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

Lecture - 08
Permeability and Seepage

Now, we have in the previous lectures I have shown some weight volume relationships 3 (Refer Time: 00:24) and their application and I have very beginning I have mentioned that the soil there are 3 important characteristics; they are permeability and compressibility and strength. And they are actually, so, now, we will try to start actually permeability and seepage.

Before going to this permeability and seepage, how seepage means what, permeability means what; actually this permeability means water actually when moved through water that is permeability. So, that means, water movement and the water is very much present in the water and what is the form of water present in the soil? What were the different types of water? Initially, I will just give some description and then later on related to permeability how to determine, how the other parameter affect the permeability and all those things slowly one by one we will discuss.

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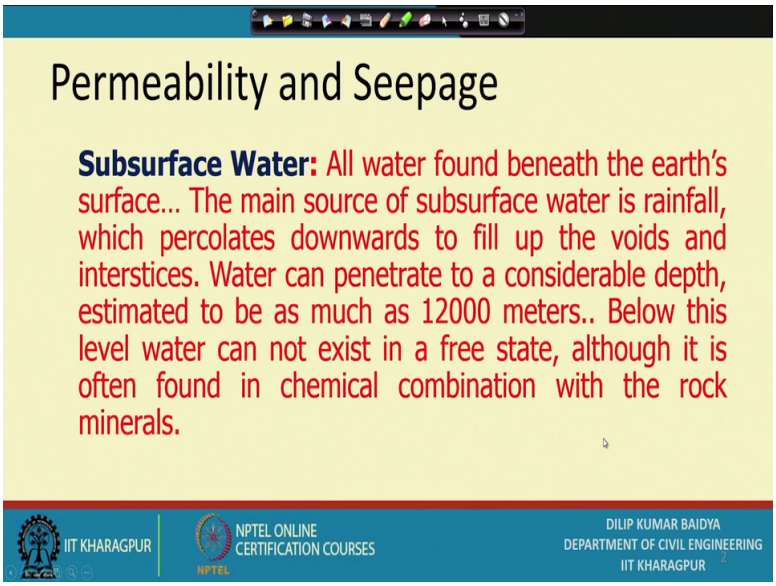

So, permeability and seepage; the water in the different form actually available with the soil and first thing I am defining actually subsurface water. All water found beneath the earth surface; that means, below the earth ground level whatever water is present that is actually subsurface water. And the main source of this water is nothing but rainfall and that rainfall when drops in the soil it will be percolates and fill the voids and penetrates downward and this way water can penetrate actually theoretically up to 12000 meter and so, that means, we can expect water period up to that much depth. And below this level water cannot exist in a free state.

Although water can be there in the form of chemical combination in the crystalline in the form in the chemical combination with the rock minerals; that means, that water are not free water. So, whatever water through rain and all weather change and vibration and then coming back and water coming to the soil and that soil percolating. So, it can go theoretically up to 12000 meter if you want that still water is there, but that water is not free water. This is in the form of minerals.

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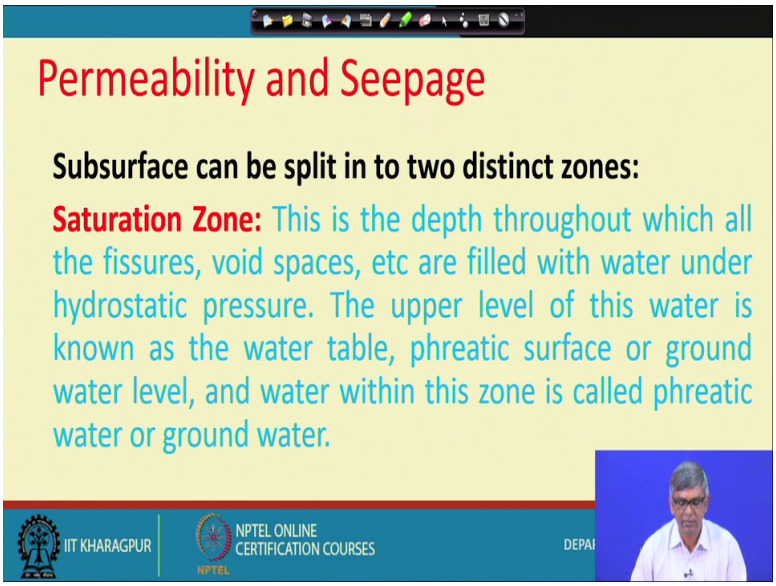

And, then subsurface can be split into 2 distinct zone; one is saturation zone, by the name itself it is quite clear and obvious that saturation means all soil mass, will have a voids and all void spaces will be filled up with water. This is the depth throughout which all the fissures, void spaces, etcetera are filled with water under hydrostatic pressure. The upper level of this water is known as the water table and phreatic or sometime it is known as phreatic surface,

sometime also known as groundwater level and water within this zone is called phreatic water or ground water. So, that means, the water depth throughout which the all fissures etcetera; that means, from the downward direction water will be saturated, soil will be unsaturated when we go upper direction then it may not be saturated. That level at which the up to which the saturated soil is there that is actually limit, that is the upper level of this saturation zone and that is called water table sometime it is called phreatic surface sometime it is called groundwater level.

