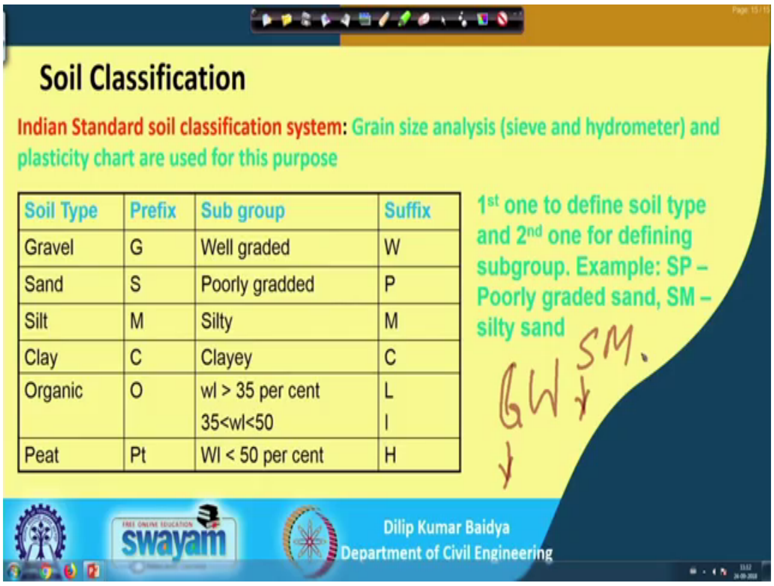

And you can see that finally, soil classification can be done this is actually 2 symbols we use one is prefix another is subgroup. First one is the soil type and second one is actually subgroup. And, you can see if the soil is treated as G sorry, if the soil is treated as G G W; that means, it is well graded gravel. So, that is the; that means, it is a basically first letter indicates the soil type and second one what type. So, it is well graded.

So, like that similarly this there can be a soil of actually C Silty sand; that means, if you have a 2 letters will be using soil of S M, if I use that as SM what I understand by this it is basically sand mixed with silt. So, that is why we have to write silty sand some amount of silt present in the sand. So, like that 2 letters we used this is also I have discussed in (Refer Time: 27:37) in the soil mechanics and that is of course, you have to understand that how by using 2 letters soil will be classified or if you get a soil report and the soil is classified by 2 letters, then you have to understand what it is?

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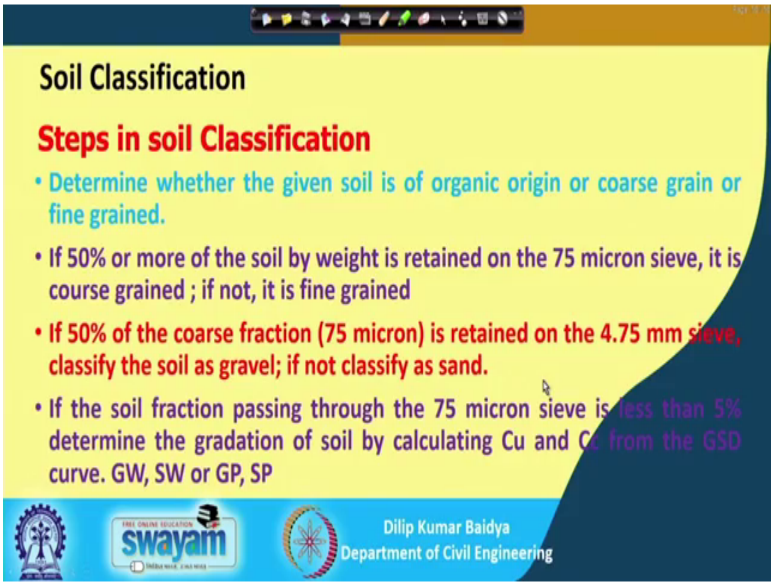

And, then steps in soil classification I already mentioned this that first of all you have to see determine whether a given soil is of organic origin or coarse grain or fine grained that I have open the bag and see that, that if 50 percent or more of the soil by weight is retained on the 75 micron sieve, then it is coarse grained and if not is fine grained and if 50 percent of the coarse grained fraction is retained on the 4.75 millimetre sieve then soil can be classified as gravel.

