Geotechnical Measurements and Explorations

Prof. Nihar Ranjan Patra
Department of Civil Engineering
Indian Institute of Technology, Kanpur

Lecture No. # 28

Last lecture we have covered this Atterberg limit, with this once again repeating, the presence of water in fine grained soil, it has significant effect in the engineering behavior of soil, also engineering properties of soil.

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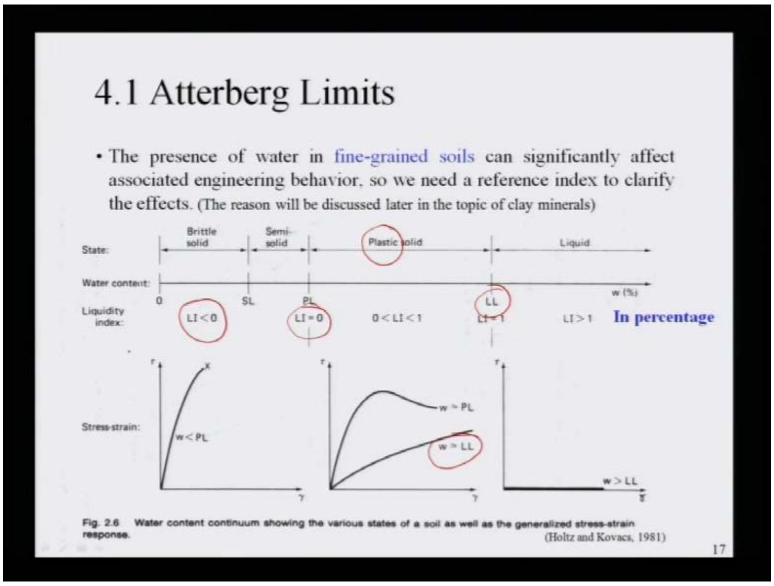

If you look at here, if I make it to, there are four states of soil, means presence of water in fine grained soil, it will be four state, one is a liquid, plastic, semisolid or solid. So liquid state, we say if liquidity index is greater than 1, at this stage your soil will behave like a fluid and it will flow and if liquidity index is equal to 1, from 0 to 1 the soil state fine grained soil state is called is in plastic state. In that case, once water content is equal to liquid limit, if you look at here water content is equal to liquid limit, at that time if you draw this stress versus strain you do not get any particular failure of this failure point if we do not get. And between 0 to liquidity index less than 0 and liquidity index is equal to 0, that is your solid state up to this we have covered.

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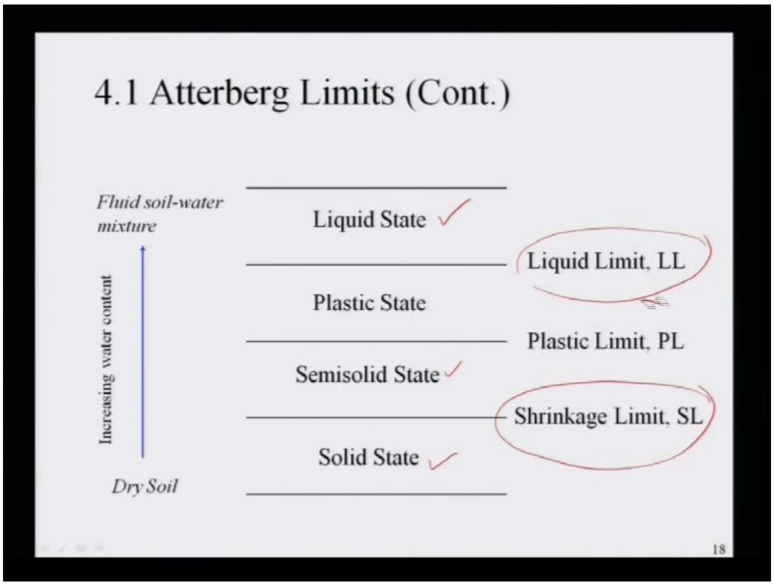

Then how it is varying from dry site of soil to fluid soil water mixer, if I take a dry soil, completely dry soil it can be said that the soil is in solid state, then you can add water, one add water increasing water then from solid state to it will go to semi solid state, then plastic state, then when soil after mixing with water will behave like a liquid then it will become, it will be, we will say that it is in liquid state.

So, as you increasing water content from dry soil, so it will go to the, towards your fluid soil means towards your, from dry to wet condition, it will go from dry condition to wet condition. So there are four different limits to identify whether it is in solid state or semisolid state, plastic state or liquid state; these are called Atterberg limits. So first one is your shrinkage limit, basically shrinkage limit will give, whether, means what is the dry state of this soil? Then plastic limit is a border line once you determine the plastic limit you can say that whether soil is in plastic state or semisolid state. If you determine the liquid limit then you can say that soil is in liquid state or plastic state.

So, what are the liquid limit? Let us start with one by one, let us start with this, first one is your liquid limit that means to determine the liquid limit of the soil.

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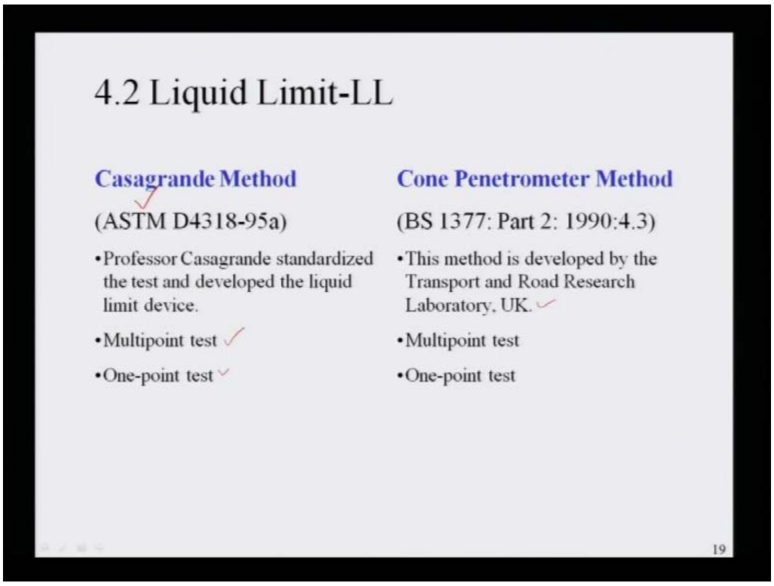

