Soil Mechanics/Geotechnical Engineering I
Prof. Dilip Kumar Baidya
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture – 04
Soil Classification (Contd.)

So, in continuation to my last lecture, I was talking about grain size distribution and grain size distribution can be done by that is mechanical analysis what I have mentioned, that is actually by using your sieve and for sieve actually can be used for coarser particles that is bigger than 75 micron and, if it is a smaller than 75 micron we have to go for hydrometer analysis and this combination finally you have to plot.

And of course, most soil will have both and sometime for this combined analysis and it is a silt and clay is present very difficult to separate. So, what we do generally we take some amount of soil and then wash through the 75 micron, and then when it will wash through 75 micron then those finer than 75 micron the silt and clay will pass through and then that will be collected and dried and that dry sample will be taken for hydrometer analysis and on 75 micron sieve whatever retain that also you can dry it and then it will be sieve through different sieve and then the combined analysis will be done.

And after combining analysis we will be doing the plot and then after plotting by seeing the shape itself I told you that if it is the s shape then it is called well graded that mean all particles by and large present in the mass that is well graded it is good and if the soil the curve is a very steep like the vertical like that means, in the particular size is present that mean uniform that is also not good and also some particles are present somewhere some particles are not that that gap graded or poorly graded soil also can be there from the shape itself. But if this curve is smooth and still sometimes, we can do some calculation to classify the soil that is one such calculation is coefficient of uniformity well uniformity, that means that cu is given by d 60 by d 10, you can see c d 60 by d 10 and d 60 is diameter corresponding to 60 percent passing.

Similarly d 10 is the diameter of particles corresponding to 10 percent passing. So, these 2 quantity actually can be obtained from the curve and you can find out the sieve, when you calculate this u then the value one number you will get and it the number the soil to be well graded it has to be between 1 and 3. And even rather than that then it is not well graded that is what we can decide, similarly coefficient of curvature that is a equation is given c c see that is d 30 square by d 10 into d 60 here also from the curve itself these three quantities to be noted and this can be calculated you will get another number, and this number actually if I get if it is greater than 4 general is gravel and greater than 6 generally it is sand. So, like that some qualitative information also from this number 1 can find out.

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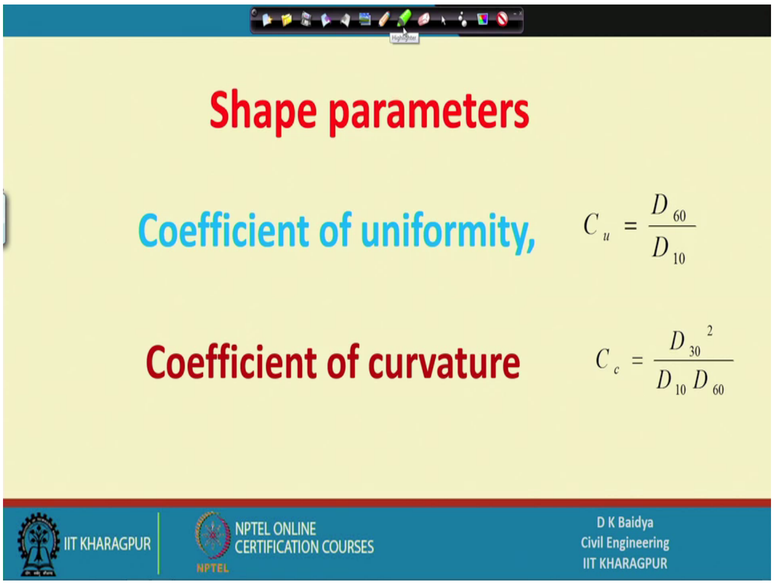

So, this is about grain size distribution and some calculation and sorry.

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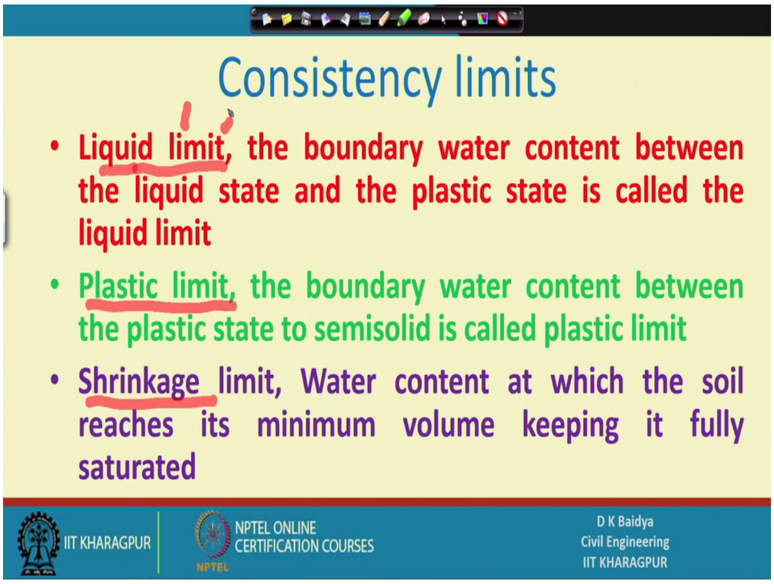

And as I have told that, this is one sort of if the particles are bigger particles and no plasticity those type of classification can be done, but if the soil contents mostly of your silt and clay, in that case you will deceiving and all is difficult and we have to do some other type of classification and for that before doing that classification you have to understand some behavior and for to understand that behavior that our past researchers did different ways to stream lining the things.