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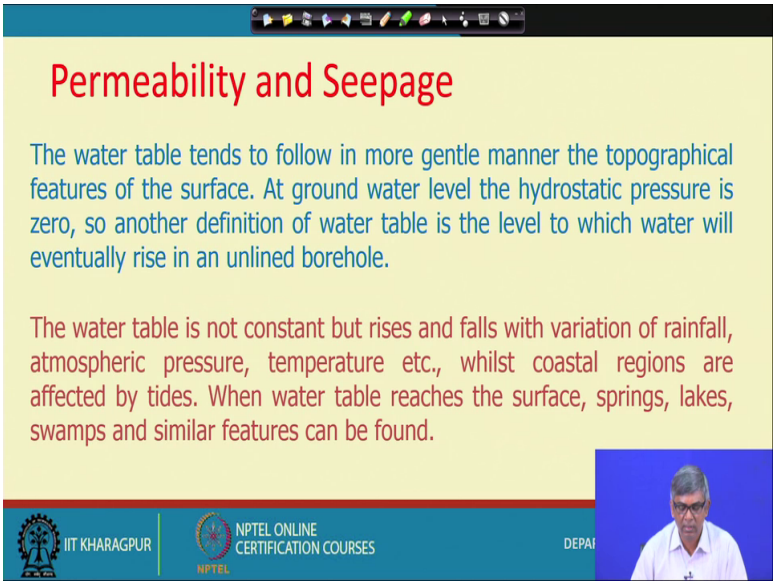

And, this water table not always very level one though in a smaller perspective actually if you dig a hole here and see the level of water and 3 meter or 5 meter away if I make a hole you may get approximation, but within largest perspectives if you consider suppose here and 20 meter away, if I calculate at 100 kilometer away if I dig then you may not get the water level same. So, that is what the water table tends to follow in a more gentle manner the topographical features of the surface. The way topographical graphical features are there they are actually parallel to that will be there.

At ground water level the hydrostatic pressure is 0 that is important. Many times a brief short and say multi will be there and that is the thing we have to remember that in the groundwater level the hydrostatic pressure is 0. So, another definition of water table is the level to which water will eventually rise in an unlined borehole; that means, if I make a borehole, automatically since it is a atmospheric pressure, after that water will come up. So, that is the

indication that if I make a borehole that water will come that level and that is the actually water table.

The water table is not constant, but rise and fall with the reason of rainfall atmospheric pressure; that means, the temperature etcetera. Summer water table will go down, in the winter rainy season it will goes up because of rainfall like that and coastal region again it will varied because of the tide when water table reaches the surface like springs, lakes, swamps and similar features can be found.

So, water table sometimes comes to the surface also because indeed we studied it can come to the surface.

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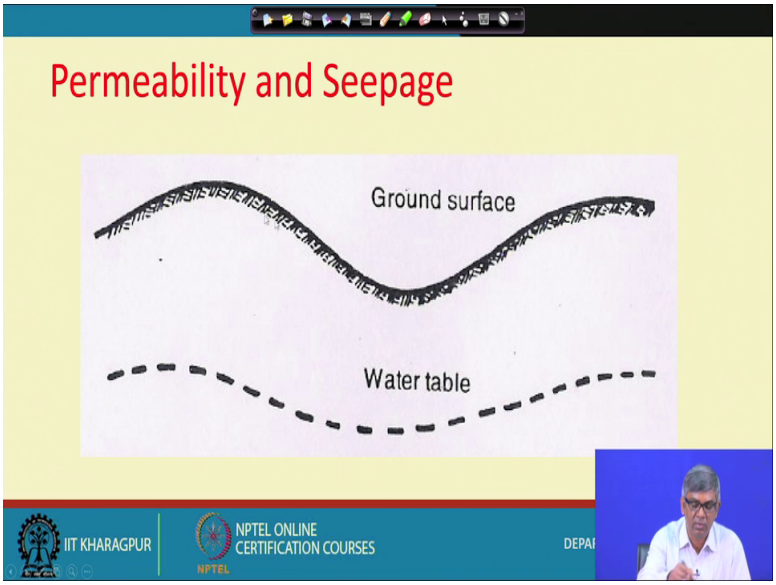

And, permeability and seepage; so, this is the typically if the ground surface is like this then your water level also will be parallel to this, but is a very small distance a few kilometer a few meter this will be distance, we will see as a level. But, when long topographical you consider then you will get the water table also parallel to the general ground surface.