Then it has been measured by means of two standards, one is your American Society of Testing Material (ASTM), American Society of Testing Material that is D4318-95a. Another is your Cone Penetration Method - that is BS1377: Part 2: 1990:4.3. So it is basically Casagrande method, comes from Professor Casagrande standardized this test and developed this liquid limit device and we can find it out there are multi point state test or one point test.

Similarly, in BS Cone penetration, a Penetrometer method, it is a BS method. It has been developed by Transport and Road Research Laboratory in UK (United Kingdom) then multi point test also one point test.

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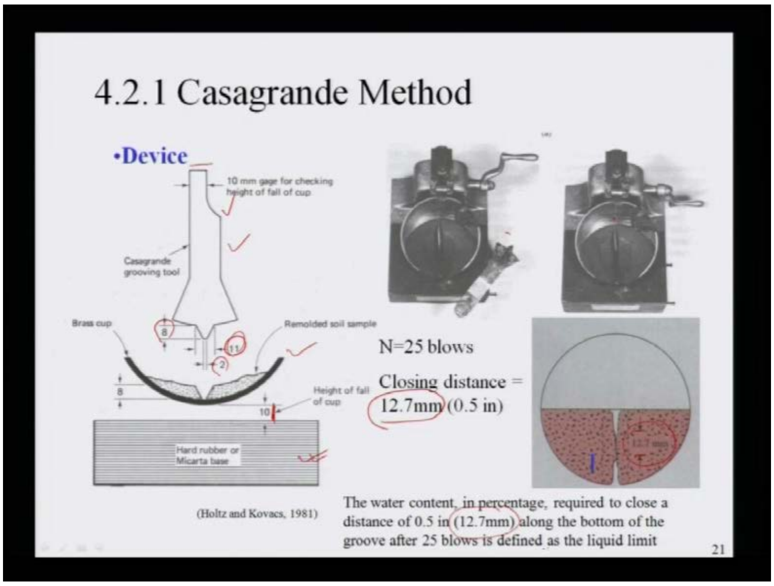

Let us move to the look at this two casagrande, first one is your casangrande method. If you look at the casagrande method, so these are the tools, one is your brass cup, this is your brass cup where you can place your soil after mixing with water. Then this is called casagrande grooving tool, it has 10 mm gauge, from this height, this is your 10 mm. And this tool is more important, this is this is 2 mm, this opening is 2 mm and this is your 11 and this is your 8.

Now, it can be placed over a hard rubber or Micarta base, hard base you can place it. If you look at this device, how it looks, look at this device, this entire device it is called casagrande device. So what will happen you take certain amount of soil, say 200 gram or 100 gram and mix the water by percentage, it start with 5 percent, 10 percent, 15 percent or 20 percent. Mix the water by water in percentage.

So, once you mix it and place this paste, look at here, place this paste inside this cup, this is a brass cup, inside the brass cup, then level it by means of spatula you level it, then after that with the help of casagrande apparatus, this is called casagrande apparatus, you held it very far in your both your hand and you simply cut it. So, cut it means it will cut, if you look at here, it will cut, it is 11 and it is 2, that means almost 12. What it says, the water content in percentage required to close a distance of 0.5 pinch or 12.7mm along the bottom of the groove, after 25 blows is defined as liquid limit. Once again I am saying, after placing this soil paste inside the brassing cup then you make a groove by means of device that is called casagrande grooving tool, you make groove.

So, automatically you find that there is a gap of 2 mm because this is 2 mm at the bottom there will a gap and the soil will tear out. Then after that, you turn this handle so that it will up-down, up-down, it will rest on the hard base, so you wait means after 25 number of blows you wait how many number of blows it takes, so that this will be 12.7 mm, this is your 12.7. Up to closing distance, once I make this handle so this brass cup will, height of fall brass cup is 10 mm, it will lift up to 10 mm and fall in a hard base. Then you identify the closing distance 0.5 pinch or 12.7 mm, you can find it out this is your 12.7 mm and record with this closing distance, how many number of blows required.

So, like this water content you mix, take the soil sample say 200 gram, then mix the water content you will have 5 percentage, 10 percent, 15 percent, 20 percent. Then the paste you place in the cup, then make a group by means of casagrande tool, then after making the groove, then make this handle so that it will height of fall of the cup will be 10 mm. So, then what happen it will start in flowing, identify what is your closing distance, this closing distance should be 12.7 mm and it says, the water content in percentage required to close a distance of 0.5 inch or 12.7 mm, along the bottom of the groove after 25 blows it define as the liquid limit.