One such step for that consistency limits otter box actually gave three limits actually that is one is liquid limit and that is your liquid limit, then that is another is plastic limit and one more is the shrinkage limit. And generally fine grained soil will have these limits more the fine particles more will be the plastic in nature and obviously will have this liquid limit plastic limit shrinkage limit depending about their core composition.

And this liquid limit is what is liquid limit as per definition the boundary what are the this liquid limits these three limits this is called limit liquid limit plastic limit, shrinkage limit actually what it is it is nothing, but water content it is nothing, but water content of the soil. What is water content actually if I take a mass of soil and that mass of soil it can be completely dry or it can be completely saturated or it can be part partly saturated or partly dry, but whatever maybe the situation if I take a mass and on that mass actually I can find out what is the amount of water present and what is the amount of solid present.

And this ratio amount of weight, amount of water divided by amount of solid this ratio is nothing, but water content and this limits are nothing but water content actually the liquid limit means actually water content at liquid limit and plastic limit means that water limit water content that plastic limit and shrinkage limit is what water content at shrinkage limit, that means all are nothing, but water content and what water content that is liquid limit water content, plastic limit water content, shrinkage limit water content and in the soil mechanics, this water content determination is a one very routine work.

Most of the test whenever we do always we require to find out water content and for finding out the water content generally we take a sample and with sample in a particular can we take the weight and then after taking the weight and you keep in the oven for 24 hours in a particular temperature, and then the moisture will be evaporated obviously after 24 hours and then with constant take the after 24 hours after drying that way to take, after 24 hours whatever weight you got that weight is nothing, but weight of the solid and difference of first weight minus second weight is nothing, but the moisture present in it.

So, moisture present divided by a solid is a moisture content or water content that is the routine work we do for every experiment or test that has to be there. So, liquid limit plastic limit shrinkage limit is nothing, but water content at different stages. So, consistency limits at there limits at different stages. So, liquid limit the boundary water content between the liquid state and the plastic state and is called liquid limit, and what is plastic limit the boundary water contained between the plastic state to semi solid state that is plastic limit, and another is shrinkage limit.

That is water content at which the soils reaches it is minimum volume keeping it fully saturated that means, I will go to the next solid slide that when there is a soil water suspension when we keep it and water quantity start reducing the soil water suspension we will have started certain volume and then if the water evaporated then amount of water evaporates the same amount of volume will be reduced in the mass.

This is a this is the assumption most soil will have that some soil will is there it may not have that is differently this it would not be applicable, but in general for understanding liquid limits, plastic limits, shrinkage limit when there is soil water mass quite is it almost like liquid states and when water will be evaporated then volume will be reduced how much volume will be reduced volume of water will be evaporated.

So, like that slowly it will be reduce and every time the soil will be saturated that means, water present in the voids sometime either just sufficient to fill up the voids or excess, voids excess that is almost liquid states and when it is just saturated that is almost solid state, but all voids are filled up with water. So, like that it will continue that means, well water will be evaporate while evaporating with evaporating of moisture the volume will be reduced linearly.

Up to certain stage that will be applicable and it is due to sometimes soil will be reached to it is minimum volume and if you further reduce the moisture then further reduction of volume is not possible. So, that limit actually that means, the water content at which the soil reaches it is minimum volume keeping it fully saturated that is called saturated that is called actually shrinkage limit. So, how to find out about all those things we will discuss later on in the subsequently right now these are the qualitative definition of the three limits.

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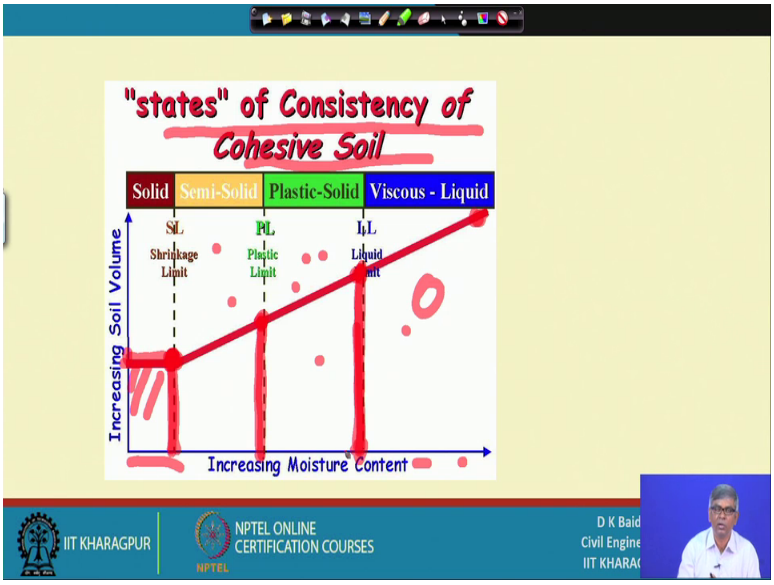