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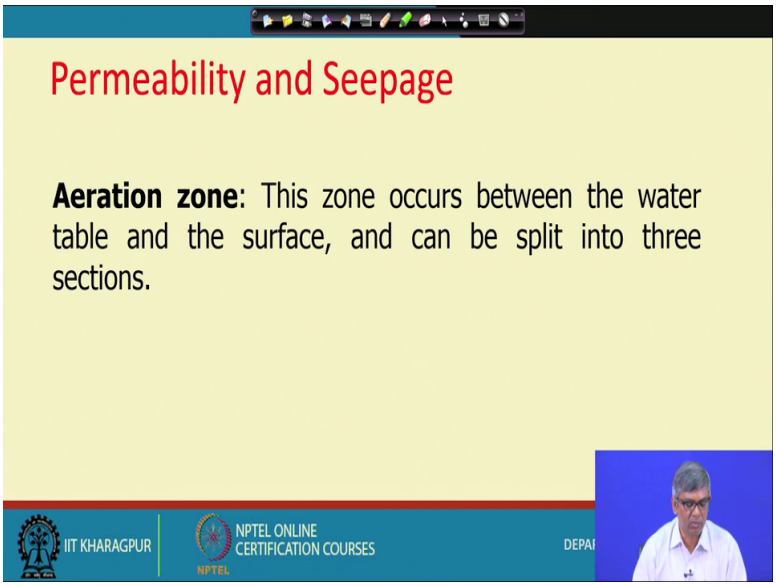

And then saturation zone I have divided actually wanted to divide into 2 parts; one I have already explained, it is saturation zone and other one, aeration zone. This zone occurs between the water table and the surface and again this can be split into 3 distinct zone, section.

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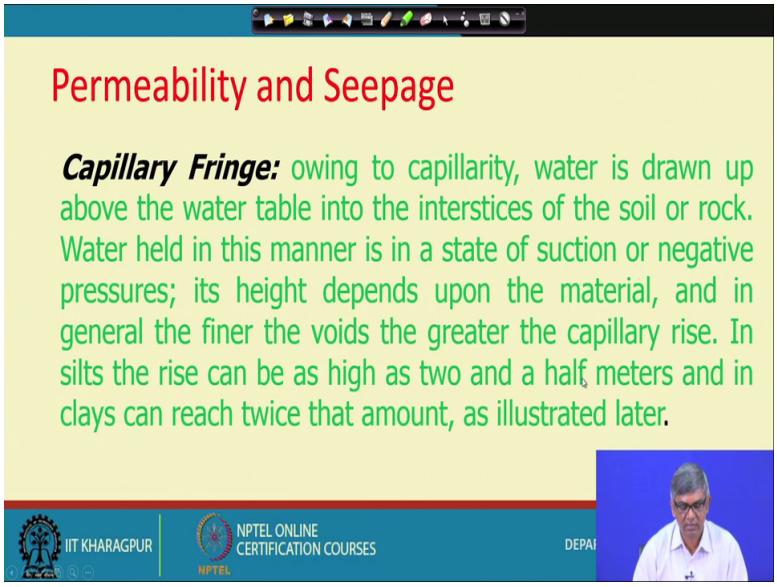

And, they are, you can see capillary fringe, what is this? Owing to capillarity, water is drawn up above the water table into the interstices of the soil or rock. Actually, when the fine voids

are there through that because of this capillarity action what is the capillarity action what other action will be there that I will be coming to the next in the subsequent presentation. But here just I am briefly telling here that, when the voids are very fine then the sometime water will be drawn up above the water table, that is actually capillary fringe.

Water held in this manner is in a stable in a state of suction or negative pressure that I will show also theoretically that is pressure is negative. Its height depends upon the material; material means what? whether it is silt sand or clay in a sand whether it is fine or coarse, and in general the finer the voids the greater the capillary rise and in silt the rise can be as high as 2 and a half meters and in clay it can reach twice that amount which will be described later on.

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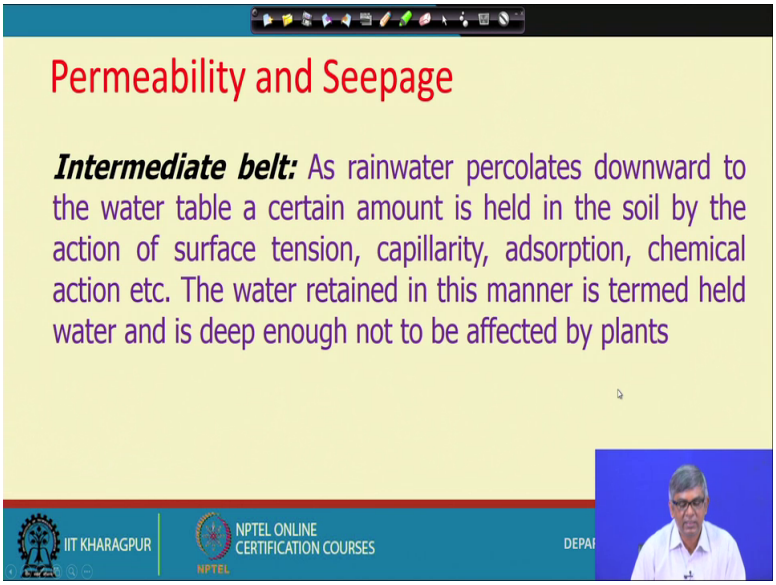