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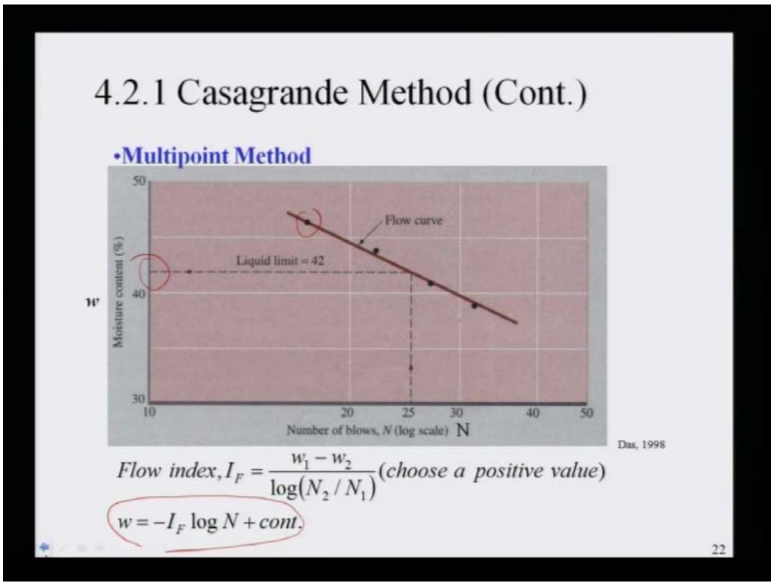

If I plot moisture content versus number of blows, in logarithmic scale and moisture content in natural scale, why this number of blows in logarithmic scale. That means, it start, it has a wide rage blow, you can take it, you can take it 5, you can take it 100, depending upon how this liquid limit we are determining for different moisture content say 10 percent, 5 percent, 20 percent, different moisture content then you can find it out is, this what is that condition at which your achieving 12.7 mm with this respective number of blows.

So, for this number of blows you recorded, you mark it and for different moisture content in number of blows has been recorded, you find it out. Then plot this and this will give a kind of a straight line graph. So, this graph is a flow curve and with these go to the, it is says that to with this 25 number of blows, the condition is liquid limit at 25 number of blows. That is your liquid limit water content. So, that means from these graph you identify, where is your 25 number of blows. With this liquidize this moisture content, that moisture content is your water content for your liquid limit.

Now, flow index from this curve, we can find it out flow index, either the slope of this flow curve or w 1 minus w 2 by log n 2 by n 1, this is a slope of this, choose a positive value, then water content, you can find it out from this WIF log N, you can find it out from their or you can find it out from this graph. That means in these case, particularly in this test a typical test results has been shown in this test this liquid limit is about you can say 42 percent. Now, casagrande method, that is one point method, these are a multiple point. If you look at here, this takes time, this takes time means you take a soil sample, add water then go for liquid limit test by means of casagrande method. Then, take the soil put it in the oven, measure its water content then again add more water, then go for this. This gives multiple point, now as it takes little bit time, so will it be possible in a single stroke? In one point, can I find it out? This liquid limit?

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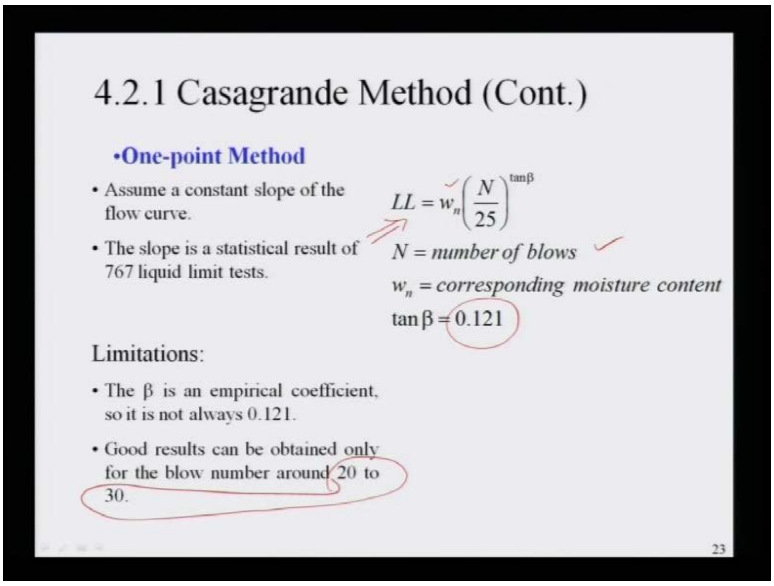

Yes, there are methods that means, this is called One-point method that means assume a constant slope of the flow curve. That means liquid limit is equal to w n N by 25 tan beta, N is equal to number of blows, w n is equal to corresponding moisture content, tan beta has been taken as 0.121. That means, this slope it has been derived from this statistical results of 767 liquid limit tests.

So, assume a constant slope of flow curve, that means what you will do, once you mix this water content you go up to 25 number of blows. Then with 25 number of blows, what is that water content you measure and with this beta is equal to 0.121 you can find it out liquid limit by one point method. One point method means by doing only one test by doing only one test, not multiple point method. Limitation, the beta is an empirical coefficient so, it is not always 0.121. Good results can be obtained only for blows number around 20 to 30. These are the, means, despite this one point method despite there are limitations in one point method. People who are scientist sometimes use one point method, this is a called a quick test or you can get only one test you can find it out, your liquid limit.

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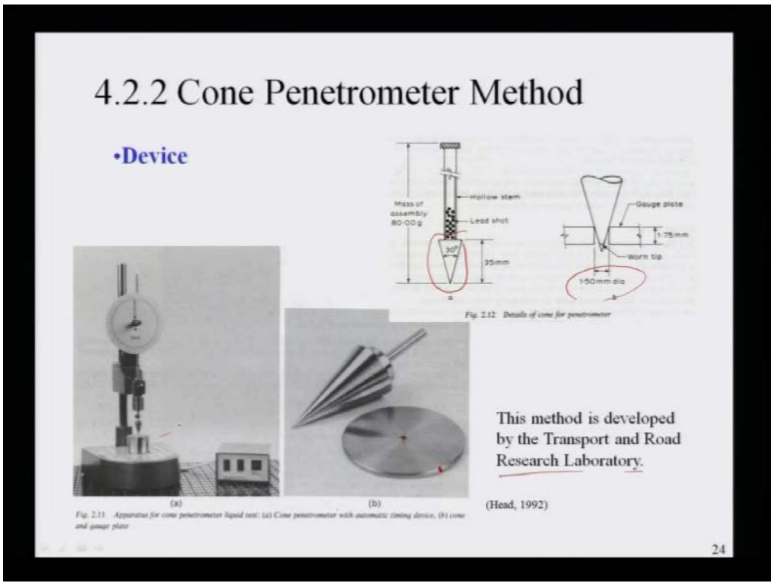

Now, next part is your, ask for the British standard BS code. This is your cone penetration method. If you look at this device, this device is a cone. This is a cone, this cone, if you look at this, this is your 1.50 mm and this is your 30 sorry 1.50 mm, no 150mm and this will be 1.75 mm. This height and this is your gauge plate and this total height will be sorry, this if it is the total cone, this height, particularly this height, if I take it very close, this will be 1.5 mm and this from this to this, it will be 1.75 mm. This is called gauge plate, you see this is called gauge plate.