And you see this is the one what I have qualitatively told in the previous slide while discussing the states of consistency, that means you can see states of consistency of cohesive soil you can see this is the one viscous liquid, that means soil and what are in the water actually if you put excessive water then viscous fluid like liquid like thing will be there that will be in this zone.

And on drying actually that it is volume this side it is volume initial is how a volume was here on drying at this stage volume become this, at this stage volume become this at stage volume become this and at this stage whatever volume it reached further reduction of moisture the volume reduction is not this volume is constant up to beyond this and you can see this site actually this has moisture more moisture and this site is moisture is decreasing and this site is increasing.

So, when I am going from this to this that mean moisture is reduced from here to here there is further reduction from here to here further reduction and from here actually we get 0. So that means, this is as we have qualitatively defined that viscous the boundary between this liquid stage to plastic solid that is actually liquid limit and this plastic solid to semisolid that boundary water content at this point at this point whatever water content at this point what is the water content that is called liquid limit that means, boundary between this state and this state that water content is your liquid limit.

Similarly, between boundary water content between these and these that mean this is a plastic limit, similarly this is the water content which is called shrinkage limit why it is called shrinkage limit, because it is least minimum volume and also at this stage the soil is fully saturated and if you reduce further moisture no volume change, that means that at this stage if volume was fully occupied by the moisture.

So, this is the one that we not drying volume changing and that this stage your volume reached many minimum volume is reaching with saturated condition that is called shrinkage limit and this is these two stage that means, semisolid to plastic solid that boundary what are going today is plastic limit, and the plastic solid to viscous liquid that boundary water content is the liquid limit. So, these are all of course, qualitative definition that, but very difficult if you without doing any experiment we will not be able to find out the exact boundary it is very difficult. So, because of that we have some mechanism to find out that boundary.

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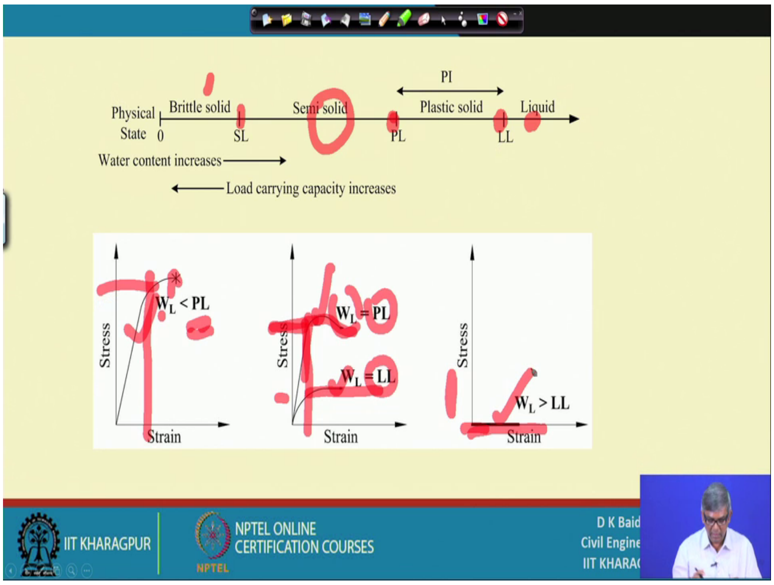

Ah. So, you can see also some qualitative behavior also at different stages, when it is a we have defined liquid limit this is suppose this is suppose water a particular soil contains water content is W L suppose a particular soil water content is W L which is less than plastic limit. So, water content is less that personal plastic limit the stress strain behavior will be something like this, because suddenly it will be brittle it will break suddenly. So, this so sink is limit to these this is called brittle solid and if your water content W L is close to plastic is equal to plastic limit, then we will get a curve like the smooth curve and then suddenly like that.

And if it is a liquid limit water content is equal to liquid limit that means, if you take a mass and it is water content is same as the liquid limit of the soil then you will not get much strength actually strain will be more with lesser stress, where as if I it is a water quantity is less than plastic limit it will be straining very less with very high stress, here also if it is a liquid limit is plastic equal to plastic limit then straining is less and also stress is compared to less and if it is a liquid close to liquid limit or liquid limit then at very less stress that deformation will be strained will be more.