And then intermediate belt; that means, capillary fringe means what? it was not below water table above water table, but because of this capillary action some water will be raised up and water and soil will be saturated. So, that is called capillary fringe and intermediate belt is what? As rainwater percolates downward to the water table a certain amount of water is held in the soil by the action of surface tension, capillarity, absorption, chemical action etcetera.

So, there are because of so many action several properties present with this soil this entire amount of water whatever drops on the surface will not go to the or not join to the water table. So, some amount will be held, in the soil particle. So, that the water retained in this

manner is termed held water and is deep enough not to be affected by plants. Sometimes though plant sometime may not be able to reach that, some amount of water will be held in this. So, that is called intermediate belt.

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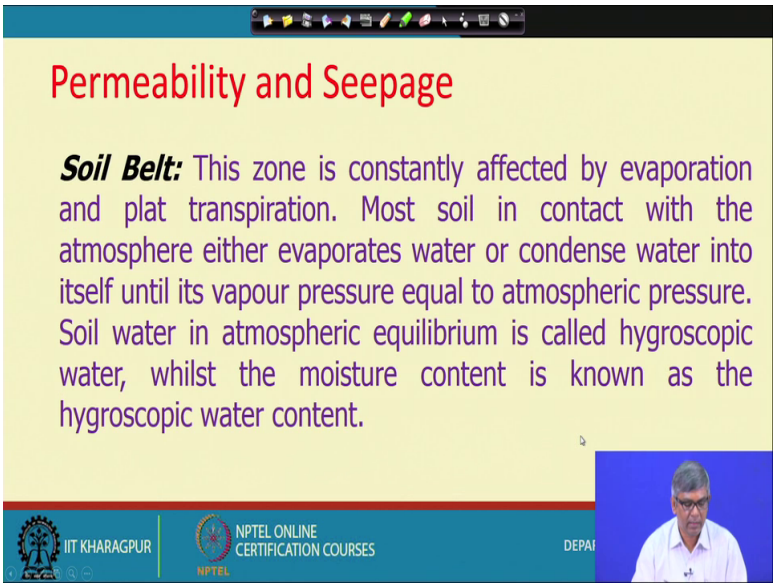

And, then soil belt. So, this is a actually top most layer. This zone is constantly affected by evaporation and plat, this will be a spelling mistake, it will be plant transpiration; that means, the top soil when rains it will be moist and when it will be sun then again evaporation and because of that it will be dried, so, like that to the constant change of wet and dry condition most soil in contact with atmosphere, either evaporates water or condense water into itself into its vapor pressure equal to atmospheric pressure.

Soil water in atmospheric equilibrium is called hygroscopic water while the moisture content is known as the hydroscopic water content. So, top soil whatever things are there that is called soil belt and from there roots of the plant will be in that zone and they will take continuously taking water from this. So, this of course, not really soil mechanic issue, but to describe water present in water what form what which area which zone what form I just mentioned this aspect, but it is not really related to soil mechanic so far whatever we have mentioned only other than water table and capillary rise those things I will explain in the laboratory later on.

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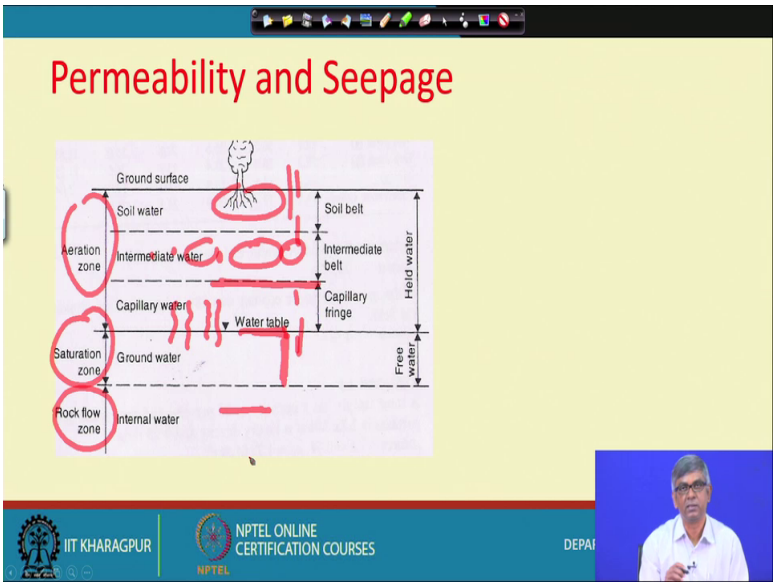

This is actually; this is whatever things I have defined they are actually number of things I have mentioned that you can see. These are actually internal water. This is the zone, this is internal water in the chemical form and from here to here actually this is actually saturation zone.

