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**NATIONAL PROGRAMME ON
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**CDEEP
IIT BOMBAY**

# ADVANCED GEOTECHNICAL ENGINEERING

**Prof. B.V.S. Viswanandham**

**Department of Civil Engineering
IIT Bombay**

**Lecture No. 13**

**Module - 2
Permeability and Seepage - 2**

Welcome to module 2 lecture 13. In the previous class we introduced ourselves to permeability at sea page, and we discussed about the quick sand condition. And then we said that the quick sand condition is not a type of sand it is a condition which actually happens when the water flows vertically upward in soil in some certain situations.

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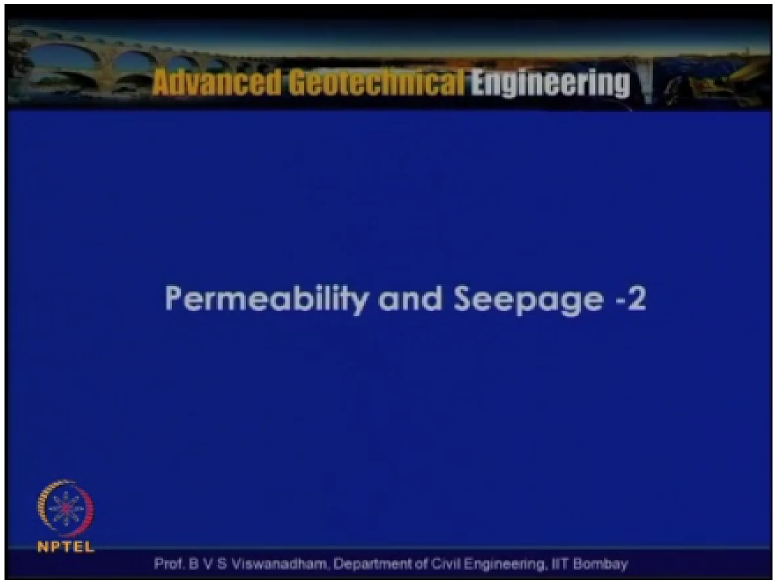


So this lecture is titled as permeability and seepage 2. So what we discussed in the previous lecture is about the quick sand condition, in the final leg of the lecture we discussed about quick sand condition and we said that the quick sand is not a type of sand.

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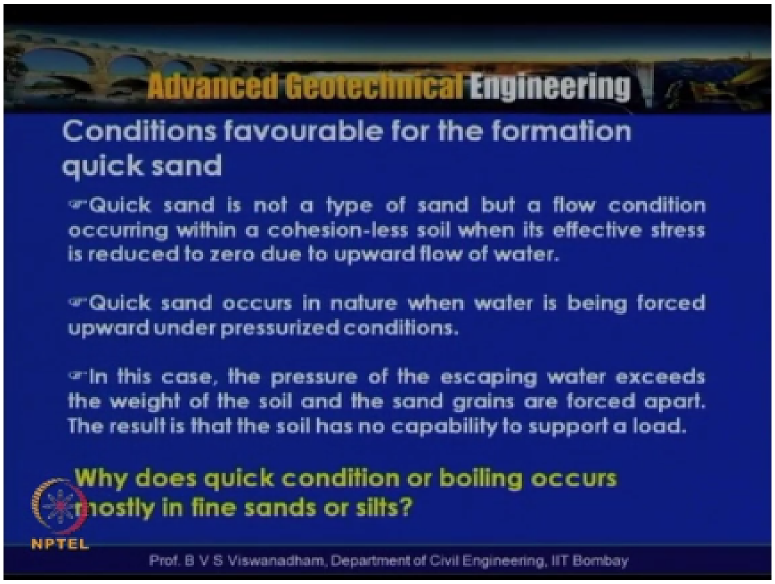


But a flow condition occurring within a cohesion-less soil where its effective stress is reduced to 0 due to upward flow of water. Quick sand condition is not a type of sand, but a flow condition occurring within a cohesion-less soil when it is effective stress is reduced to 0 due to upward flow of water. So quick sand condition occurs in nature and water is being forced upward under the pressurized conditions.

So why does the quick condition or boiling occurs mostly in fine sands or silts because of their low binding tendency.

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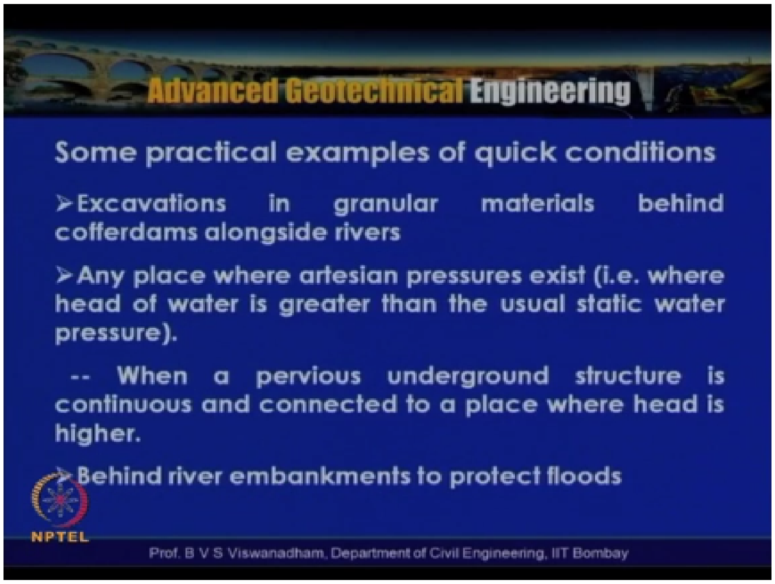


Some practical examples also we discuss there are excavations in granular materials behind the cofferdams along the long side rivers. Anyplace where artesian pressures exist that is where the head of water is greater than the hydrostatic water pressure. Or when a pervious underground structure is continuous and a connectivity a place where the head is higher or behind the river embankments that is levees which are actually constructed to protect floods.