Similarly, if it is a in the mass it is liquid limit is the water content is equal to the liquid limit then it is like liquid only and if I apply force it will not be able to take any force because of that we can see the there is no stress here, that means no without increase in stress the straining will be very high. So, this it will not be able to take any load so that means, at different stages what will be the behavior of the soil from this curve actually one can understand.

So, like if I take a sample from this zone then this type of behavior if I take this one then we will get this figure, and if I take at this then we will get this one, and if I take the sample from here then will get the this type of behavior. And so these are actually some behavior actually expected behavior at different stages of water content, if the water content is close to liquid limit that means we will get very low strength, and the water content is very close to plastic limit we will have good strength that is what here we want to explain through this slide.

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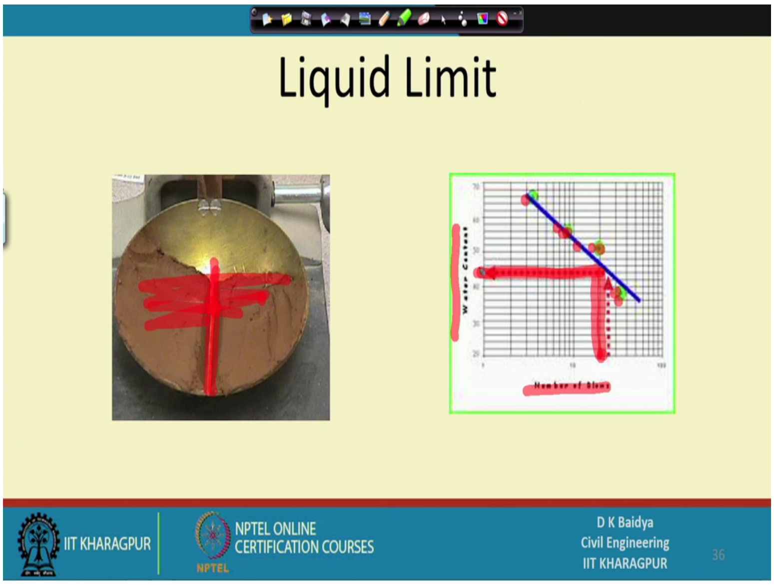

And now as I have mentioned that liquid limit we have denser mentioned that is qualitative different definition that is the boundary between these two, but how to find out boundary that for that actually, crushaganda developed a apparatus that is called crushaganda apparatus and it has a cop.

On that cop actually we have to prepare a sample soil mix with some water and make a paste and that that paste with that paste we can make a soil over here on the this one and then find finally, from there you have to cut a group that there is a particular grooving tool it will have a some dimension at the bottom some dimension at the upper surface, it is like it is after cutting the group it looks like 2 slopes one slope this side another slope this side this is one embankment this side another embankment this side, and when this sample is ready then there is a handle through that handle nowadays of course, the motorized is there through motor also we can do it by handle actually we have to rotate and when we will rotate that one there is a mechanism by complete rotation and it will be lifted maximum by one centimeter and dropped.

So, it will be doing it is lifted like this and dropping on a particular base. So, while doing this then there is two side, that is two embankments like this it is there through grooving tool groups those slopes when there is impact will get then they will be coming closer. And we have to note when these two sides close by around 12 13 millimeter distance that to be noted that number to be noted that means, how many numbers required to close 13 millimeter distance.

So, that number and then that is one data that is number of blows, and observation is 13 millimeter distant they come closer, and third measurement what you have to do you have to take a sample from here and that sample finally, that sample from here you have to collect at for water content determination. Finally what we will get number of blows corresponding to water content, water content and corresponding number of blows.

So, we are doing this test cutting a group doing the impact by blowing and when it become 13 millimeter closed closer, they are coming closer at 13 millimeter distance then I am counting the number and taking some amount of soil for more as moisture content determination. So, after knowing the moisture content then this become one data moisture content versus number of blows, like that I have to do for 5 trials and by definition actually water content exactly at which we can two sites of mass from two sides touched by 13 millimeter distance when we give able to require 25 blows, that means if the water content is charged by 25 blows I can bring mass up from both sides closer by 35 sorry 13 millimeter distance. So, if that is the definition of liquid limit.

So, if that is the definition. So, I will not be able to do exactly how much quantity is required. So, I will add different amount of water and I will prepare different sample and do this test. So, I will get 4 5 data points that mean water content versus a number of blows like that and like the suppose there are number of blows and those corresponding points are here plot it, and this is observed that is a good control test and whatever data we get and if you plot in a semi log plot that is number of blows this side and water content this side, then those points by a large come in a straight line and you have 4 5 point.

They are not exactly 25 to while testing we may not none of the test may not have 25 blows, it may have 18 blows, it may have 22 blows, it may have 35 blows, but we may not get 25 blows, 25 blows actually corresponding water is the water content is the liquid limit, but what how you can get it we can plot this and from this plot I can fix here 25 blows and corresponding go to here and from here we can find out what is the moisture content that moisture content become liquid limit.