This will be and top of this will be water table which we have defined and then because of this capillary rise like this it is a fine particles water will be raised up and then it will be saturated up to the this is actually because of that this is called capillary fringe and then intermediate belt, that means, this zone actually because of this absorption and all other property surface tension etcetera some amount of rain water will drops here this is going downward, but it is joining to water table, but still some parts water would be retained by the soil that is intermediate water and this is the soil water; that means, on the within the soil some amount of water will be there evaporation transformation all those things are happening.

So, these are all different zone what I have defined one by one these are explained in this figure. This is aeration zone, this is saturation zone and this is rock flow that means, water will be in the form of minerals.

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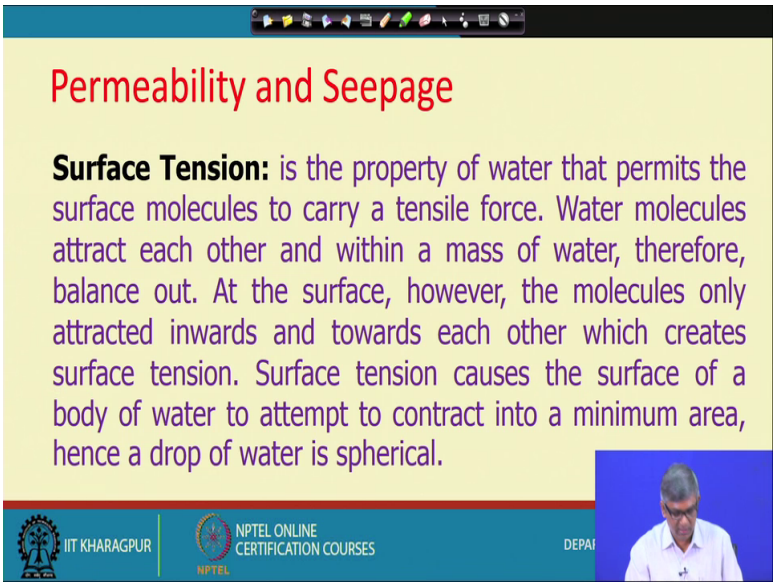

Now, this is the thing which is important for us as I have told you that this is a property of water this surface tension. Capillary is the effect of the surface tension. Capillary is the action and surface tension is the course actually. Whatever I have said that if the voids are fine and water will be raised; how it will be raised? Because of this capillarity and capillarity caused by what? Surface tension. So, this is the thing.

And, let me define what surface tension is. Surface tension is the property of water that permits the surface molecules to carry tensile force. Water molecules attract each other and within a mass of water therefore, balance out. So, each molecule will be attract each other, within mass. So, all are attracted by the inside mass it will be balanced, but in the surface, but at the surface, however, the molecules only attract to the inwards and towards each other which creates a surface tension, because one side only the outside there is no molecules.

So, because of that surface tension cause the surface of a body of water to attempt to contract into minimum area and because of that a drop of water is spherical and why it is so, because of the surface tension effect. Because, periphery the one side tension is there, so, it will attract in an inward direction. So, because of that they will try to be in the spherical form.

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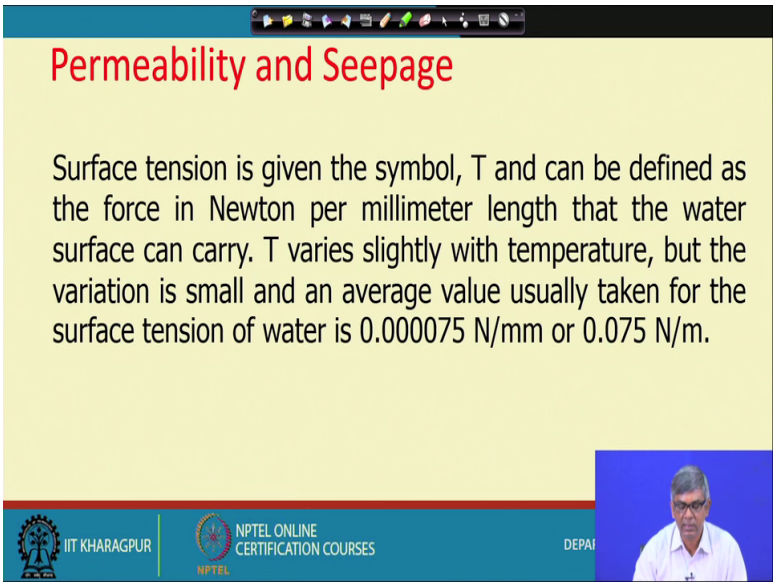

Surface tension is given the symbol, T, surface tension sometime T, sometime Ts, uniformly everywhere it is a surface tension symbol is T and can be defined as the force in Newton per millimeter length that the water surface can carry how much Newton per millimeter length force can carry that is actually your surface tension. The T varies slightly with temperature, but the variation is small and average value usually taken for the surface tension of water as 0.000075 Newton per millimeter or 0.075 Newton per meter.