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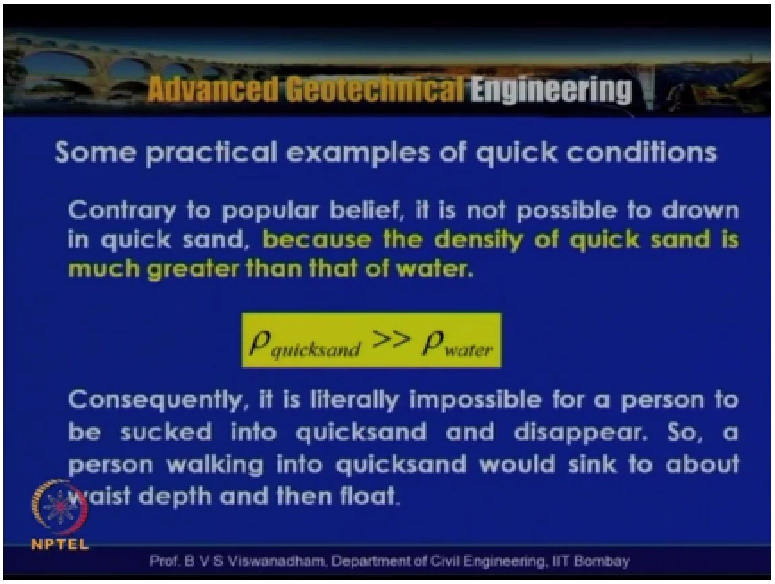


In reality contrary to the popular belief it is not possible to drown in quick sand. The reason is that density of the quick sand which is nothing but a mixture of water and sand particles is much greater than that of water. Consequently it is literally impossible for a person to be sucked into quicksand and disappear. So a person walking into quick sand would sink to about waist depth than the then float okay.

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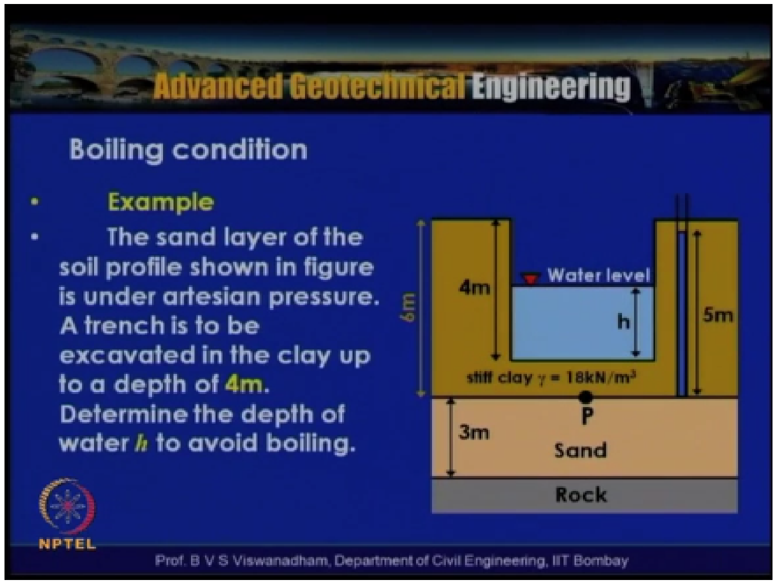


Let us based on the discussion whatever we have made let us consider this example on the boiling condition. In this problem the sand layer of the soil profile is shown in the figure here which is under artesian conditions. That means that we have got a stiff clay layer here and a sand layer and a rock strata here. And this particular sand layer is subjected to some artesian pressure that means that this particular sand layer has actually has got a continuous source of water where it can actually maintain a head of water which is equivalent to 5 meters.

That means that when you measure the pressure here, the head of the water is actually measured as 5 meters. Now in that situation if you would like to you know dig a trench here, a trench is to be excavated in the clay up to a depth of 4 meters, then we need to find out what will be the depth of water H to avoid boiling. That means the sand layer of the soil profile is shown and basically it is a stiff clay which is actually having a unit weight of 18 kilo Newton per meter cube.

And the depth of the trench which actually has been made as 4 meters. Suppose here determine the depth of the water H to avoid boiling.

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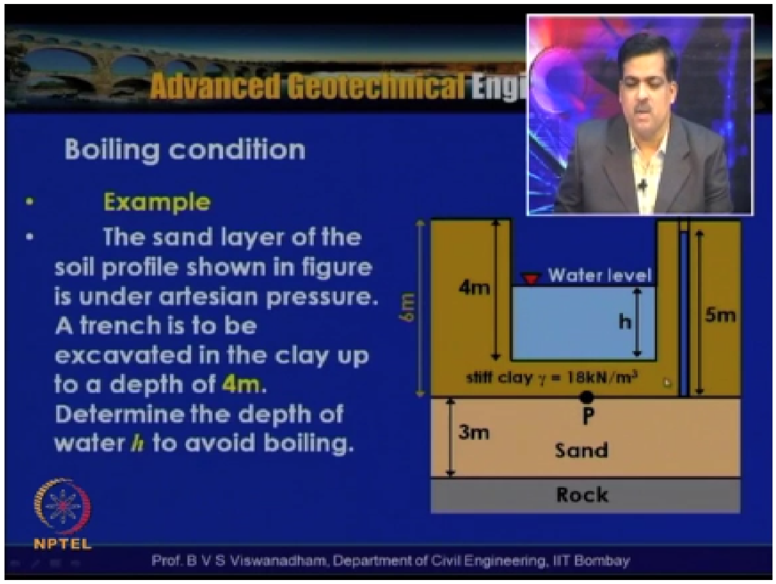


So this can be solved like this. We are interested in this point P. So at Point P the stress at this point is nothing but γHW that is whatever the resulting war button which we are going to put into 6 - 4 that is 2(γclay) that is the sooty clay which is nothing but HγW + 2clay. And at P the water pressure is 5(γWP). So at P the effective stress is nothing but γWh + 2γclay - 5γW. For σ'=0 for boiling condition to occur here if you apply this one what we get is that H=1.33m.