So, if I have a soil that soil I will take and some amount and that soil has to be passed through 425 micron soil sieve and then you mixed with water make a paste and then put a sample here cut the group then apply blows and that blows should be 2 blows per second and then you observe when it becomes when it is touching by 13 millimeter distance, when it is 13 minute then you have stopped and then record the number of blows and collect the sample for measurement of moisture content.

So, the moisture content and number of blows that become one point like that five points like 1 2 3 4 then maybe another you plot in a semi log from here 25 blows corresponding to these project and then corresponding water content that becomes liquid limit. So, like that one can find out the liquid limit of soil.

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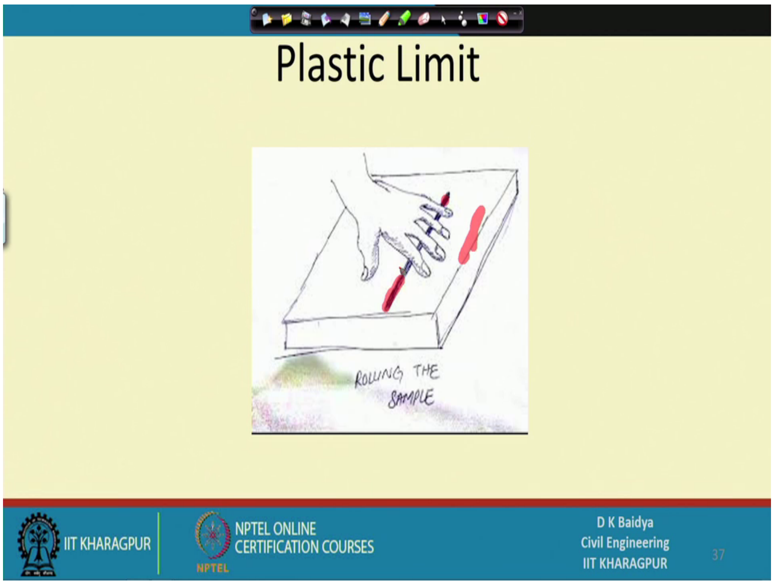

And similarly plastic limit actually plastic limit is also a very qualitative test and this is actually you have to mix with water some amount of soil and then finally, you have to roll fine final initially you have to make a roll and then later on you have to in on a glass plate like this you we can see here this is a glass plate on that glass plate this is the soil, this is the actually soil on below this your fingers very lightly you have to roll it and roll and when it will become too long and we have to see still we are able to roll, that means moisture present is much higher than the plastic limit. So, you have to remold it and again roll it, like that you have to continuously do it and when we find that we are able to make approximately 3 millimeter diameter thread and about to crack, that means it is reached to it is plastic limit.

So, when we are about to make 3 millimeter thread like this and it is some cracks are formed that means, it is a plastic stage this is a lot of experience is required this is not. So, easy to do though it is a very simple test; that means, below your palm plate, glass plate you are rolling it and making trying to make it 3 millimeter thread when it will become exactly 3 millimeter and start cracking that is the water content that a plastic limit, then what you will do you immediately collect that and keep it in a container put it and take away it and then put it in a oven next day you take weight and from there you get the water content and that water content is nothing but plastic limit.

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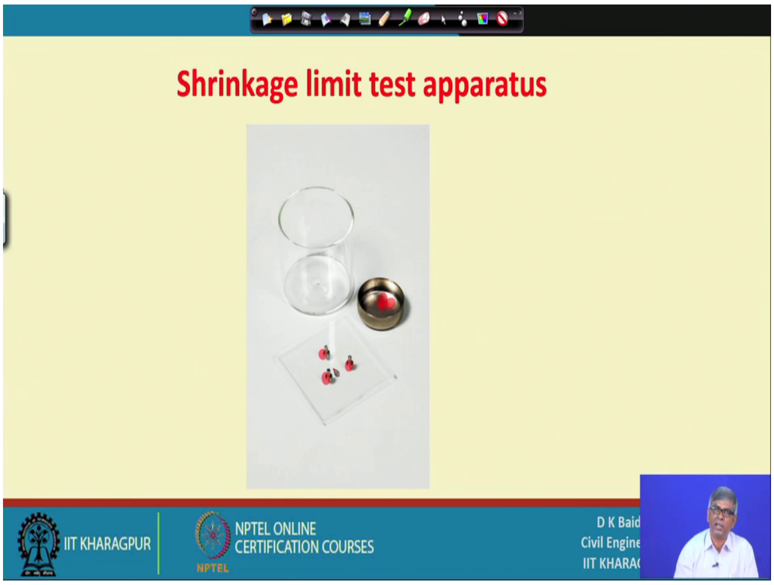

So, that way one can find out the plastic limit. And so one we have got this is a liquid limit procedure this is the plastic limit and then we can go for shrinkage limit and this is shrinkage limit. Test apparatus you can see there will be marker displacement method generally used and this is the this is called shrinkage this is call say this is a small container you have to mix with soil mix with water and make sufficiently thin and then this container will be filled up, level it properly and then it has to weight has to be taken and after taking the weight we have to keep oven drying for some amount of time and then after whole day if it is kept for here some water will be evaporated and it will become if the sinking soil it will be become smaller, or it will be semisolid and with less moisture content and under that stage you have to you can put this one in the oven for complete drying when it will be completely dried, we will see the soil sample which was originally with entire occupying entire container and you may see that 30 40 percent may be empty become soil sample becomes smaller.