So, this is the unit we have to remember. Sometime if it is not given surface tension in some calculation it may be required. So, you have to better to remember surface tension of water is 0.075, but it is mentioned that with temperature etcetera it varies slightly, but average value is like this. So, one can use without any hesitation if there is a value not given.

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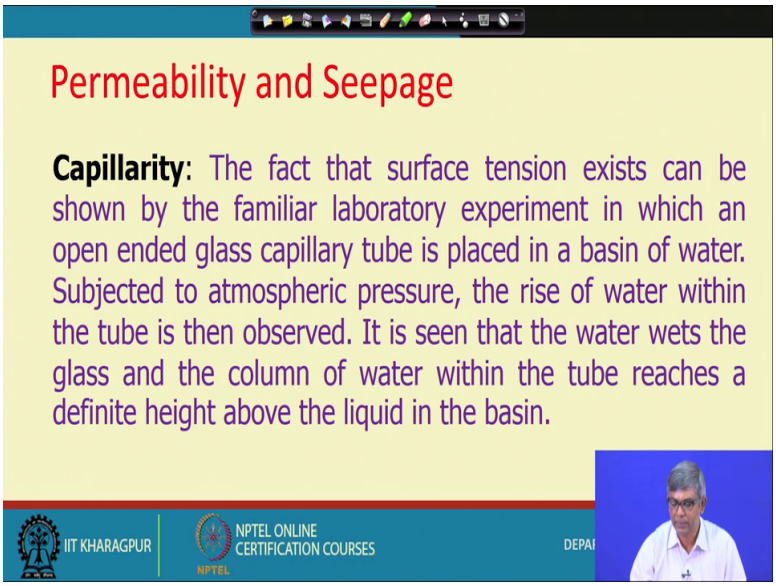

Then capillarity; the capillarity is an action, the fact that surface tension exist can be shown by the similar laboratory experiment in which an open ended glass capillary tube is placed in a basin of water. So, in a basin of water if I put a very fine tube on the water both side open, subjected to atmospheric pressure, the rise of water within the tube is then observed

So, because of this you will see some amount of if I put a very thin tube within the water basin you will see some amount of water will drawn up within the tube and it is seen that the water wets the glass and the column of water within the tube reaches is definite height about the liquid in the machine. If it is like this, if I put a basin and water level is here and if I put a capillary tube here then you may find that water reached here. This is water level here and then if this is capillary tube then you may find that water reached at this much height. So, that is actually because of the capillary action.

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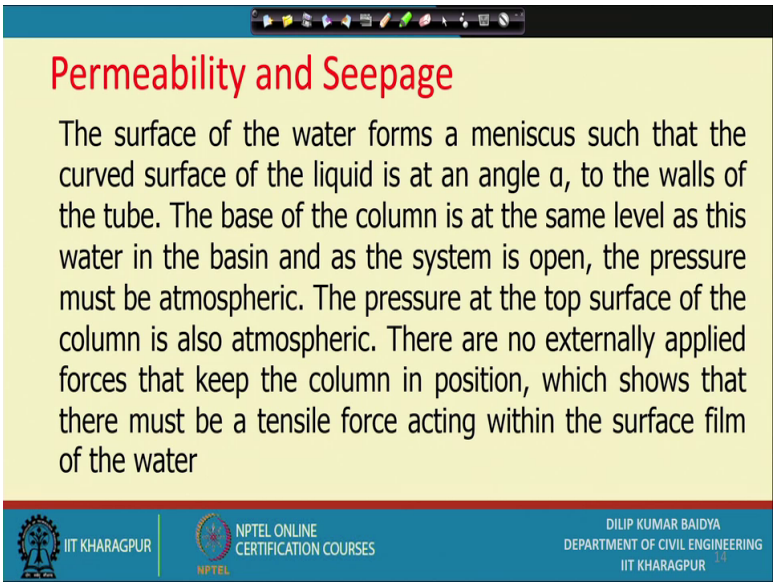

The surface of the water forms a meniscus such that the curved surface of the liquid is at an angle alpha to the walls of the tube. Meniscus means actually when it is between the water and surface of the glass tension is there, it will rise like this. So, meniscus typically it will not be water level if it is a glass here never be like this, it will be if the glass is like that it water level will be something like that. So, this angle this tangent that is alpha this angle is telling this is with a alpha angle walls of the tube.

