Unsaturated Soil Mechanics
Dr. T.V.Bharat
Department of Civil Engineering
Indian Institute of Technology, Guwahati

Week - 04
Lecture – 11
Suction Measurement/ Control Techniques – I

Hello everyone, we have seen several laboratory techniques and field techniques for the estimation of water content. Another important state variable for establishing soil water characteristic curve which is a fundamental constitutive relationship for soils, for partly saturated soils is matrix suction or total suction. Let us see the different techniques that are available for, either to estimate or control the suction of the soil.

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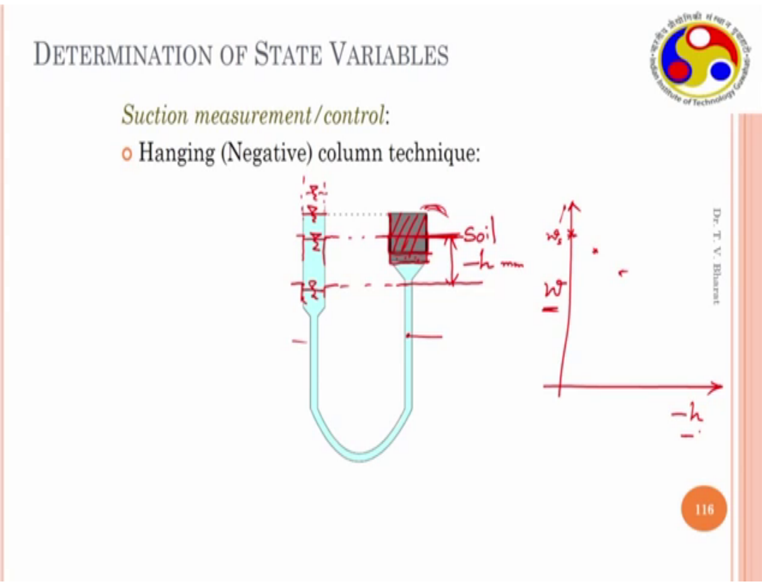

First, the basic technique is hanging column method or negative column method. A pictorial or illustration of the hanging column is given here; where soil sample is placed in a container. You have a porous stone which is attached here, and this is soil.

So, now the soil, this whole setup is connected with a flexible pipe, and a water level is maintained up to here. When you know the equilibrium to take place, at steady state you would see that the soil is completely saturated. If you raise this level, then water will start flowing. So, now what if you bring this column down? For example, if the column is brought down to this level, so, water level is here. New water level is here or it could be further brought down to this water level is here. So, what will happen to the soil? Soil, because of the capillary action, soil tries to keep the water within the soil pores, depending on the air entry suction of the soil, water may remain in contact with the soil and, you may have completely filled tube. This U tube will be completely filled with water and that is a state you may have.

So, now if you observe the pressure in the water, that will be negative pressure. Because, if this is a mids, midpoint point or mid-section of the soil, there is a negative head off minus h meters or millimeters is maintained in this particular column. Under this negative head, soil is completely saturated or some water content may exist. So, this is on a, soil water characteristic of plot. If I plot the water content, either gravimetric or volumetric water content, this is negative head, or if I multiply with gamma w, this is pressure.

I can represent in terms of pressure. When negative head is 0, the water content is fully saturated. This is a w s maybe, this is fully saturated water content. So, when the negative head started increasing, the water content may decrease, but still the soil maybe saturated. Because, as I explained earlier, the meniscus curvature might change, but still water will be completely filled within the soil pores and there is no air.

So, it is completely saturated; however, water content may slightly decrease. As you increase the head further, you would suddenly see that the, there is a discontinuity between soil and the water and water is up to only here. That is the point where, the air enters into the soil system. When air enters, there is a discontinuity between soil and this watercolor. So, this is the simple way of explaining the hanging column technique, where the, how the water content changes with negative head. A very good soil water characteristic curve could be estimated using hanging column technique in this procedure also.

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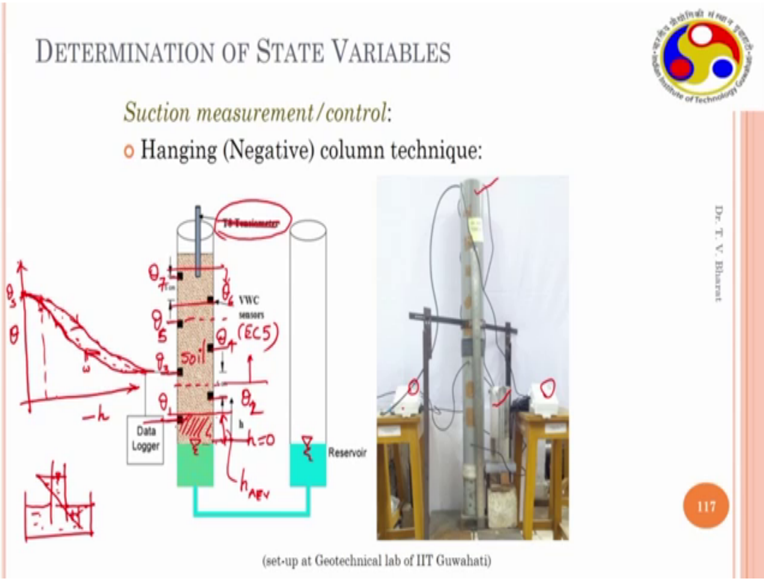

In this particular procedure or method, we have a soil column. This is a soil and, which is connected to a water reservoir, and water level is here. So, water level in the soil is also here. It is only to understand this particular thing as of now. But, there are volumetric water content sensors, are placed at different levels. So, these are EC5 sensors; these are EC5 sensors are placed at different levels, which can directly measure the volumetric water content. And these sensors are connected to the data logger.