And then that in the dry condition what is the volume, that volume is important for calculation of shrinkage image. So, how to find out this volume by you can take the weight how hard is the soil is present we can find out and for finding out the volume actually what we can do, we can by mercury displacement because it is not a uniform shape it may be down in the middle and raised in the edge. So, because of that irregular shape it is very difficult to find out the volume by measurement, so what you can do we can do by mercury displacement.

So, mercury displacement what actually in a container a definite volume of container we can fill up with mercury, and then this soil sample can be kept on it dry soil sample and then this plate is there this is with three pins that through that pin on that touching on that soil sample and force it to immerse in the mercury, when it is fully immersed in the mercury then some amount of mercury will be displaced. Thus amount of mercury displaced amount of mercury to be collected and weight will be taken and once we know the weight and density of the mercury is known we can find out the weight divided by density volume.

So, that volume of the soil can be obtained by the soil and moisture can be content can be obtained initially when it is a full of the can we could have taken the weight and after drying you can take the weight difference of that will be the moisture content. So, these things can be done after doing all those things we can take help of sorry.

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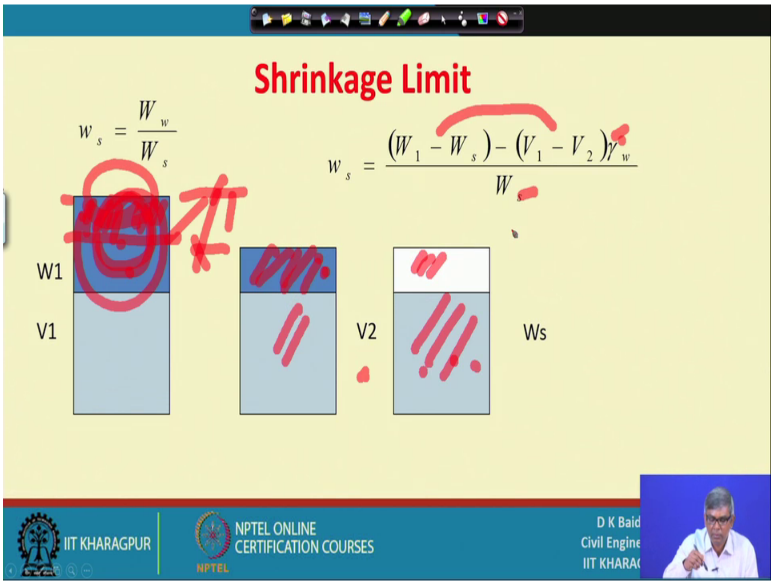

Take help of this diagram to find out the shrinkage limit calculation. So, suppose the initial volume is this, initial volume was this and it was some weight was W 1 volume was V 1 and after drying at suppose if the shrinkage limit determines the volume and this portion was water and this portion and this portion was solid and after drying volume will not change. So, this become air which has does not have any weight and this becomes solid.

So, ultimately you have to find out that water content at this stage, what is the water content at this that is a shrinkage limit. So, I can find out this weight minus this weight that is nothing but W s, I can find out this minus this if I do then I get this water. So, these minus this gives you this water then how to find out this water, I can find out this volume I can find out this volume how to find out this volume I know this volume I know this volume, so difference of these two will be the volume.

So, that you can see V 1 minus V 2 is the difference of this much volume is V 1 minus V 2, if it is V 1 and if it is V 2. So, V 1 minus V 2 is the volume and what was the, this much volume what was the weight the water only was there. So, V 1 minus V 2 into gamma W was the weight of water in this zone initially. So, I have this minus this I have got that means I have got entire water now this minus this into gamma W this much water. So, now if I do this minus this I will get this water. So, by doing this I am getting this water and divided by the weight of solids so water divided by solid that is nothing, but water content and that is water content at shrinkage limit. So, this is the way we can find out the shrinkage limit.