The base of the column is at the same level as this water in the basin as the system is open, the pressure must be atmospheric; atmospheric, here actually from the top it is atmospheric and the basin there is the atmospheric pressure. There are no externally applied forces that keep the column in position. To push the water there is no external force is applied, but still water is rising, which shows that there must be tensile force acting within the surface film of the water. So, that means, there must be some tension which is growing the water up. So, that is what we will try to see by some calculation also.

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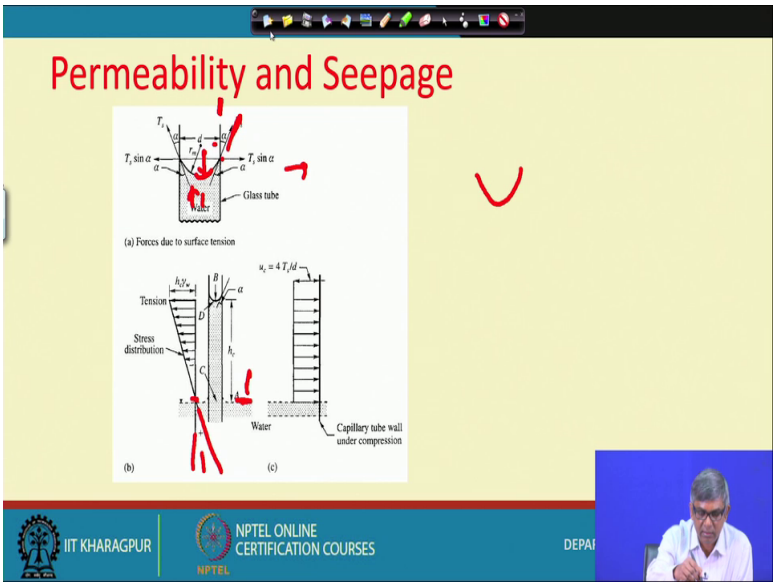

You see this is the one. This is the suppose tube this is exaggerated, is a enlarged view you can imagine and then this is the meniscus and this angle this is the surface tension direction of this will alpha and diameter d suppose and if the surface tension implant to this then you can take a component in this direction component in this direction.

And then finally, I can consider the equilibrium, actually what, in the periphery of the glass tube the tensile force is there that will be into multiplied by your perimeter and then atmospheric pressure is there and this site is atmospheric that bottom there might be some pressure which is lifting this, so, that pressure multiplied by the cross sectional area though the it is spherical the area will be different, but since they are small we can approximately take this as a circular area or the cross section of the tube and if you take that way then you can find out how much height it can raise which in the diameter is given.

And you can see this water table is here and if; that means, there it is already mentioned in atmospheric and; that means, if I go this direction if I go this direction then water pressure hydrostatic pressure will be gamma w times h going downward. But, when it is going above then it is negative. So, that is what it is going up it will be minus when the above water table using against gravity, that will be minus. So, with keeping this points in mind and you can see that different calculation.

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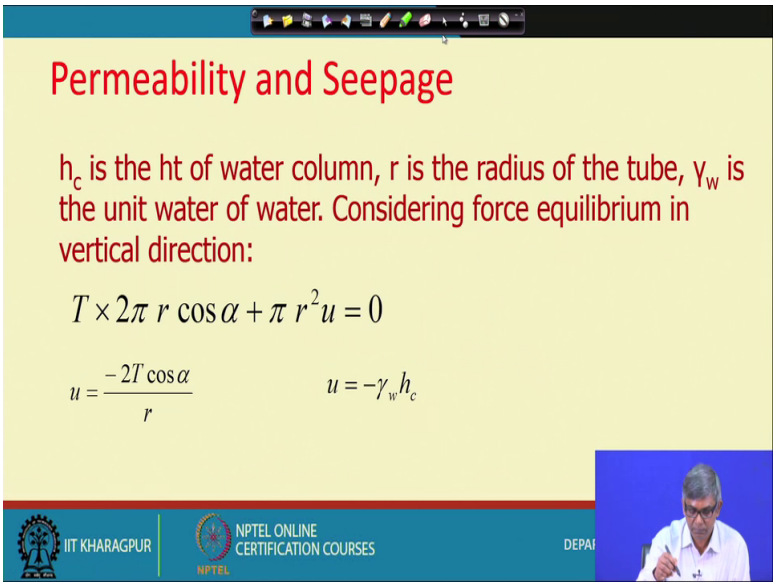

See h c is the height of water column, r is the radius of the tube, and gamma w is the unit weight of water. Considering the force equilibrium in vertical direction; we can see we have taken 2 pi r is the perimeter sorry 2 pi r is the perimeter T cos alpha we have taken that we force surface tension force in the particular direction component we have taken. This is one force and upward direction and from bottom also there is a u pressure we have shown, that pressure into pi r square. So, these 2 are in the same direction.