So if you are able to maintain the height of water which is in the field say at least 1.33m minimum then we can actually avoid boiling condition. That means that for example, say by mistake the excavation has actually happened and there is a anticipation of some boiling condition. So the one of the immediate remedy is to fill the trench with water to provide to prevent the caving of the excavation.

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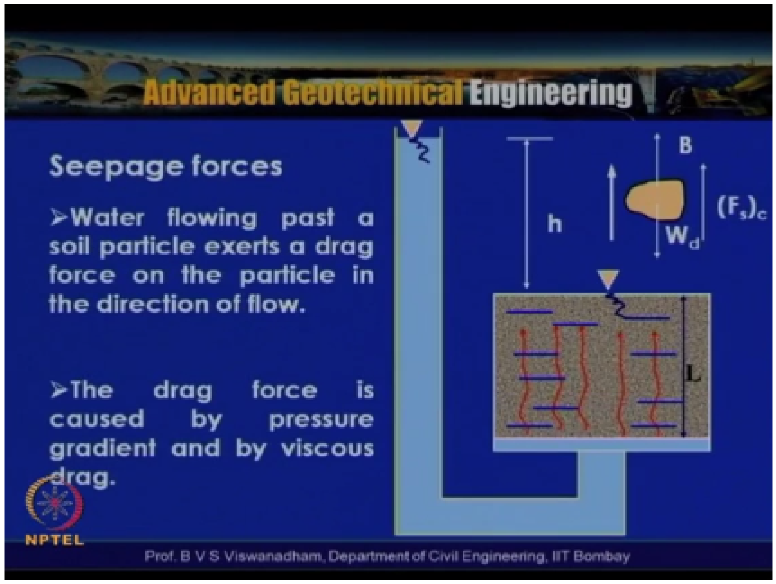


Now we actually have discussed it that when the water flows from higher energy higher head to the lower head, it exerts an energy on soil particles in the process of flowing from higher head to the lower head. So that these particular forces which are actually exerted on soil particles are called as seepage forces. So water flowing past a soil particle exerts a drag force on the particle in the direction of the flow.

For example, here if you consider a stem which is actually having a head H and this is the water level, and this is the length of the sample, then water flows vertically upwards in this direction. If we consider an equilibrium of a soil particle here the weight of the particle is acting downwards by an end force acting upwards the drag forces act in the direction of the flow. The drag forces surrounding the particle they act in the direction of the flow.

So this is the direction of the flow which is upward in this case. So the drag force is caused by the pressure gradient and by viscous drag which is actually occurred, because of the water solid interaction, and also the head pressure gradient which is actually maintained here.

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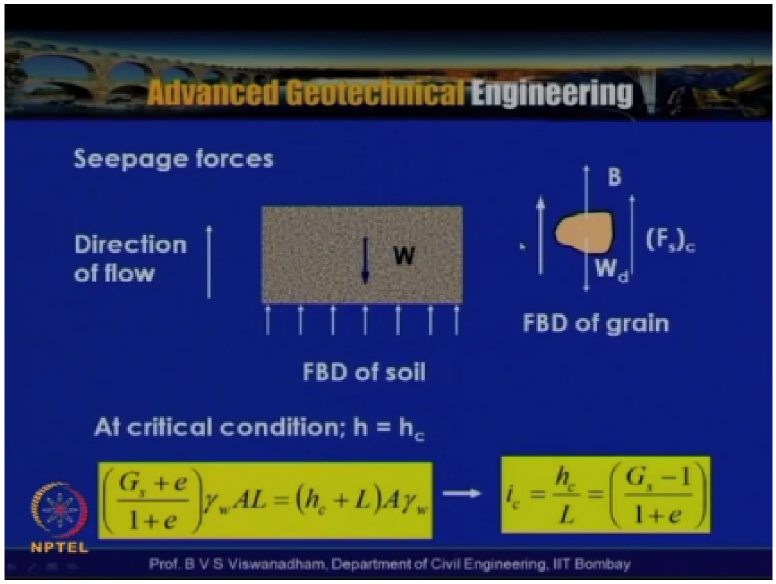


Now further if you look into the equilibrium of an element having cross-sectional area A in the direction of the flow the FBD of the soil is that the weight of this soil mass is W, and the pressure which is actually exerted by the water is actually acting at the base here. So this is the free body of the soil particles or a particle or a grain which is actually shown here. At the critical condition which tends to become HC.

So it is nothing but GS + e/1+eγW(AL) GS + e/1+e(γW)AL. So this is nothing but the saturated unit weight acting over area A and length of the sample L that is the weight and based on the pressure here HC + L(AxγW) which is nothing but the upward pressure is actually acting at this point. So by simplification what we get is that IC=HC/L=GS-1/1+e. So GS - 1 means GS is nothing but the specific gravity of the solid particles, and the e is the void ratio of the soil matrix.

So the critical gradient IC=GS – 1/1+e. And considering the free body diagram of the grain in the direction of the flow at I=IC so with this once if we simplify this we will be able to calculate what is the seepage pressure seepage force acting in a given volume where the flow is actually occurring. And if you are able to take the seepage force per unit volume of the fluid phase where the flow is occurring you will be able to get this seepage pressure.