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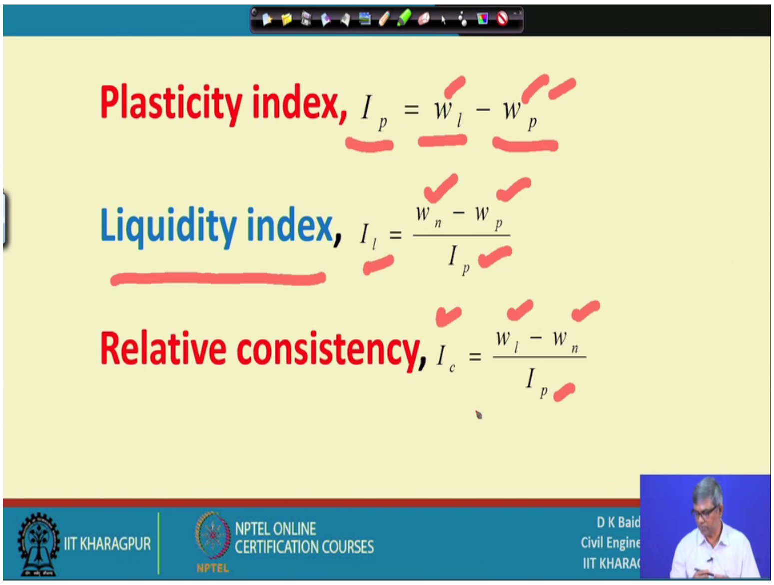

So, like this three limits one can find out. And after getting this liquid limit, plastic limit and shrinkage limit we can sorry we can get actually plastic limit, this is one plasticity index I p which is nothing but liquid limit minus plastic limit and these are the notations actually different places at sometime we can say W l sometime W p ll l p like that pl like that we have used, but here W l W p is nothing, but liquid limit this is W p means plastic limit dependence of liquid limit and plastic limit is the plasticity index.

Similarly liquidity index there is another natural water content minus plastic limit divided by I p is the I l and relative consistency I c is the W l that means liquid limit minus natural water contained divided by I p is the I c. So, this these are the different parameters one can find out after knowing liquid limit and plastic limit and this can utilized for classification purpose.

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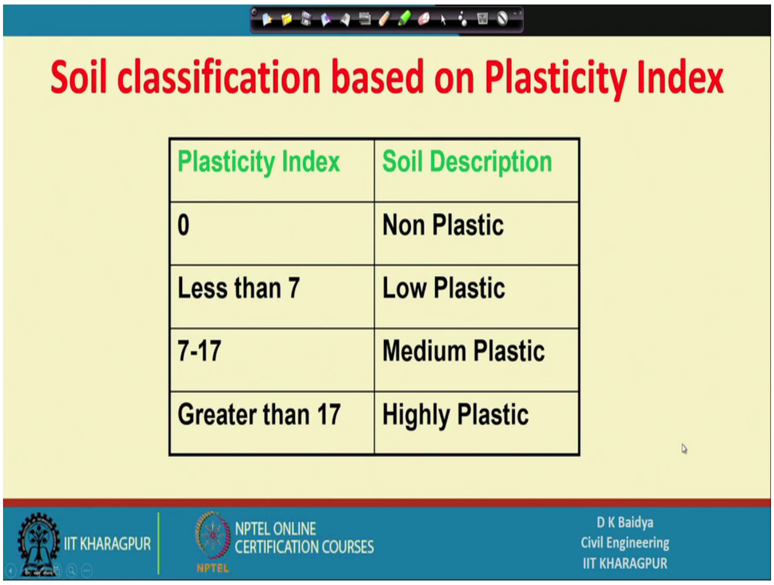

And you can see the soil classification based on plasticity index, when plasticity is 0 then soil description is not in plastic plasticity index that is I p zero, that means the soil may not have any if it is a sand if I try to do liquid limit test you will not get. So, that is actually non plastic soil so you will get 0 sorry. So, 0 similarly if that is a plasticity index is less than 7 that soil is classified as low plastic, if it is between 7 to 17, 7 and 17 it is medium plastic greater than 17 that is highly plastic.

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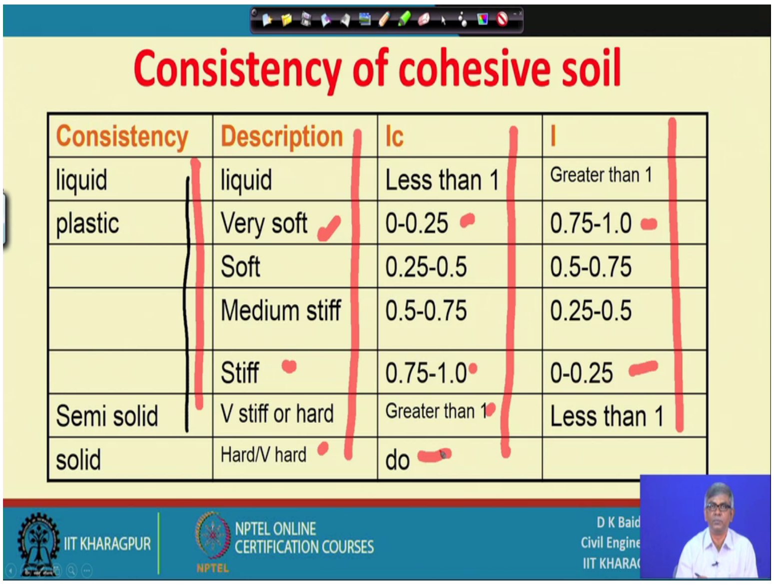

And consistency of cohesive soil, that is consistency is liquid description is liquid I c value will be less than 1, we have I have just shown parameter I c and I l liquidity index and that is actually what are there if this is the consistency, if these are the consistency sorry, if these are the consistencies and this is the description of the material then what is the value of I c expected what is the I c value or I c value is this then what is the corresponding soil.