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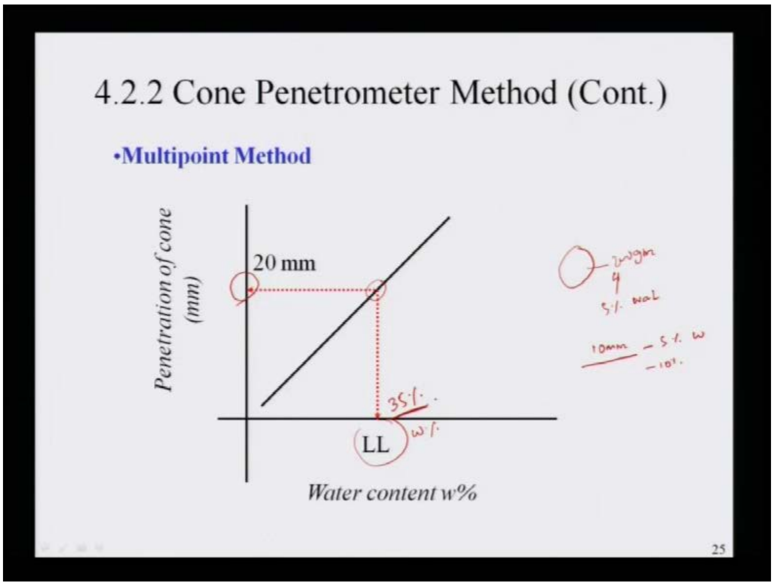

Now, if you look at the complete cone, this cone it consist of a cone and lead shot, this is a lead shot with the hollow stem and mass of assembly is, total mass of the assembly is 80 gram and cone angle is 30 degree. Now, this is your called, this is called your gauge plate, with this gauge plate, this height is entered, this height is it says 1.75 and this distance is your 1.5 mm dia. And it has been set here, so in such a way that you can take soil so this cone has to penetrate inside the soil. This method is developed by Transport and Road Research Laboratory in UK.

Look at this, means, what will happen in this case? In the cup, this is a cup, in this cup you take soil sample say, 200 gram and mix some water.

Now, say 5percent, 10 percent, 20 percent, as you have done for liquid limit test, you mix some water then this cone has to, you allow this cone has to penetrate. Now, if you look at here, penetration of cone, how much cone you allow freely, it fall and it has to penetrate, how much cone penetrate inside the soil with respect to its water content.

Suppose say, soil you have taken 200 gram, then mix with 5 percent water, then take inside the cup with a soil and water paste and allow this cone to penetrate, then you measure how much it penetrate because this is a scale from where you can measure how much is your penetration. Then once you measure how much the penetration, say the penetration is 10 mm with 5 percent water content. Then what will happen? Then next step, in the same soil add another 5 more percent water content, so it will become 10 percent water content. Then measure its penetration in mm. 10, 20, 30, 40 you increase, go on. Then plot a graph between penetrations of cone in mm versus water content.

So, this graph will go like a straight line then penetration of the cone with respect to 20 mm. So, this is say 20 mm, mark it in the curve with respect to what is your liquid limit? What is your water content? Say with 20 mm water content is 35 percent, that means this 35 percent is nothing but your water content.

So, this gives multiple point, that means every time you mix soil with water then go for the cone penetration, then take out the soil for measure this water content in oven, then again mix soil and water higher water content then go for cone penetration, then again take out the soil to test its a moisture content, like this it is a multipoint method. It takes time. Now similarly, in cone penetration also you can go for single point cone penetration test.

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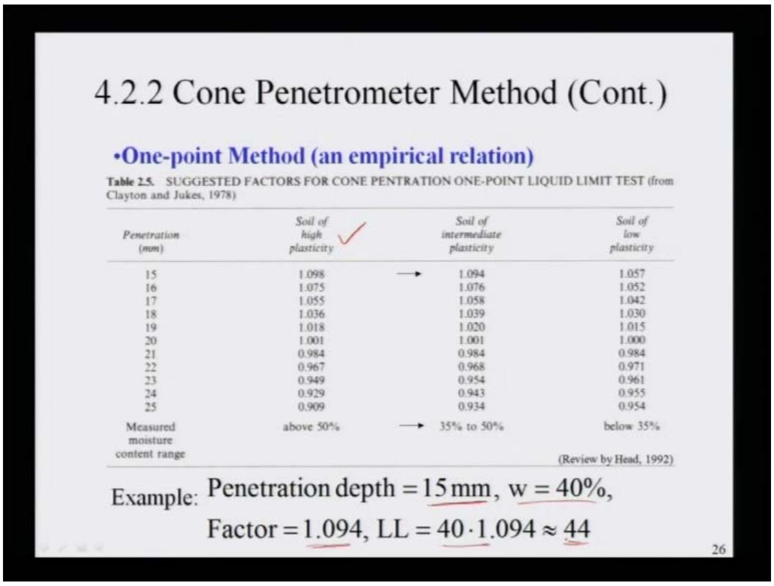

One point method an empirical relation so these are all suggestions. It has been given by Clayton and Jukes 1978, so they have considered various experimental and suggestion factor they have given. So this is soil of high plasticity, with these this penetration has been measured. Moisture content has been measured. Soil of intermediate plasticity moisture content has been measured, soil of low plasticity. So penetration depth 15 mm, water content is equal to 40 percent, factor they have taken 1.094, liquid limit is 40.9 or 44 they have consider.