And, if not if (Refer Time: 28:28) it a sand in the soil fraction passing through the 75 micron sieve is less than 5 percent determine the gradation of the soil by calculating Cu Cc from the; that means, if the fine with less than 5 percent, then based on grain size distribution curve we can classify that will be enough. But, if you are passing more than 12 percent that 75 micron then you have to do something else we can see that.

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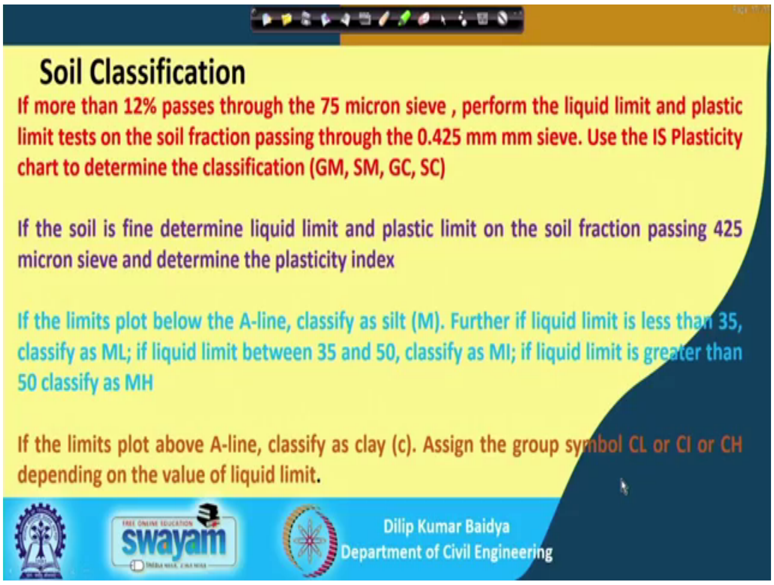

If more than 12 percent passed through the 75 micron sieve then perform the liquid limit and plasticity limit test on the soil fraction passing through the 425 micron sieve use the I S plasticity chart to determine the classification. So, this is as I have mentioned sometime you have to do grain size, sometime you have to do plasticity chart, sometime you have to do both also.

And, if the soil is a fine determine the liquid limit and plastic limit on the soil fraction passing 425 microns sieve and determine the plasticity index, and if the limits plots below the a line; that means, of course, as I have shown the I have explain the plasticity below the a line, the soil is silt. And again further if the liquid limit is less than 35 classify as ML; if liquid limit is 35 to 40 classify as MI, that intermediate and high and then liquid limit is greater than for 50 is classify MH. So, like that as I have mentioned if that limits plots above a line the classify as clay and again clay can be intermediate plasticity, medium plasticity, and plasticity that I have mentioned. So, how that is the various steps of classification by plasticity chart?

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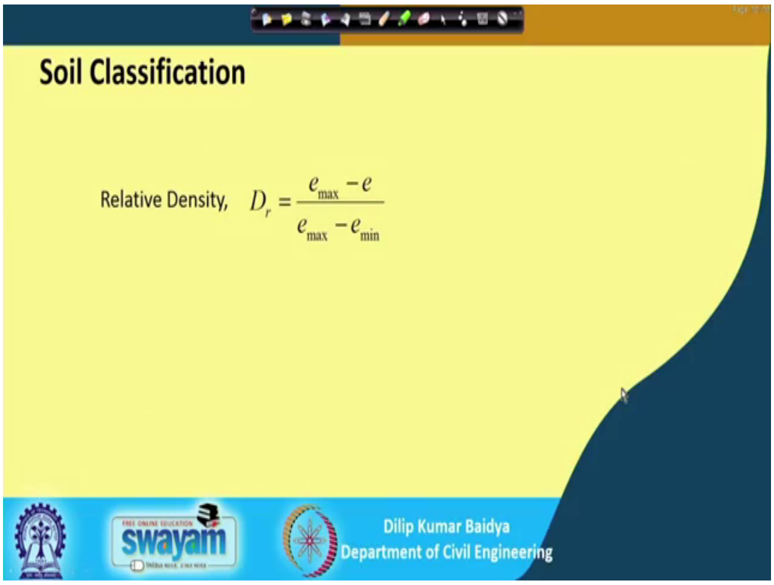

And finally, the fine grained soil sometime we also classify by another important term that is called relative density and that relative density you can see defined by D r equal to e max minus e by e max minus e minimum, e max means actually the void ratio in the loose state and e minimum means void ration at the dense state. So, if you have a soil granular soil sample, we can find out it is e max and e minimum m by laboratory test; that means, you have to create the situation of dense state, create another situation of loose state, corresponding void ratio you have to find out and initiative void ratio you have to find out, and based on that you can calculate sorry.