So, like liquid less than one I c I l will be greater than one very soft soil then I c will become 0 to 25 and I l will be .75 and 1, like that if it is plastic soil then stiff then . 751 is the I c and this one will be 0 to 0 .25 and semisolid this is plastic this is semisolid very stiff or hard then the I c value will be greater than 1 and this will be less than 1 and solid hard to very hard and it will be also greater than 1.

So, this are the classification that means, if I know the those values liquid limit parameter liquid limit plastic limit and shrinkage limit of course directly it is not coming in picture in this classification, but liquid limit plastic limit and natural water content then what we can find out those I c and I l and based on that i can classify what is the state of the soil whether it is liquid state or very stiff soft soil or soft soil or medium stiff soil or stiff soil or very stiff soil or hard or very hard soil. So, based on this we can classify them sorry.

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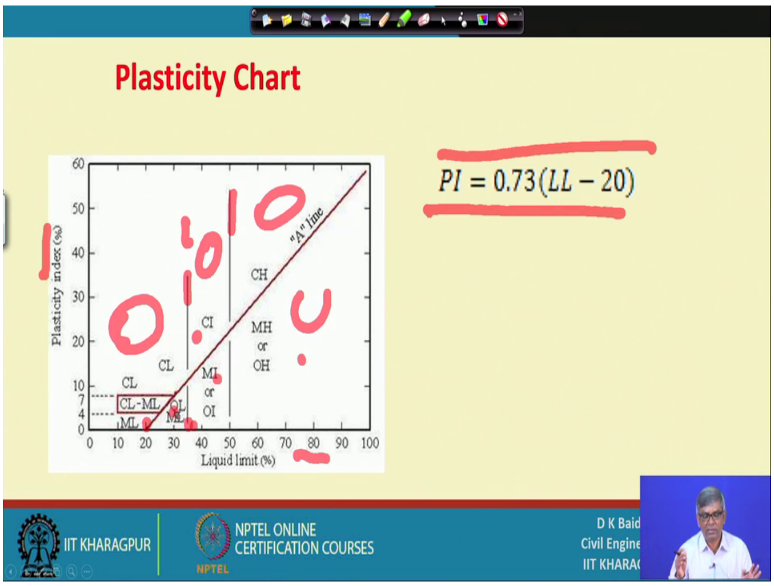

And this is another actually plasticity chart that means, when the soil is plastic that means, when the silt and clay is present then when it is a granular soil for classification purpose we have used that sieve and hydrometer and we have plotted grain size distribution curve from there some calculation and do the naming of the soil, and but where it is a fine grained soil then this classification and sometime not applicable and instead fine grained soil what you have to do, you have to do the consistency limit test and once you get the consistency limit then you have to form the liquid limit or plastic limit one can find out the plasticity index which will be kept in this axis and liquid limit in this axis and this is the plasticity chart called and this plasticity chart which has a different component you can see from the line started from 20 water content and sorry.

And this was started from 20 and this this equation of this line is P I equal to 0 .73 liquid level minus 20 and if this of particular soil suppose you have calculated liquid limit actually 35 and plastic limit is 20 then plasticity index become 15. So, and liquid limit is 35. So, 35 somewhere here and 15 somewhere here, that means the soil is coming somewhere here.

So, what it indicates actually from this chart actually if the point comes here, that means I can classify the soil, that means the if the point comes above this line that comes actually it is clay and the soil comes below this line it is actually silt and again there are two vertical boundaries one is here and one is here another is here, if before this it falls in this zone then it will be low plasticity and it falls between this that means, this zone that is intermediate plasticity and if it falls in this zone that is high plasticity and similarly if the points comes below this that below this line again whether it is in this zone or in this zone or in this zone based on that soil will be classified the silt with low plasticity intermediate plasticity and highly plastic.

So, like that that means, the way we have classified the granular soil that is grain size distribution, plot, do calculation and find out name the soil here actually if you have the fine grain soil do the consistency limit test and then if you know the liquid limit plastic limit and then based on that the point you bring in this plasticity chart based on the presence of the point, location of the point, I can classify the soil as whether it is clay silt, highly plastic or low plastic like that suppose one soil plasticity and one plasticity test if I data if I plot and comes here, that means the soil is clay with high plasticity and if it comes here soil is silt with high plasticity, so like that this chart can be utilized for classification of fine grained soil.