So, since there is no external force applied, summation of these 2 force will be 0. So, that is what we have done. Then you can see ultimately you are getting the new value the negative sign and the value is 2T cos alpha by r. And u since actually the height and it is above water table that definitely minus h c, so gamma w h c is the u and if you substitute that, then you will get the value.

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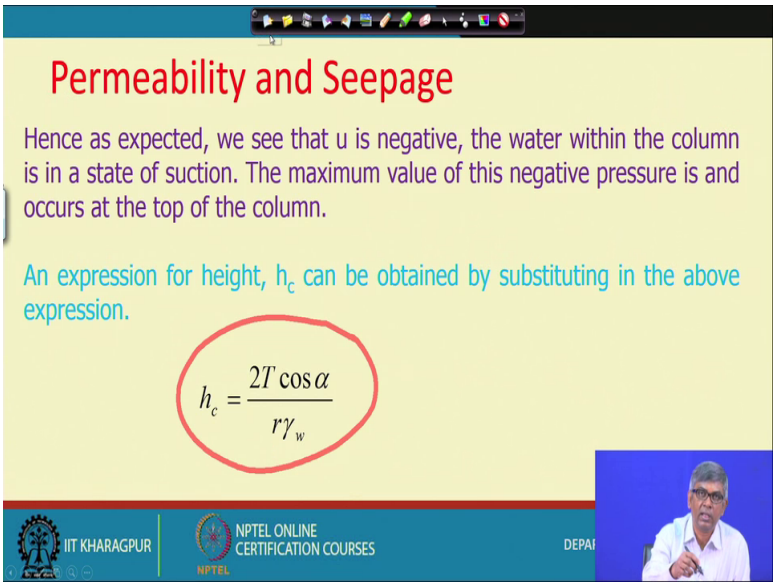

Hence as expected, we see that u is negative, that is, what we have shown in the water within the column is in the state of suction, that means, since it is negative, the maximum value of this negative pressure is and occurs at the top of the column and an expression for height h c can be obtained by substituting the above expression, you can see; that means, h c equal to; so, this is the expression we can get and you can see the rise will be inversely proportional to radius. So, finer the particles of that been voids then your raise will be more. So, that it is clear from this.

So, because of that in the clay soil, the capillary rise will be maximum, silt will be in between and in the sand and gravel will be difficult, but sand also can raise up to some height.

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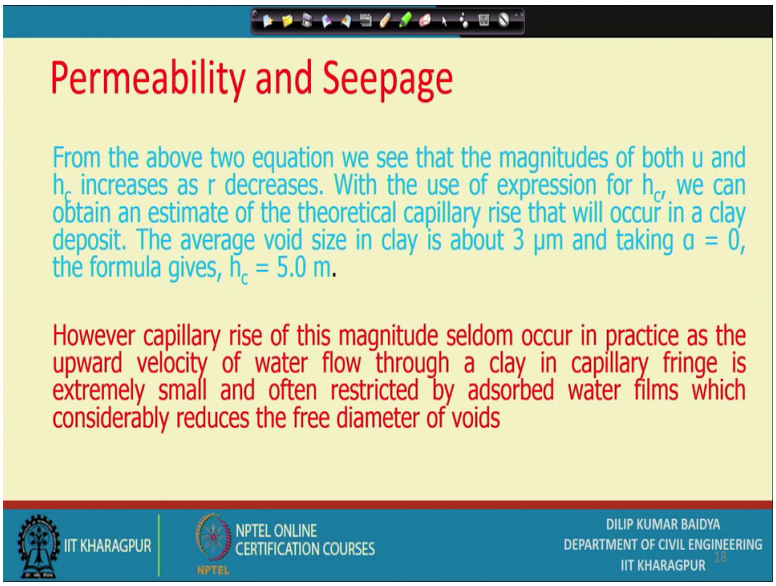

From the above 2 equation we see that the magnitude of both u and h c increases as r decreases. What I have said; inversely proportion. With the use of expression for h c, we can obtain an estimate of the theoretical capillary rise that will occur in a clay deposit. So, clay size we have mentioned already in the classification, that is, less than 0.002 millimeters. So, average void size if it a clay if I consider 3 micrometer and taking alpha equal to 0, in the expression alpha is there for water to soil you can take alpha equal to 0 and if you take this size as a 3 micrometer the formula gives you h c equal to 5 meter. That means, in a clay soil if I take the average side, void side then we can the capillary rise can be at as high as 5 meter.

However, capillary rise of this magnitude seldom occur in practice as the upward velocity of water flow through a clay in capillary fringe is extremely small and often restricted by adsorbed water films which considerably reduces the free diameter of voids.

So, that whatever theoretical diameter we have considered that much diameter may not be available because of this water present in it and also this resistance. There are different types of resistance will be there, though theoretically if you see, but at much lower than that value it can reach.

Thank you.