The seepage pressure which is nothing but the seepage force per unit volume the units of the seepage pressure are nothing but kilo Newton per meter cube. So now the free body diagram of the grain once we consider the weight of the dry soil particle is equal to frictional drag force acting on the on the soil grain in the direction of the flow plus the violent force. So crystal drag on the acting and the soil particle can be obtained by WD the weight of the soil particle – B.

Weight of the soil particle can be obtained by dry unit weight of the soil particle that is GSγW/1+C(AxL-B) is nothing but the volume of the solid into γW. So this we can write it as FSC as GSsγW/1+C(AL-V-VV/V(VγW).

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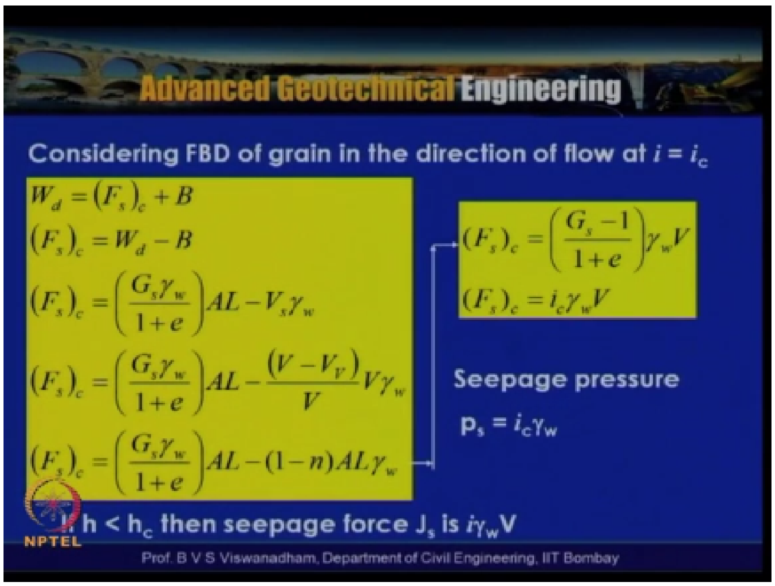


So what we have done is that V is what we are replaced by V-VV/V(VγW). So factor this frictional force that is nothing but the applied on the soil particles is nothing but GSγW/1+V (AL-1-n)AL(γW). So this is upon simplification what we get is that FSC that is the seepage force acting are applied on the soil particles is equal to GS – 1/1+e(γW)V. So this once we write it as at I = IC, it can be written as FSC that is the frictional force which is actually applied in the direction of the flow as ICγW, where IC=HC/L which is nothing but GS-1/1+e(γW)V.

V is the volume or which the fluid flow is actually occurring with I headed to the lower head. So if H is actually say less than HC where the critical head is not at reached then the seepage for GS is nothing but IγWV. So when H tends to become HC that means that when the H tends to become the critical head which actually can make the effective stress equivalent to zero, in that situation the seepage pressure is given as ICγW.

In case when H is less than HC when I is less than IC the seepage pressure is given as PS=IγW. Both the seepage force and seepage pressure act in the direction of the flow.

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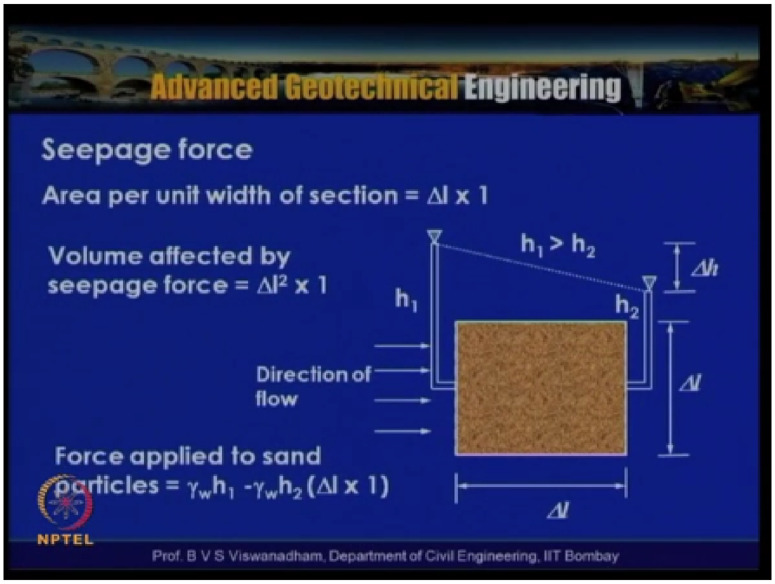


The seepage force can also be applied by this particular deduction. For this to happen a consider a rectangular element let us assume that this element is actually having dimensions in two dimensions like ΔL in this direction and ΔL in this direction, and assume that this is the direction of the flow, because here the pressure had maintained is H1 and here the pressure at it is maintained H2 then the assuming that H1 is greater than H2 the total head the difference is nothing but ΔH which is actually happening over length L.

That means that the head available here is H1 - H 2 that is ΔH by the time we actually does what water flows our erupts out of this particular point it is having a head available that is the head loss which actually happens is almost complete 100%, that is ΔH = 0 here, and ΔH is equal to full head will be here. So the area per unit width of the section is nothing but ΔLx1, if you consider.

If we can if we consider the unit width perpendicular to the flow direction means that 1 meter here 1 units here, then the area war which the flow is actually happening is ΔL x 1. And volume affected by the seepage force is nothing but ΔlxΔlx1. So $\Delta L^2 x1$ is the volume of the fluid phase. Now by writing an expression for force applied to sand particles as a difference of force applied on the left hand side here, and the right hand side here from here to here there is a drop which is actually occurring.