So, if you have such a system in place, now, when you maintain the water content within the soil to this particular level, you would see that there is some water, water content, that exist above this level also, because of the capillary action. For example, at this particular height above this water level, there may be water content theta 1 and sorry. Here at this level, the water content is theta 1. Here, the water content is theta 2. Here, water content is theta 3. Here, the water content is theta 4. Here, it is theta 5. Here, it is theta 6. Here, it is theta 7.

So, you have around, 7 sensors placed at different depth level. In this situation, now, if I want to plot the soil water characteristic curve, on x axis I plot head, and y axis theta. This head is negative because we are measuring above the water level or water head is negative, above the water level. As we have seen the capillary, if I draw the capillary here, which is immersed in a water reservoir; this is water; you would see that there is a water level, that exist up to certain level. If you draw the pressure diagram, with depth, you would see that there is a negative pressure in the water, in the column above this level and, here it is 0; and this is positive. This is positive. This is negative.

Similarly, above this, you have a negative pressure. So, here the head is, some value. Correspondingly, the water content may be very high. Head is 0; the water current is theta s. And, similarly, you have theta 1, theta 2, theta 3. Likewise, you can plot a soil water characteristic curve. In this particular case, you will have theta, not significantly changing up to certain depth, but the soil is fully saturated and beyond that, you have water content decreasing drastically up to that point or that head is called air entry value or unity suction head. So, that is somewhere here.

Beyond that, you have a partly saturated; you may have fully saturated system up to certain depth. That is, h A E V; air entry value head. This is actual setup, that is available at IIT, Guwahati, geo-tech lab. So, this is the soil column. And there is a reservoir, water reservoir. And, several sensors are placed at different depths. They are connected to the data loggers. These 2 white color boxes are data loggers. They are EM50, which are supplied by decagon. So, here you get several data points. Similarly, now if I raise this water level to again certain depth. Now, this sensor realizes, that the water content at this particular depth and at this particular depth, both are theta s only.

Now, this theta 3 would change, and theta 4 would change. Now, you need to estimate, what is the head from this particular point onwards. You get new points in between again. This way, you can establish the entire soil water characteristic curve for coarse grained soils, like sands. Because, generally, in coarse grained soil, because the diameter, poor diameter is smaller. So, the air entry value is smaller. Also, the total capillary effect, that is considered, or that is available within the soil mass will be less.

You can conduct such tests, in the laboratory. In course grained soils, this is possible. Otherwise, if you have fine grained soil, when you compact; as we have seen that the capillary raised express to very high values of height. So, therefore, it is not possible to conduct the test by considering such columns. So, this hanging column method is a wonderful technique for establishing soil water characteristic curve accurately, for coarse grained soils.

So, here whatever is described here, is a wetting technique where, the path is from right hand side to left hand side because, soil initially is a dry strait. As the head is decreased by raising the water level, the water content increased. So, this follows a wetting path. One can conduct the drying technique also; drying, one can establish the drying path also, by lowering the water level from the initial depth. For example, the water level is slowly raised up to here, and maybe, it reach to maximum value. Now, the soil is completely saturated and, you obtain this particular point.

Now, when you lower down this value, this particular value to here somewhere, you can measure the water contents at different points. These points, represents the drying path. So, as the drying path lies above the wetting path, you would get, the hysteresis can be established using this particular technique. So, the hysteresis loop can be established using a single technique that is hanging column technique, on the same soil sample, without considering duplicate samples.

However, you cannot have a very lengthy columns like, beyond 1 meter, 2 meters. It is not possible to conduct the test, and not possible to have so many number of water content measuring sensors, at different depths. This particular test is limited for coarse sands. Coarse sands and maybe for fine sands generally, this is limited for coarse grained soils.

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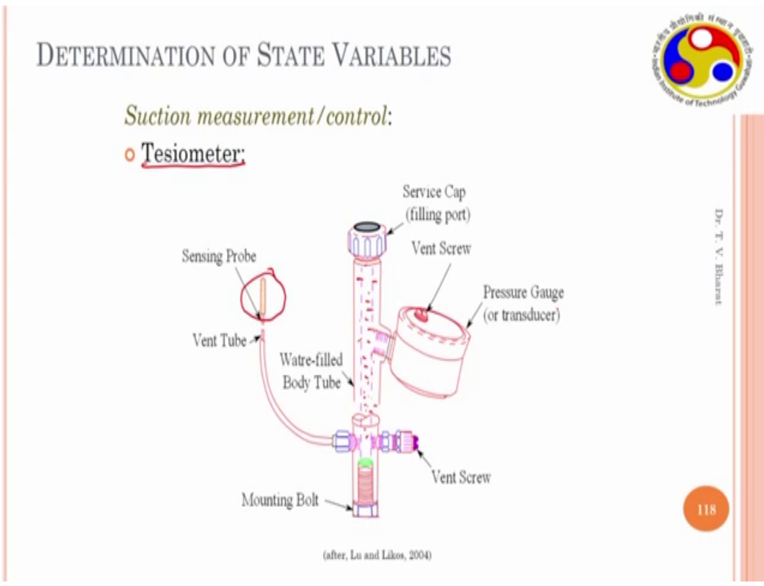

A very common method, that is used in unsaturated soil mechanics, and also in soil science is Tensiometer; for measuring the suction value. This is a popular technique, for measuring the suction in both science and engineering disciplines. And also, this particular technique could be used in the laboratory, as well as in the field. Earlier technique which we discussed, that is hanging column method, cannot be used in the field; which is purely a laboratory technique. When you alter the density of the soil, you can alter, because, it is a reconstituted sample. So, then you get different soil water characteristic curves. But, it is not possible to conduct this particular hanging column technique in the field. But, however, this tensiometer is very advantages, because, this can be carried to the field, and test can be conducted, and directly it can be measured. Suction can be measured.