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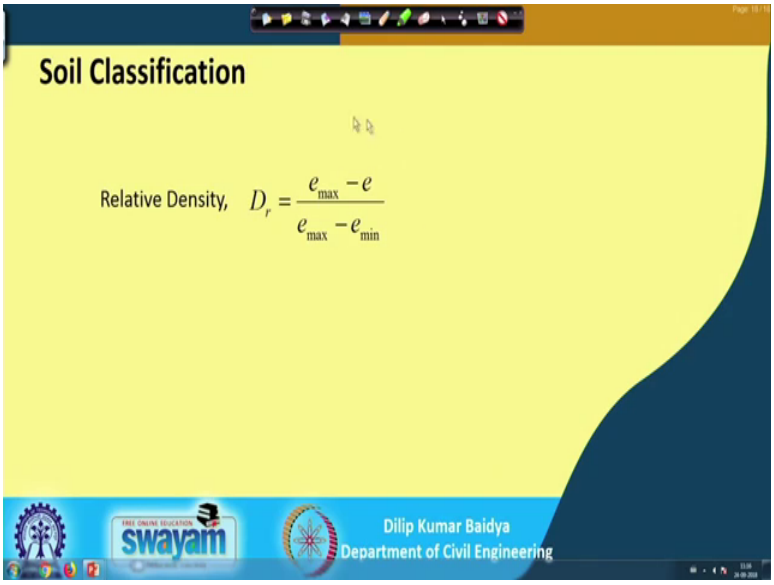

You can you can calculate this D r and that that give you a number and based on that number you can classify the soil as in the next slide.

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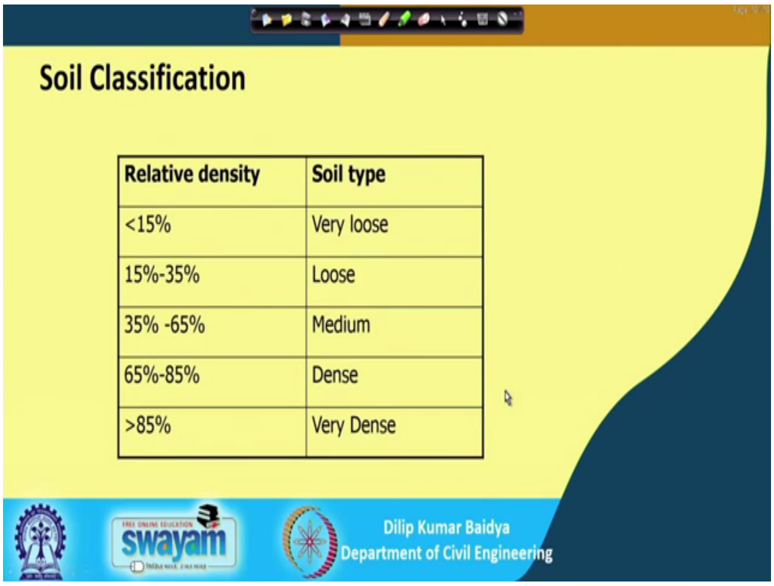

You can see that a relative density is less than 50 percent means soil is very loose, relative density between 15 to 35 percent, it is a lose only and if between 35 to 65 it is a medium and 65 to 85 is a dense and greater than 85 percent is a very dense.

In fact, that relative density greater than 85 percent is very difficult to achieve and of course, sometime you may able to achieve 95 90 92 percent, but these are the things classification based on relative density of the soil; that means, if you have a sample carry out some test find out e max e minimum and void ratio initiative void ratio. And, then carryout D r and if you know the D r that is a value we will get and that value if based on the position of this value, we can classify the soil either as a loose condition, very loose condition, dense condition, or very dense condition; obviously, lose means soil is very poor condition and dense means or very dense means soil is in a good condition.

So, that is also another type of classification to assess the strength and compressibility behaviour of the soil. So that means, by this type of classification will help you first to understand the soil; still we do not know what will be the strength and other things that I have to do some more things, I will come in the subsequent slides.

Thank you.