And this is this is the direction of the flow and this is called as this distance between these two points is called as the flow channel. So the force applied here is nothing but γWH1xΔLx1, force applied here is γWH2xΔx1 as H1 is greater than H2 γH1 - γH2xΔLxΔ1.

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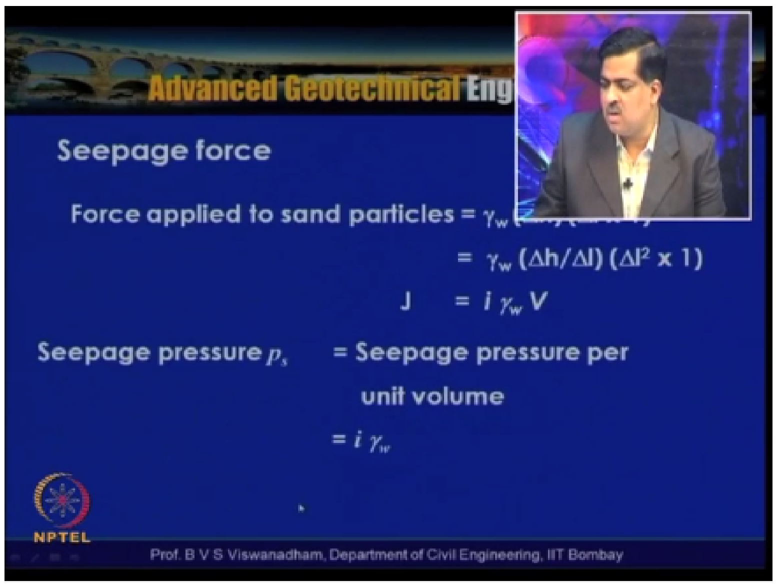


So here there will be a bracket which is here, so with this what we can write is that the force applied to sand particles is nothing but γWxΔHxΔLx1. Now by writing γWxΔH/ΔLx$\Delta L^2$1, we can write $\Delta L^2$1 as the volume and ΔH/ΔL is nothing but the hydraulic gradient. So with that I can write IγWV. So this is nothing but the seepage force which is IγWV, I is the hydraulic gradient which is nothing but here the definition is that ΔH/ΔL.

Because ΔH is the drop between the points left hand section and right hand section which is shown in the previous slide and γW(V), V is nothing but the volume of the fluid phase which is nothing but ΔLxΔLx1. Seepage pressure is can be given by seepage force per unit volume which is nothing but IγW. So the critical hydraulic gradient and quick condition.

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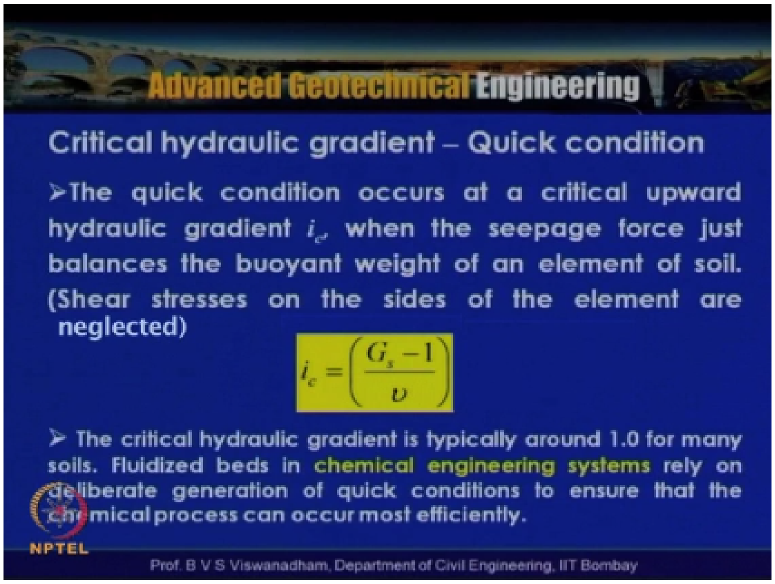


The quick condition occurs at a critical upward gradient I see when the seepage force just balances the buoyant weight of the soil and the shear stresses on the sides of the element are neglected. So here the shear stresses on the sides of the elements are neglected. So the critical hydraulic gradient is typically around one for many soils fluidized beds in chemical engineering systems rely on the deliberate generation of condition to ensure that the chemical process can occur efficiently.

So in some cases where fluid is it beds in order to generate the chemical processes the quick conditions are deliberately generated, so that this actually serves for the purpose. So the critical hydraulic gradient is typically around one and in considering these deliberations what we have neglected is that shear stresses on the sides of the element are neglected.

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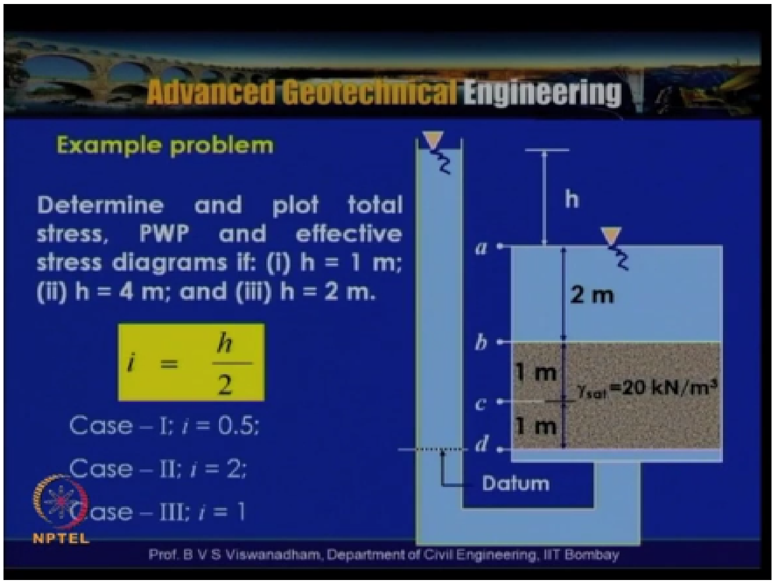


So let us consider another example problem, the problem is described like this here. We need to determine and plot the total stress pore water pressure and effective stress diagram or we need to plot. If incase 1 H=1m, case 2, H=4m, and H=2m. So this is the H which is actually shown here the difference in water level between the this portion of the stem to the this level at a.