Now, the let us understand the principle behind this tensiometer. So, this tensiometer has, a sensing probe; and this is connected to water filled body tube. So, here, the body contains the water fully, and de-aired water and there should not be any vapor, or air component in this. And, de-air water should be filled completely in this, water, this body; this tube. Then, it is connected to a sensing probe. This is sensing probe. And, I will discuss what exactly the sensing probe contains. And, this water filled body tube is connected to a gauge; pressure gauge. So, essentially the, this has a service cap which can be opened up to fill the water, de-aired water; and which can be closed during the measurement.

Now, this sensing probe, when it is in contact with a water which is at negative pressure, the negative pore water, the negative pressure is transmitted through this tube, and negative pressure is transmitted to the water, which is contained in this body tube; water filled body tube. So, that can be measured using pressure gauge.

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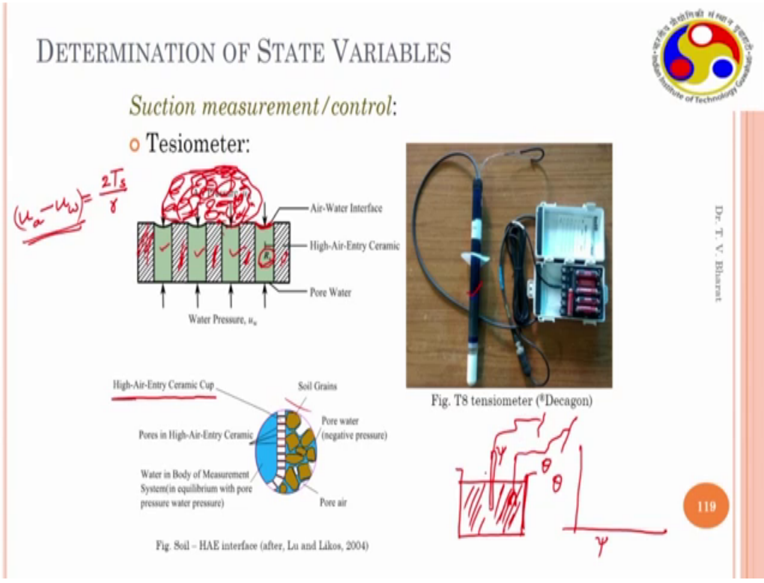

So, what does it contain? The sensing tube contains, a high-air, high-air -entry ceramic disk. High-air-entry ceramic cup, which has uniform pores so, these are all pores. It is a pore diameter of, or pore radius of R, and this is a surface. This is surface, and these are pores. Now, a uniform capillaries that contain in your sensing probe. So, as you fill the, this whole tube; so, this is initially saturated completely. The, sensing probe, should be completely saturated. So, the capillaries are completely filled with water.

That is the initial condition. This is the tensiometer, T8 tensiometer, supplied by Decagon, which is available, at out IIT Guwahati lab; geo-tech lab. Now, this tensiometer, when it is in contact with soil, when the soil is fully saturated, the negative pore water pressure within the soil mass is 0. Soil pore water maybe at, atmospheric pressure so, then, water in the water filled bodies, also at the atmosphere pressure. Then, there is no issue. But, as, when the soil contains, when the soil is partly saturated.

So, then, there is a negative pore water pressure that exists within the soil. So, when that soil, comes in contact with the high-air-entry disk, for example, the soil is placed here. This is soil; contains several grains, and within this, there is a water. When this is in contact with this, with these capillaries, air cannot enter into this, provided, the air entry suction of this pore space is higher than the air pressure that exists within the soil mass. Earlier using (Refer Time: 15:58) equation, we have estimated, what is the air entry value so, which is simply, 2T s by r. If you know the radius of the high-air-entry disk, so, you can estimate, what could be the, u a minus u w, that could be sustained. So, this is the pressure across the interface that can be sustained. So, assume that this pressure that can be sustained here is 100 kilo Pascal.

. So, then, when the soil contains negative pore water pressure, say up to 100 kilo Pascal, so, air cannot enter. But, water within the soil pores can establish good contact with the water in the high-air-entry disk, which is again connected to the water filled body. So, therefore, negative pore water pressure is transmitted through the water in the high-air-entry disk pores, and is communicated to the gauge. So, gauge reads, that, this much of suction is existing. Because, there is a negative water pressure, so, when it is transmitted, the water is sucked from that water filled tube. So, that much pressure that can actually detect, and it can be read on the gauge pressure.