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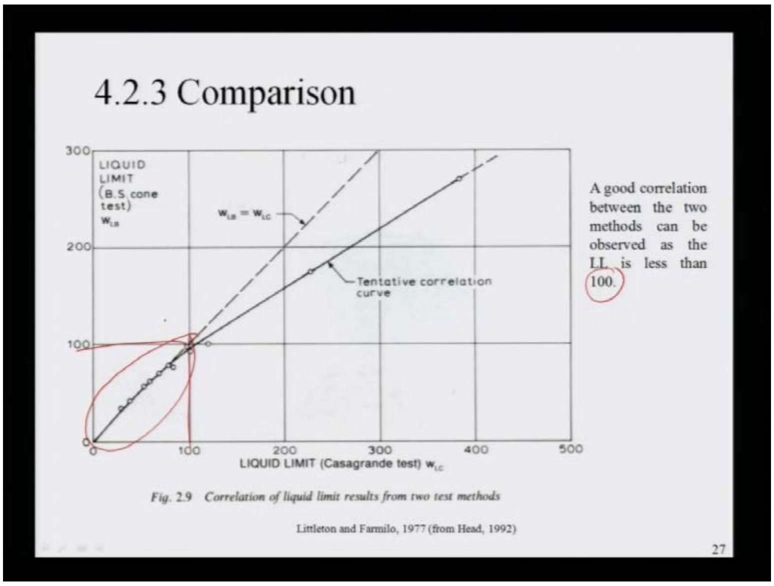

So, these are all if you look at liquid limit by BS cone method. By BS cone method and tentative correlation curve provided by this Clayton and Juke, 1978. If you look at here, means a good correlation between two methods can be observed as the liquid limit is less than 100. A good correlation between this, correlation and your liquid limit by means of British Standard cone test, it will be achieved.

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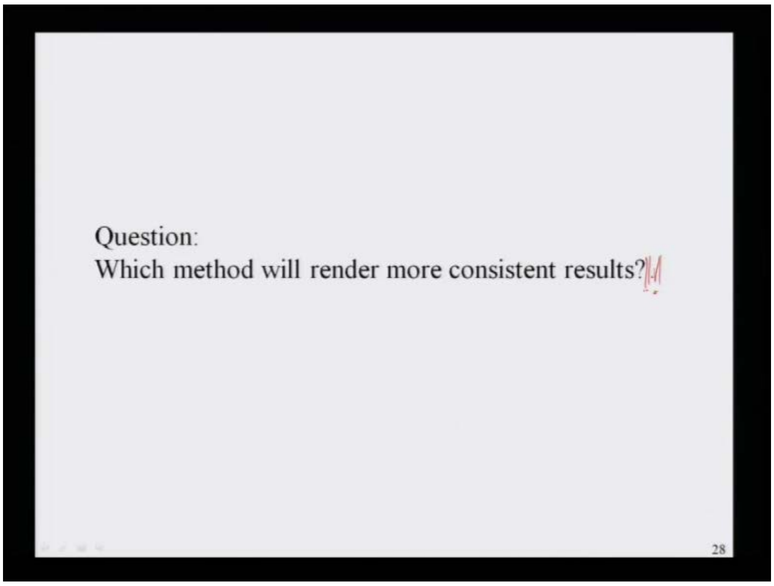

Now next question is, out of this two, one is your by means casagrande method, other is your cone penetration method that is BS method which method will render more consistent results and why? Any idea? Which method will render more consistent result and why? You can think and answer me, may be we will discuss it later on. Just think it, which method out of this two methods? One is your casagrande method, other is your cone penetration method. Out of this two method which method will give more consistency result consistent result and why what is the reason?

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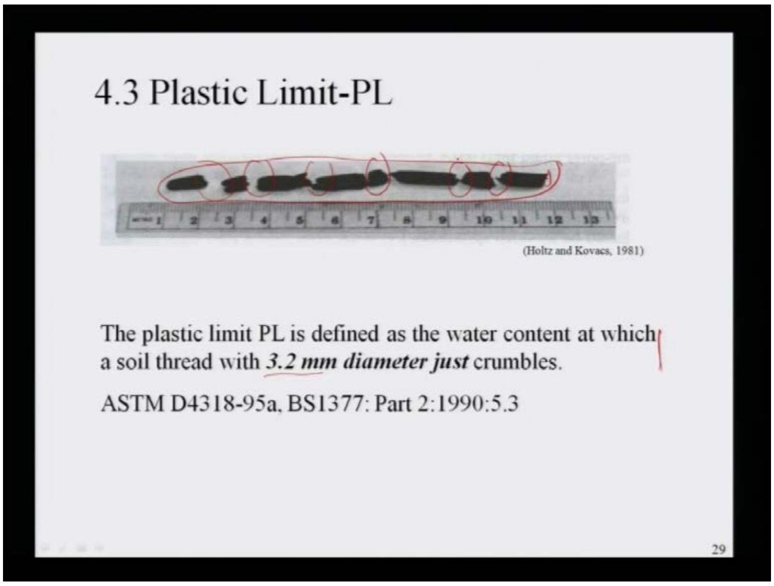

In the next part, is your in atterbergs limit, that is your plastic limit. The plastic limit is define as the water content at which a soil thread with 3.2 mm diameter just crumble. What does it mean? That means similarly, you take 100 to 200 gram of soil mix with water like 5 percent or 10 percent or may be 15 percent water with mixing this water.