So this particular portion of the stem actually has got across section area A and having soil thickness of two meters and this is the this C point is at the midpoint mid distance above D, and this level is actually considered as a datum. The saturated unit weight of the sand particles is given as 20 kilo Newton per meter cube. So this level is C, D, B and A. So in case one the hydraulic gradient is nothing but the length of the soil sample is 2 meters.

So I is nothing but H/2, so here when the H=1m, it is 0.5 and H=4m, it is 4/2 that is 2, and case 3 I=1. So in one case I is equivalent to IC, other case is I greater than IC, in another case I less than IC. So in the three conditions based on the three conditions now in the case 1, I=0.5 in all the three cases which is actually shown here, because this H is actually greater than this the water actually flows in vertically upward direction.

So the flow occurs in the vertically upward direction. So this is the datum and this D is at the d is at the datum level, and the C is at the midpoint, and B is at the top of this soil surface and A is the top of the water surface.

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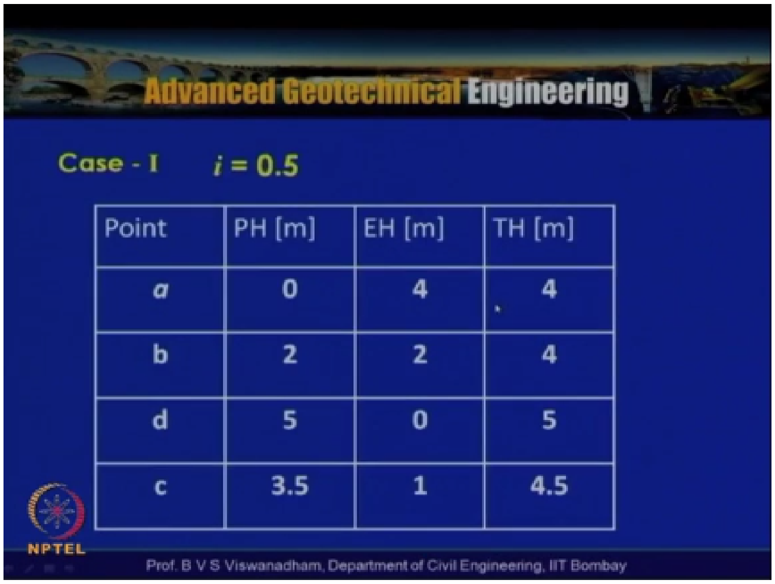


So at point A that is at the top of the water surface on the right hand side stem the pressure head is 0, and the elevation head is 4 meters, because it is 4 meters above the zoom of datum. So total head is 4 meters, at point B the pressure head is 2 meters, elevation head is 2 meters, total head is nothing but pressure head + elevation head which is nothing but the 4 meters. At Point D pressure head is 5 meters, and elevation head is zero because it is on the atom.

So the total head is 5 meters, at Point C here what actually happened is that 50% of the head which is actually available as actually already dissipated. So the pressure head is now is 3.5meters, elevation head is nothing but 1meter, because it is 1 meter above the assume of datum, so total head available is 4.5 meters.

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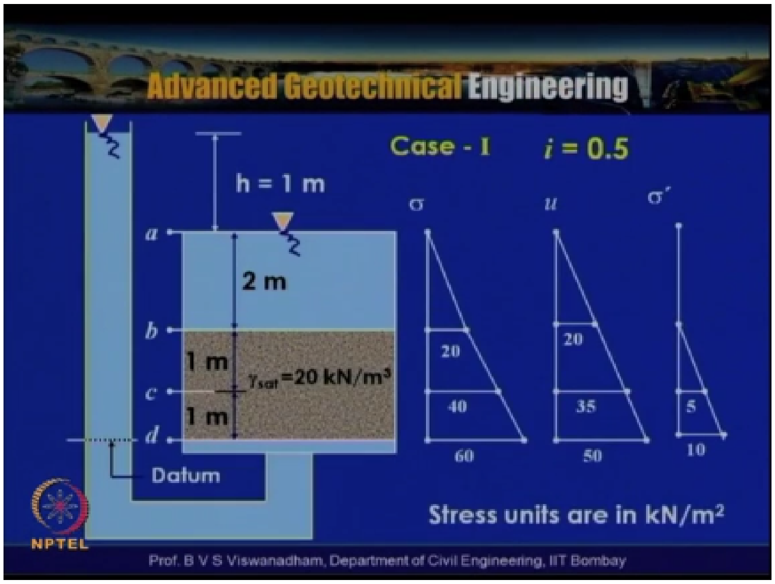


So with this when we plot this diagram with the D, C, B and these points and A at this point, the total stress can be given like this the total stress diagram in units of kilo Newton per meter square can be plotted as 20, 40 and 60. So at this point actually it is 20, 40 and 60 and pure water pressure with the whatever the total heads we have derived we can actually say it is 20 35 and 50 kp so our kp are kilo Newton per meter square.

So in this case here it is nothing but the effective stress which is nothing but σ – u we can say that which is still it is actually having a 10 kp effective stress at the base and five kp are five $KN/m^2$ at the mean height and here it is 0, so this is for a case of I is equal to 0.5.