So, when it is in contact with soil here, the pore water, which exists in the soil is in good contact with the high-air-entry disk. And, the water in the high-air-entry disk is in contact with the water through this and water in the, this tube. So, therefore, this negative pore water pressure in this particular, negative pore water pressure, that is u a minus u w, positive value indicate, that there is a negative pore water pressure in the soil. So, therefore there is a suction, or suction pressure that is exerted on the water which is available here. That pressure can be recorded on the pressure gauge. This way, you can establish the soil water characteristic curve, for example, you take a soil column, and in which the tensiometer is placed.

So, this is the tensiometer and this is the soil. So, when the soil gets dried with time, directly, the reading of the suction value can be monitored or measured. If you place tensiometer along with the EC5, or the volumetric water content sensors, both water content and suction using tensiometer, both can be measured simultaneously at different equilibrium water contents within the soil mass; and one can establish the relation between theta and psi. So, similarly therefore, it can be used for laboratory, or it could be used in the field. So, that is the advantage of this particular technique.

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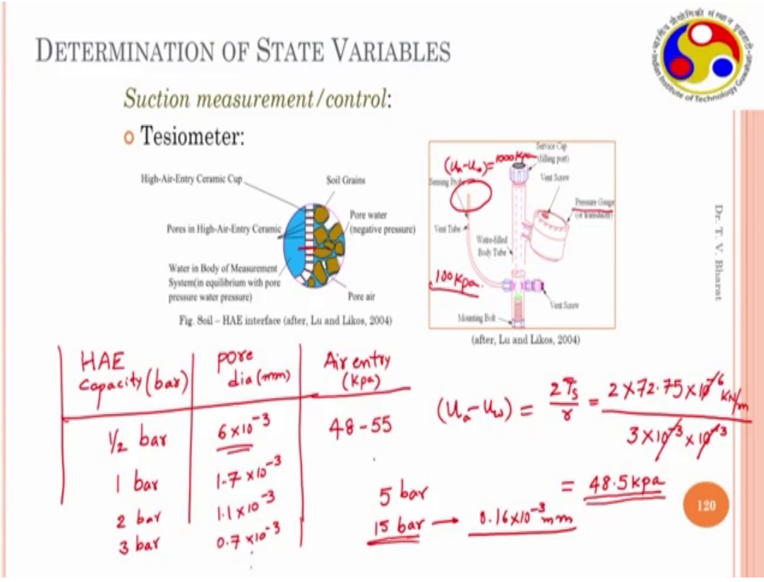

As have seen, the limitation of this particular technique is, a air entry disk. Because, if the soil contains a negative pore water pressure of more than 100 kilo Pascal or minus 500 kilo Pascal, but the air entry value of the high-entry-disk is only 100 kilo Pascal, water enters through the high-air-entry disk, pores, and water enters into the, this body. Then, there is a negative pressure within the soil mass which is in contact with the high-air-entry disk. The negative pressure maybe as high as 1000 kilo Pascal.

So, in that particular case, if the high-air-entry, high-air-entry disk capacity is only 100 kilo Pascal, then the air enters into the high-air-entry disk. Because, the sustainable air water interface or sustainable pressure at the air water interface, is only up to 100 kilo Pascal. That is a capacity of the high-air-entry disk. So, therefore, the air enters into high-air-entry disk, and air enters into your system. So, your pressure gauge will not read the values. So, therefore, the maximum value that can be measured by the, measured by the tensiometer, is dictated by the high-air-entry disk capacity. You have several high-air-entry discs.

The high-air-entry disk, which is ceramic disk; the capacity, HAE capacity, are expressed in bar. 1 bar is atmospheric pressure. So, if it is a half bar, that ceramic disk will have a pore diameter of in mm, approximately 6 into 10 power minus 3 millimeter, which is equivalent to the air entry value of in kilo Pascal, that can be estimated using (Refer Time: 21:09) equation as we have done earlier, u a minus u w is, 2T s by r, to into its standard temperature. You may use 72.75 milli Newton. If I represent in kilo Newton, then it is minus 6 kilo Newton per meter, divided by, the radius is 6 by 2. So, 3 times 10 power minus 3 mm. If it is represented in meters, then this is 10 power minus 6. So, 10 power minus 6, 10 power minus 6 gets cancelled. So, this is equal to about, 48.5 kilo Pascal.

So, the air entry of the particular disk is, it may vary around, 48 to 50, or 55 kilo Pascal. So, that is why it is called, half bar. Half bar is around 50 kilopascals. Similarly, if it is 1 bar, so, the 1 bar higher entry capacity, will have the pore diameter, approximately, 1.7 times 10 power minus 3. Here, however, in the calculation we did not use the contact angle. We are assuming the contact angle is 0. So, with that approximation, this comes to be around, 48.5 kilo Pascal. For 1 bar, this pore diameter comes out to be, 1.7 times, 10 power minus 3, and 2 bar, 1.1 into 10 power minus 3, and 3 bar point,7 into 10 power minus 3 millimeter so on and so forth.

. So, one can choose. And, you have up to, 5 bar and 15 bar as well. So, 15 bar will have the pore diameter of,16 times 10 to the power minus 3 millimeter. So, this is very fine. So, one can choose, what ceramic disk we can use in tensiometer. One can use 15 bar, or one can use 5 bar, one can use 1 bar. But this high-air-entry disk pore diameter is not the only parameter that controls the maximum measurable suction in tensiometer.