Let us start with the 5 percent or let us say 10 percent water mix this with this water and make it soil paste so that you can make it by hand and make it paste it. So in a flat plate you roll it, to see you roll it and make a thread 3 mm size. Make a thread, this threads size should be, make a thread by this two hand you roll it, make a thread, it should be 3 mm. That means, it says this is a limit as the water content. This is the water content at which with a thread of approximately say 3 mm or 3.2 mm, it will crumble. That means, you just go on increasing water content and make a thread of the soil water paste of 3 mm size, you look at 3 mm and diameters size it will crumble, once it will crumble.

Look at here, it will break. That point, corresponding to your water content that is called your plastic limit. The moment you start crumble, so it will break one by one. Because it is in between it will start particle crumble. So, it will break one by one so this is the condition. The plastic limit is defined as the water content at which a soil thread with 3 mm diameter, just crumbles.

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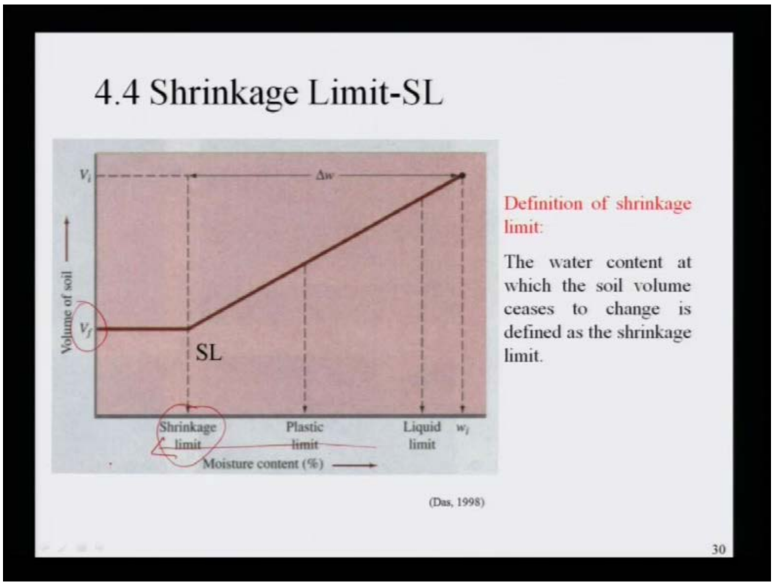

Now, shrinkage limit. Definition of this shrinkage limit. It says, the water content at which soil volume ceases to change is defined as shrinkage limit. That means, suppose I take a water mixer of soil and water. That means, from here I try to reduce the water content. It is some stage, if moment it is in liquid limit, I want to reduce water content that is all of sudden its volume will change. At some stage, further decrease in water content. There is no more change in volume of soil, that stage it is called shrinkage limit. That means, once I measure this shrinkage limit I can say that the, whether this soil is in solid state or semisolid state.

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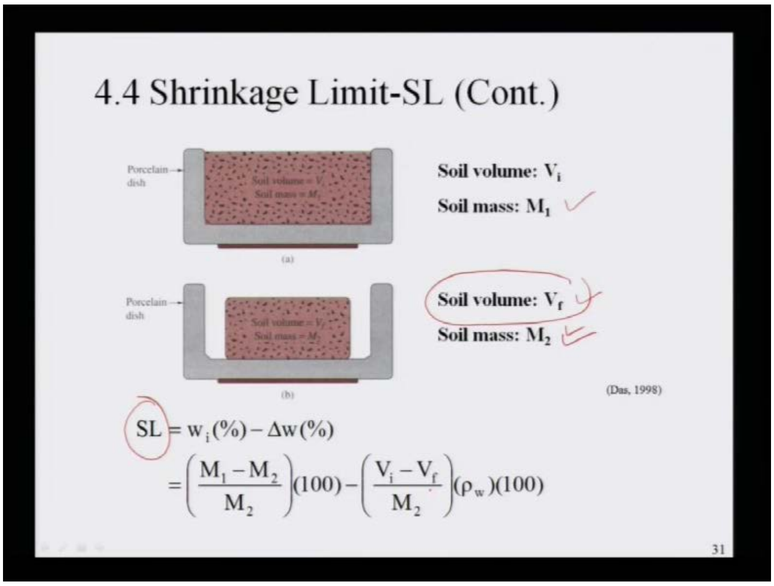

How do you find it out, shrinkage limit? Shrinkage limit generally you find it out, porcelain dish. Inside the porcelain dish and let us say soil volume V1 and M1, then with this mercury you can find it out. Take a porcelain dish, then in this porcelain dish measure the soil volume and soil mass. Then make it completely dry, then measure its soil volume and soil mass. How to measure this soil volume? That is the question, how to measure the soil volume? That means, it is soil, the soil volume and soil mass. Soil mass you can weight it, soil volume can be measure it with this porcelain dish, make full of mercury then at the top, the dry soil you try to push.

So, once you push it inside this porcelain dish with mercury so, equivalent amount of mercury will flow out. That gives your soil volume. What is your soil volume in dry state as well as in wet state? Once, you measure the soil volume then find it out your shrinkage limit, moisture content that is M 1 minus M 2, soil mass M 1 minus soil mass M 2. Soil mass M 1 is your soil with water. Suppose, I take it soil plus water of 5 percent, I take it and make a make a paste so, I find it out what is the soil mass then I make the dry and find it out what is the soil mass, then by M 2 minus V i minus V f. V i is your soil mass of soil with water, then V f is your soil volume of dry soil. Completely dry soil, so this is M 1 minus M 2 by M 2 minus V i minus V f by M 2 into rho w into 100, from there we can find it out the shrinkage limit.