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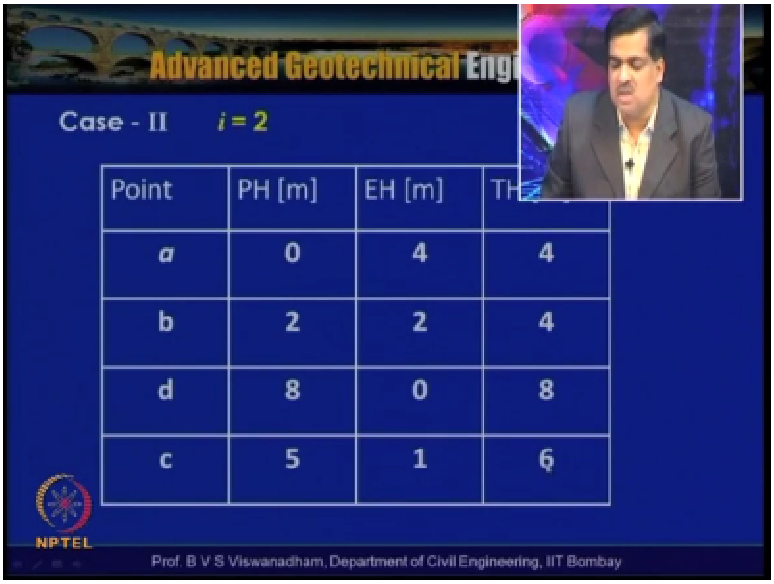


In the second case what we discuss it is that head is equal to 4 meters which becomes I is equal to 2 with that we can actually say the point a now again pressure it is 0 elevation head is 4 meters total head is 4m and point b pressure head is 2m elevation at is 2m total head is 4 meters and Pro Point D pressure head is 8 meters elevation head is here it is 0 because it is on the datum and the total head is 8 meters 0. C where pressure head is 5m elevation head is 1 meter total head is 6 meters.

So here when you plot the diagram based on the head which is actually available we can write the total stresses like this which is same and then here in this case the because of the change in the header conditions here because it is 4 meters it actually gives 20 50 and 80 KP or $KNm^2$, so this indicates that when you take $\sigma - u$ the this indicates that all the pressures are actually negative that means that quicksand condition would have already occurred because the head is so high the kook and sucks and condition would have already occurred.

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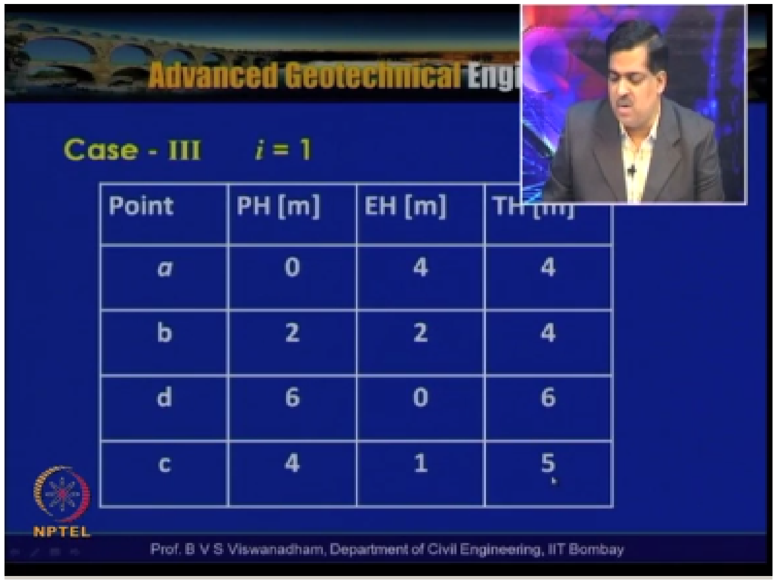


In the third case where I = 1 is maintained with that case you know the point at a the pressure head is 0 elevation head is 4 meters and total head is 4 meters and point b pressure head is 2 meters elevation head is 2 meters total head is 4 meters at Point d now because of 2m head which is actually mean H = 2m with that I is equal to 1 is maintained for that with elevation head is equal to 0 the total head is 6m and Point C which is pressure head is 4m elevation head is 1 meter and total head is 5m.

With this we can actually write from the case 3 as at this point taught σ total stress is same but pore water pressure U which is nothing, but 20 40 60 then we take a subtraction of σ - u at all points you can say that it indicates zero that means that this is when I when head of 2m is it is subjected when you neglect all the frictional forces it can be said that is just subjected to a quick sand condition just subjected to a quick sand condition another example problem which is relevant to the field conditions.

Here a large open excavation was made in a stratum of clay with a saturated unit weight of 17 point 6 KN/$m^3$.

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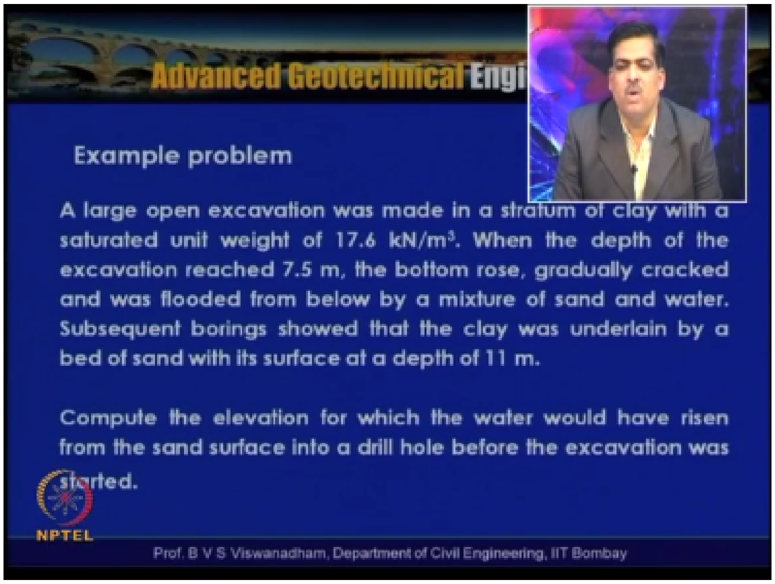