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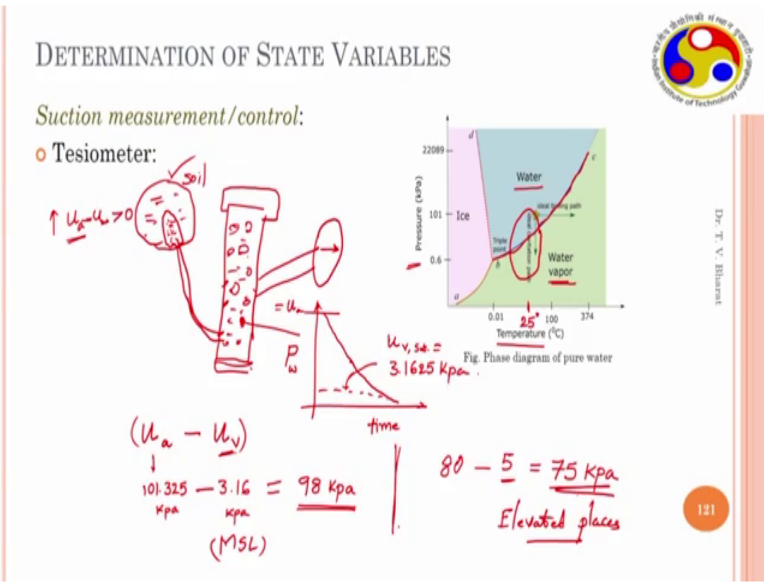

There is another important factor if we revise our knowledge on phase diagram of pure water. So, this is the diagram which I got for you. So, here, with respect to temperature on x axis, and pressure on y axis if you plot so, this is the phase, this is the phase diagram. It represents several phases. This is the water phase; this is a vapor phase, and this is the water phase. We have seen that, there is a cavitation that takes place, when the absolute pressure decreases for the same temperature, at the same temperature. Pardon about the scaling here.

This is not a linear scale. This is some scale we have used here. And, similarly, y axis some scale we have used so, here the same temperature. For example, at say 25 degree, at 25 degrees, when you are decreasing the absolute pressure of water. When it reaches the vapor pressure, this is the vaporization curve; this is the vaporization curve. If it touches the vaporization curve or if it reaches the saturated vapor pressure then, water turns to vapor so, therefore, how this is useful for tensiometer?

So, in tensiometer we have seen that there is a water filled tube, which has a cap. And, here, this is connected to a gauge, and here I have vent etcetera. So, this is connected to, on flexible tube; through which you have a sensor which is connected, this a sensor. This is a high-air-entry disk, which is connected. Now, with this sensor, when it comes in contact with soil; soil has negative pressure. So, water pressure is negative within the soil mass. So, u minus u w is positive; that means, pore water pressure is negative right? So, because u a is, if you take 0, as a gauge pressure, then u w is negative. Otherwise, if you take absolute, this is 101.325 kilo Pascal. And then, u w maybe some value. So, then you have a positive value right? You have some suction. So, there is a negative pore water pressure.

So, now, due to this negative pore water pressure which is transmitted through this tube, and the pressure is transmitted to this water filled body, which is the red on the pressure gauge here. Now, imagine the water pressure within this tube is decreasing. Because, the soil is in contact with this, and the soil which is; this is the soil which is getting dried with time. So, therefore, the negative pore water pressure is increasing with time, which is transmitted through the tube, and the water pressure in this one is changing. So, if it is changing. So, if you consider the absolute water pressure, p w, within this tube which is decreasing with time. Initially it was at atmospheric pressure, which is equal to atmospheric pressure, which is decreasing continuously. When it reaches, so, vapor pressure maybe at 3.1625 kilo Pascal, at standard temperature, this is a saturated vapor pressure. u v sat. And, depending on r h, you may have some u v, value slightly less than or significantly less than 3.1625 kilo Pascal, at standard temperature.

So, when the pressure, water pressure reaches this particular value then vaporization occurs. So, this water turns to vapor. So, you will see lot of vapor bubbles inside the tube. So, when the vapor bubbles form within this tube, then you cannot measure because, water volume does not significantly change. There is a pressure that is exerted on the water, that is you are able to measure. But, when there is a vapors, are bubbles that are formed within the system, then the measurement unit will not work because there is a discontinuity that is, that has happened here. Because, of the discontinuity of water. So, because of which it does not measure the negative pore water pressure.

Actually, this vapor pressure that controls the maximum measurable suction, by the tensiometer, if the atmospheric pressure is say, 101.325 kilo Pascal; if it is decreased continuously to the vapor pressure, so, vapor pressure value. This is atmosphere pressure; u a. This difference controls what is the maximum measurable range of your tensiometer; suction measurable range of your tensiometer. So, for example, the atmospheric pressure is u a, and the vapor pressure is u v, the difference between these two quantities would dictate what is the measurable range of suction of your tensiometer.

So, for example, at sea level, this u a value maybe, 101.325 kilo Pascal. Kilo Pascal and this u v, if it is 100 percent r h, u v is equals to u v sat. At standard temperature, this values maybe, this value maybe 3.16 kilo Pascal. This difference, whatever the value may be, 98 kilo Pascal, is a maximum measurable value by your tensiometer. Beyond that, vapors, vaporization takes place, and tensiometer does not work.

Similarly, if you take the tensiometer to hillside, maybe, 1500 to, 2000 meter above the mean sea level, then the atmospheric pressure drastically drops. Atmospheric pressure, may become, maybe 80 kilo Pascal. Your vapor pressure at that point, maybe, that can be estimated, depending on the temperature. One can estimate, maybe, it may vary in the range of 5 or something. Then, the measurable range will become 75 kilo Pascal only.