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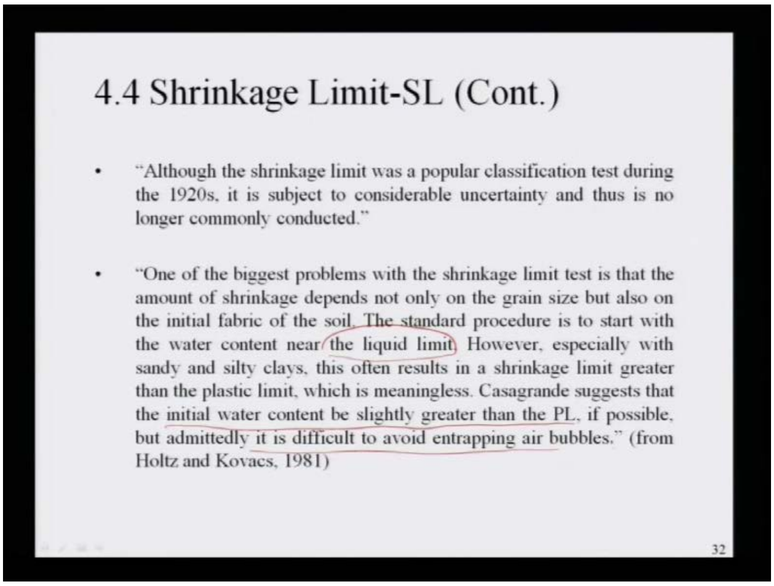

Now, if you look at this shrinkage limit, this shrinkage limit was a popular classification during nineteen nine twenty's. One of the biggest problem with the shrinkage limit test is that the amount of shrinkage depends not only on grain size but on the initial fabric of the soil. The shrinkage, it depends upon the grain size and also what is the initial fabric inside the soil. This standard procedure is to start with water content near the liquid limit. How do you start the water contents, means shrinkage limit? That means, the standard procedure you start means, you have to mix soil and water with a water content near to the your liquid limit and however, especially with this sand and silty clay, the results in a shrinkage limit greater than the plastic limit which is meaningless. Casagrande suggested that the initial water content, by slightly greater than plastic limit if possible, but admittedly it is difficult to avoid entrapping air bubbles. That means, at what point exactly will you start? Means what is your water content you start from there you are mixing soil and water.

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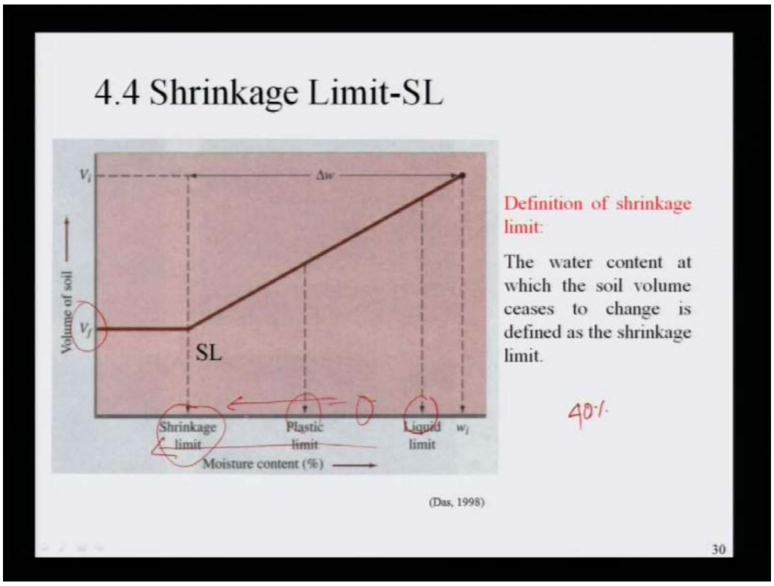

So that, that water content you will start. You start with a water content near to liquid limit but higher to plastic limit. This water content you start, let us say with this 40 percent water content you start then make it dry then find it out it is shrinkage limit then you decrease towards this water content. So this is your starting point of your starting for this shrinkage limit.

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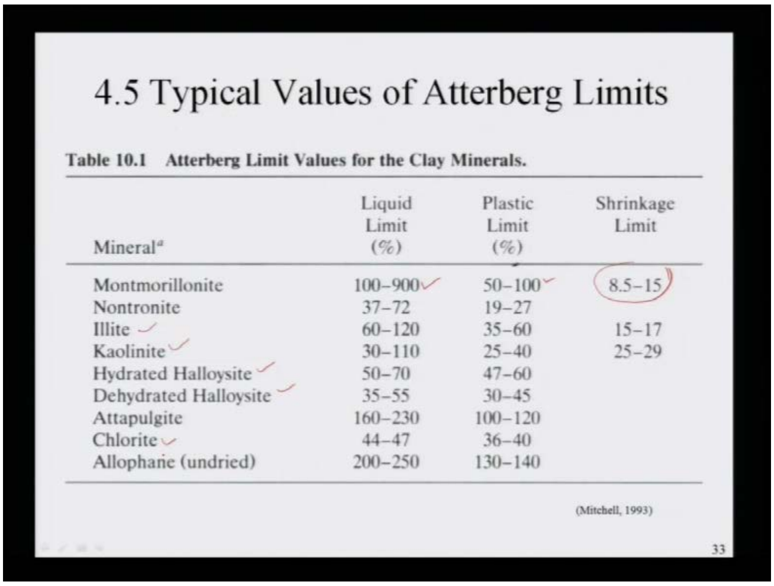

Mineral[a]	Liquid Limit (%)	Plastic Limit (%)	Shrinkage Limit
Montmorillonite	100–900	50–100	8.5–15
Nontronite	37–72	19–27	
Illite	60–120	35–60	15–17
Kaolinite	30–110	25–40	25–29
Hydrated Halloysite	50–70	47–60	
Dehydrated Halloysite	35–55	30–45	
Attapulgite	160–230	100–120	
Chlorite	44–47	36–40	
Allophane (undried)	200–250	130–140	

So, typical value typical atterberg value of this clay minerals, if you look at this, it is it has been given by Mitchell, 1993. Montmorillonite its liquid limit is 100 to 900, plastic limit is 50 to 100 and shrinkage limit is 8.5 to 15 percent. If you look at with, if go here, this is a clay minerals particularly montmorillonite, illite, kaolinite, hydrated halloysites, dehydrated halloysite, sattapulgite and chlorite, these are the typical range. It has been given by Mitchell, 1993.