So, as your measurement is done at elevated places, the measurable range of tensiometer will decrease. This is at elevated places. This is at mean sea level. This is at mean sea level. So, we have seen the negative column technique or hanging column technique, where, you can probably measure maximum value of about, maximum suction range. You can establish maybe, if you have a 1 meter high column, then, you can establish the soil water characteristic curve up to 10 kilo Pascal suction. Beyond that, it is not possible. Then, you should have increased the height of the columns.

But, it is not possible to have whatever the length of the column you want to have. Therefore, it has severe limitations in establishing the soil water characteristic curve for, other than coarse grained soils. Coarse grained soils, generally, the air entry value lies in the range of 1 kilo Pascal to maybe, 3 kilo Pascal at max, for fine sands. So, beyond that immediately the water content decreases as the suction increases. So, be within 10 kilo Pascal range, you can establish the entire soil water characteristic curve.

So, for red soils or other soils, where the water content significantly varies between suction range of 0 to 150, 200 kilo Pascal, you cannot use hanging column technique. But, you can use tensiometer up to the atmospheric pressure minus vapor pressure. In that particulars range, one can use tensiometer to establish the soil water characteristic curve.

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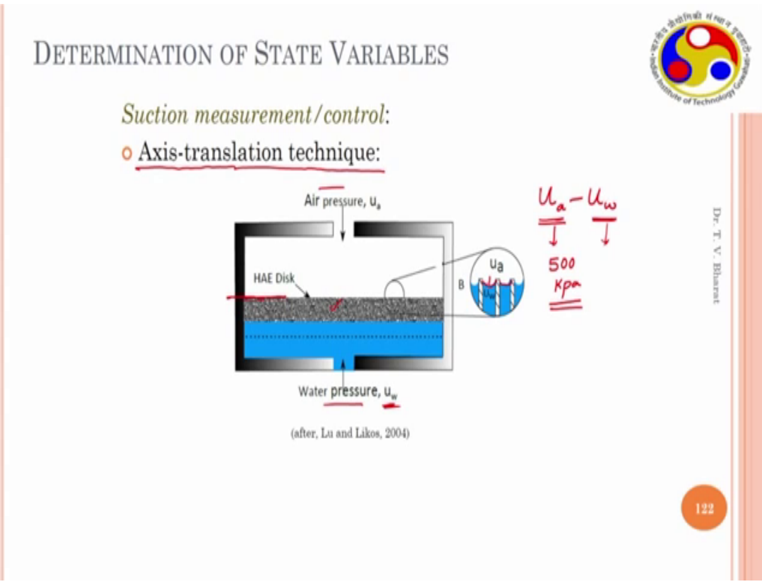

We have another technique that is developed, taking the inspiration from tensiometer. The technique is called axis translation technique. Actually, the name itself indicates the principle behind the technique. In this axis translation technique, you have a high-air-entry disk, similar to the tensiometer. And in a closed chamber, thick vessels you should have. In a closed chamber, where the one top is connected to the air pressure valve, and another one is connected to the water pressure valve at the bottom. So, here the axis is translated. As we have seen earlier in the tensiometer that, as elevation increases atmospheric pressure decreases because, decrease in the atmospheric pressure causes the decrease in the, or the decrease in the maximum measurable suction value by tensiometer.

What if, you increase atmospheric pressure? So, that is the principle behind axis translation technique. Air pressure is maintained at elevated values may be as high as, you can maintain very high values. Then, water pressure can be maintained at lower values; maybe at atmospheric pressure itself. So, then, if you see, your u a minus u w, u a is positive. Because, you are maintaining very high values; maybe 500 kilo Pascal, at air pressure you are maintaining. And, u w is maybe 0 or which is equal to atmospheric pressure. At, gauge values if you consider, a suction of 500 kilo Pascal could be applied, without causing any vaporization; without causing any cavitation.

So, therefore, that is a principal, here it is used. When the water level is up to here, so, the air entry disk is completely saturated, and these are the pores that are formed. And, the curvature indicates the pressure drop across the air, air water interface. On this air entry disk, if you play some soil like this. Now, soil pore water, is in very good contact with air entry discs. So, therefore, the water in the soil pore, and water in the high air entry disk, both are in good contact. They form a good channel.

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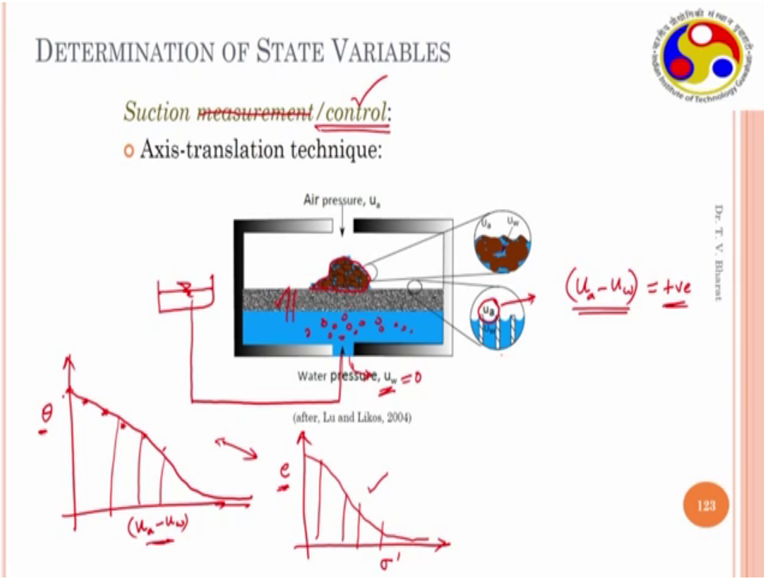

Now, when you start increasing the air pressure, so, u w is constant; maintained constant, may be equal to 0. So, then, you are increasing u a, which is the positive value; that means, this indicates the suction; matrix suction. So, you are actually maintaining certain suction.

So, then, slowly the water has a, u a minus u w is increasing, water starts bleeding from the soil, because water leaves from the soil because you have increased the suction. As there is a good contact between the high-air-entry disk and soil, the water leaves through this and water comes out. So, you can collect this particular water. If you collect the burette stand, you may collect the amount of water that is coming out. So, as and when u a minus u w is increased, the amount of water that is coming out is known. So, when u minus u w is increased, which is plotted on the x axis; u minus u w is increased, the water content; it could be gravimetric or volumetric or here you are measuring the volume of water which is coming out. So, it could be volumetric water content which, starts decreasing.

For example, initially the it has certain water content and then you have placed inside. Then, you have increased certain u a value, and u w is 0. Then, a 5 kilo Pascal of air pressure is applied then you have water content slightly decreased because, some amount of water that has come out. Then, at equilibrium once the water stop coming out; that means, it has reached, soil reached equilibrium with the u a minus u w, are atmospheric conditions surrounding ambient conditions. Then, you increase further value and some more water comes out.

So, this is how you can continue the experiment, just like applying a suction value, which is similar to your consolidation test. In consolidation, you have sigma applied and you have void ratio on the y axis. So, this void ratio is similar to your theta. This is water content, and this is void ratio. Both are state variables. Here, u a minus u w; that is, the negative suction or matrix suction. And sigma is a positive load that is applied on the soil. At equilibrium, where 100 percent or 90 percent consolidation takes place, this sigma is equal to sigma dash, then the curve is similar. The curve is, this is similar to this. Similarly, here also, you are applying some load, matrix suction load. When you have increased, then water comes out. So, the water content drops. Same thing is happening.

However, the difference is the consolidation is conducted at fully saturated state. Here, at any given point, the soil is at saturated condition. But, here, it is unsaturated case. Beyond air entry, there is unsaturation in the soil. So, both are similar. But, here air pressure is applied. Instead of directly measuring, we are controlling the suction. So, this is not a measurement this is the controlling suction. We control the suction and measure its corresponding water content to establish the soil water characteristic curve. So, there is, this is again a laboratory technique. This cannot be used in our field. So, to understand the field dynamics you may have to get other representative soil sample and then place it in the chamber and conduct the test by increasing the air pressure. And, this way you can establish the entire soil water characteristic curve.

Here in this particular technique also, you can do both, drying and wetting. So, you can establish the hysteresis. Here, air pressure you are increasing. Once, it reaches certain value, you can also start decreasing the air pressure and water will be a sucked inside and water content will increase within the soil mass. So, you will get wetting path. Here, if the air pressure is beyond the air entry suction value of the high-air-entry disk, then water enters into the high-air-entry disk. And, then therefore, when this becomes unsaturated, when the air enters into the high-air-entry disk. So, that will be a vapor bubbles that exist here. Because, air bubbles will start going into the water phase; then, there is a discontinuity you cannot measure beyond that.

So, therefore, the maximum measurable suction range in this particular technique is limited by the high-air-entry disk capacity. One can use 5 bar or 15 bar. They are available in the market; so, based on that one can establish the soil water characteristic curve using this particular axis translation technique. The chamber should be strong enough because, you are applying a huge air pressure. So, you consider a thick chamber.

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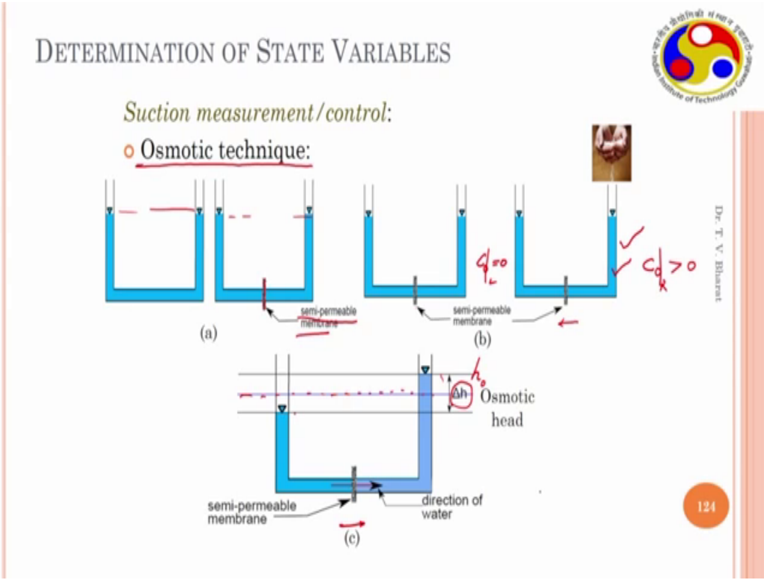

So, this is another technique, which is used for establishing the soil water characteristic curve of laboratory techniques, which is called osmotic technique; osmotic technique, which is based on the osmosis. Just recap, recapitulate what exactly this osmosis is. When you take a U-shaped tube, when you pour water, both at the same level and also, when you place a semi permeable membrane still both will be at the same level. Remember that this semi permeable membrane does not allow the solute to pass through. Here, water is solvent and solute we have not added. So, therefore, water simply passes through from one side to another. So, therefore, it maintains the same level as it was earlier.