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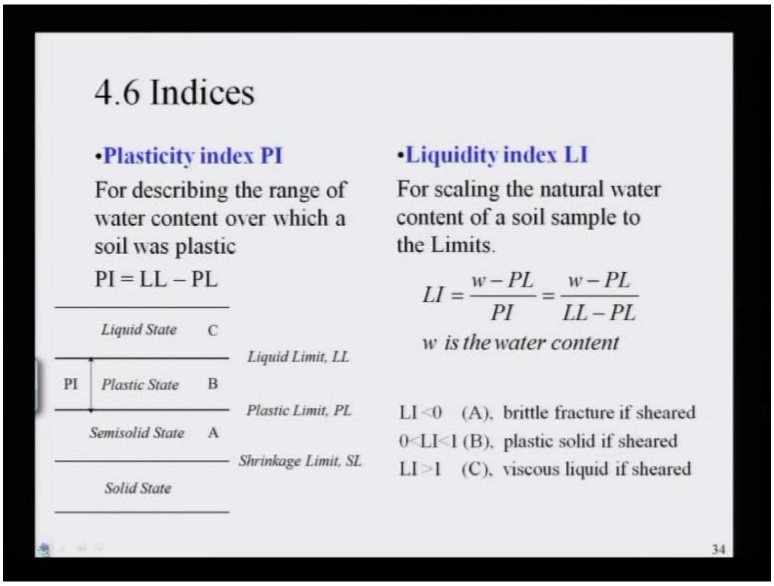

Now, what are the indices from this test? What are we suppose to get? First one is your liquid limit, then is your plastic limit, then is your shrinkage limit.

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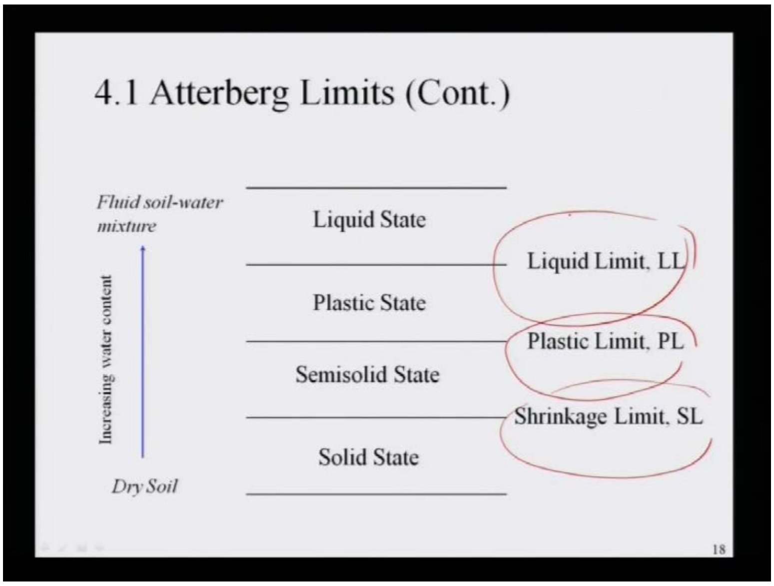

As I said earlier, to find the four state of soil, solid state, semisolid state, plastic state, and liquid state you need to have this shrinkage limit, plastic limit and liquid limit. So these limits are called atterbergs limits. Based on these, this tests liquid limit, plastic limit and shrinkage limit now there are indices that means plasticity index that is called P I.

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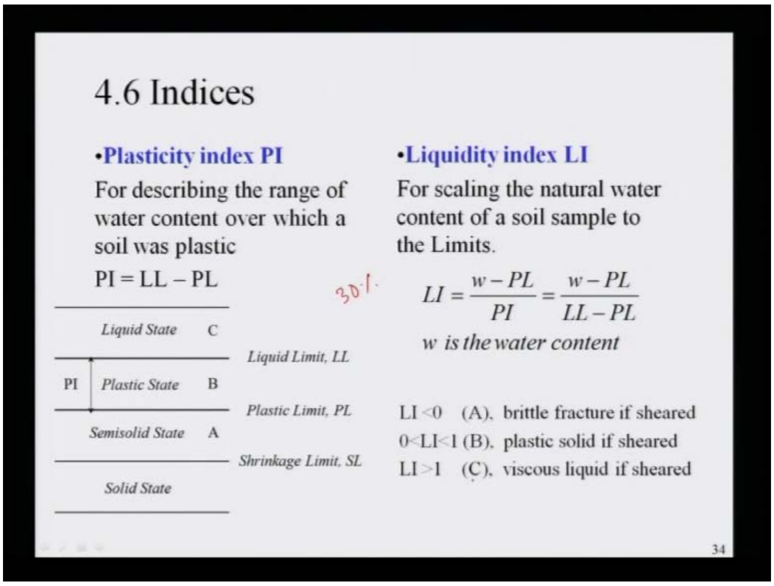

For describing the range of water content over which soil was plastic. Plasticity index mean, that means the water content over which suppose, water content plasticity index that means suppose the water content is giving 30 percent, over which that means above the 30 percent of water, soil was in plastic state.

Now, if you look at here, plasticity index is your liquid limit minus plastic limit. This is in the plastic state. Now liquidity index, if you look at this liquidity index for scaling the natural water content of soil sample to the limits. Liquidity index is your water content minus plastic limit divided by plasticity index. So w minus P L by liquid limit minus plastic limit. So, w is the water content.

So, next one is your sensitivity index, next year activity these we will discuss in detail may be in the in the next class about the indices one by one.