So, in the second case I have the semi permeable membrane. But, I have added some salts on the right-hand side or some solute on the right-hand side. As the solute is filtered, which cannot pass through the semi permeable membrane, there is a concentration, higher concentration of solution on the right-hand side. And, here the solute concentration is 0 on the left-hand side. This is on the right-hand side. So, this is the condition. So, this now this is chemically, in equilibrium. So, the because the chemical potential of the right-hand side system is smaller, lower than the chemical potential of the right-hand side.

So, generally the solute should have moved from right to left to make the equilibrium, chemical potential through-out the system; however, because semi permeable membrane is acting, semi permeable membrane is resisting any movement of solute, it is filtering the movement of solute, now the water moves from left to right to dilute the solution that is available on the right-hand side, which causes; this is the initial level of the water now there is a decrease in the level here and then, that water is going to right-hand side. So, there is increase in the head. This head is osmotic head we have seen earlier this could be h o, osmotic head.

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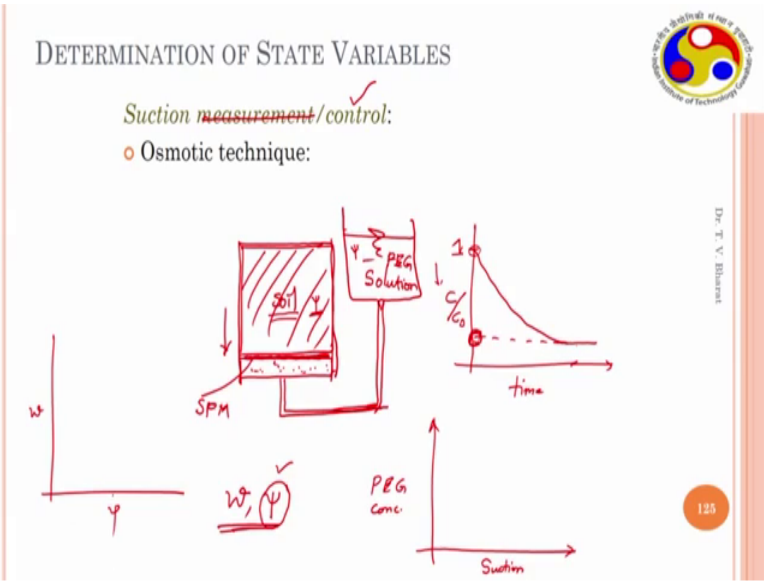

The same technique is used to establish the soil water characteristic curve. So, here you have a soil sample taken in a small column and you put a semi permeable membrane on the top and bottom, or, only just at the bottom. And, you have a porous stone which is placed. So, you have a membrane here and this is a porous stone. So, now, this is, everything is contained in a column. So, this is the soil.

So, now, this is connected to a reservoir; if you maintain some solute or some solution; something like a PEG solution; polyethylene glycol. Polyethylene glycol solution which is maintained on the, in the column in the right hand side, the PEG molecule size is much larger than the filter size or the pore size of the semi permeable membrane. This is semi permeable membrane. The semi permeable membrane pore size is much smaller than the PEG molecule size. So, PEG molecules will be filtered to pass through. So, initially if the soil is completely saturated then, water will be taken out from the soil to dilute the PEG solution, to maintain the chemical equilibrium.

So, therefore, with time, you see that the PEG solution concentration starts decreasing The concentration of the PEG solution, initially c by c naught if you consider, initially it is 1. It starts decreasing with time and it reaches one standard value, one equilibrium one steady state value. This concentration corresponding to one particular suction, and this concentration, this c by c naught value corresponds to what suction, can be established based on PEG concentration. One can establish the PEG concentration, concentration versus the suction.

So, based on this, you have one particular PEG concentration, based corresponding suction value can be read and that could be used. And, this soil could be weighed, this particular soil could be weighed to measure its water content. So, one can establish water content versus suction. So, at equilibrium the suction in the peg solution will be same as the suction in the soil pore water, at equilibrium. So, therefore, measuring the PEG solution concentration, as well as the suction, chemical potential would help in establishing the suction value within the soil mass.

Here also, we are actually controlling the suction. We are not measuring the suction. By changing the PEG solution concentration, we are measuring the suction value. By measuring the suction value and weighing the soil, we get the water content versus suction that could be established. And, but this suction is again is total suction. In tensiometer, you have a high-air-entry disk and axis translation techniques. You have, you have, high-air-entry disk. This pore size is not much larger than the solute molecular, size molecular size. Therefore, it does not filter the molecules of the salt. So, therefore, you measure only the matrix suction there. It cannot curtail the movement of molecules. So, you will not get the osmotic suction. In this case, you are getting the total suction values.

Whether it is a total suction, or, matrix suction, it only matters, when the soil pore water consists of some salts. In case, the semi permeable membrane arrests the movement of salts, to either leave or to come in, then it only measure the osmotic suction, it does not measure the total suction. We need to be little careful about it. Otherwise, if there is no salts in your pore water, then this is equivalent to your matrix suction itself. So, then you have a suction versus water content relationship that is the soil water characteristic curve. So, the soil water characteristic curve could be established.

Thank you.