When the depth of the excavation reaches 1.5m the bottom rows up that means that the heaving of the bottom has taken place and gradually cracked and the flooded from water by mixture of sand and water, so subsequent boring showed that the clay was underlined by a bed of sand with the surface at a depth of 10m, so compute the elevation for which the water would have risen from the sand surface into the drill hole before the excavation was started so we need to calculate elevation for which the water would have risen from the sand surface into a drilled hole before the excavation started.

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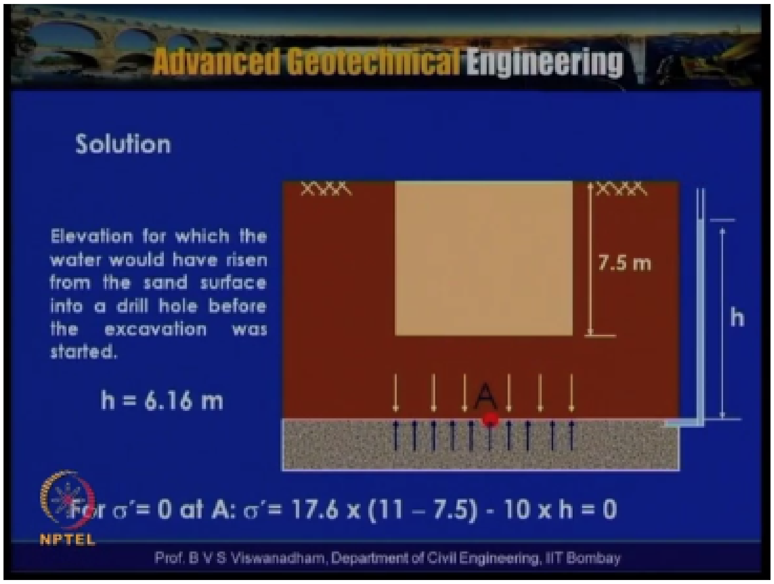


So the problem is that alone meter thick soil underlined by a pervious layer and in which the excavation which is actually planned to a depth of 7.5m and hitch is the H is the head which is actually may cause might have caused the heaving, so for that to be determined what we need to do is that what we have saw the way we have done in the previous problem we can calculate here at Point a the effective stress and at the it this can actually can lead to the failure when the effective stress at Point a is equal to 0.

So we can actually by knowing the saturated unit weight we can actually calculate 17.6 into 11. – 11. 7.5 this is which is available and this particular portion of the soil has been excavated – 10 into H that is nothing but the 10 is the unit weight of the water which is actually taken as 10KN/m3, into H, so with that we can actually get the answer as H = 6m that means that when the head actually suppose the sand layer here at this point when it is subjected to head of artesian head of 6m.

Then there is a possibility of so that meant this particular head might have actually caused the so called heaving of the excavation in their particular problem another example problem in this case we have the problem statement is like this de turbine and plot the total vertical stress.
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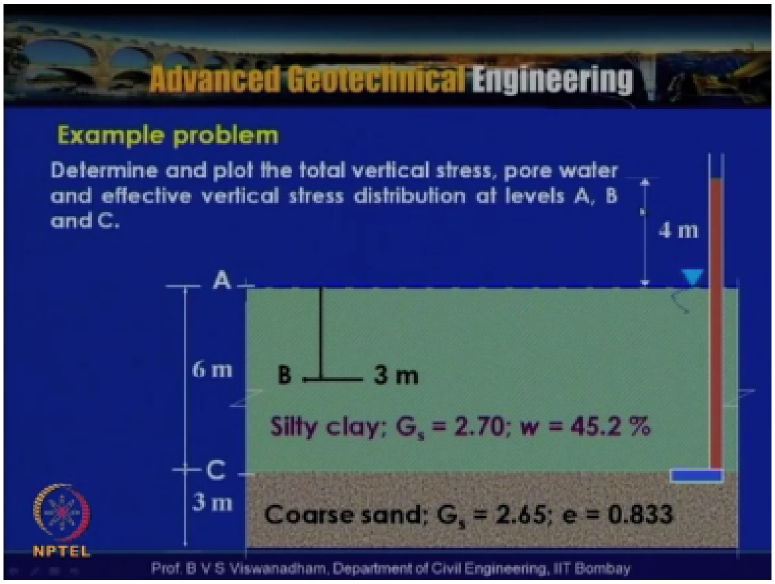


Pore water and effective vertical stress distribution at levels a B and C so the soil strata which is actually given like this it is 6m is suited clay and below that there is a course and so a is tops on top of the surface and water table is actually a zoom to be at this surface, so the hydrostatic water surface is actually at this surface and the C which is nothing but the joint interface between silty clay and course sign and the 3m is the thickness of the clay layer we of the 3m is thickness of the coarse sand layer coarse sand layer thickness is which is actually having a 3m and the specific gravity of the solids is $G_S$ is equal to 2.65.

And wide ratio is 0.8 33 and the silty clay which is actually having $G_S = 2.7$ and natural moisture content of 45.2% and the head of the water which is actually measured here is assumed that it is it is 4 meter above this groundwater table, so the given problem in artesian pressure exists in the lower sand layer.

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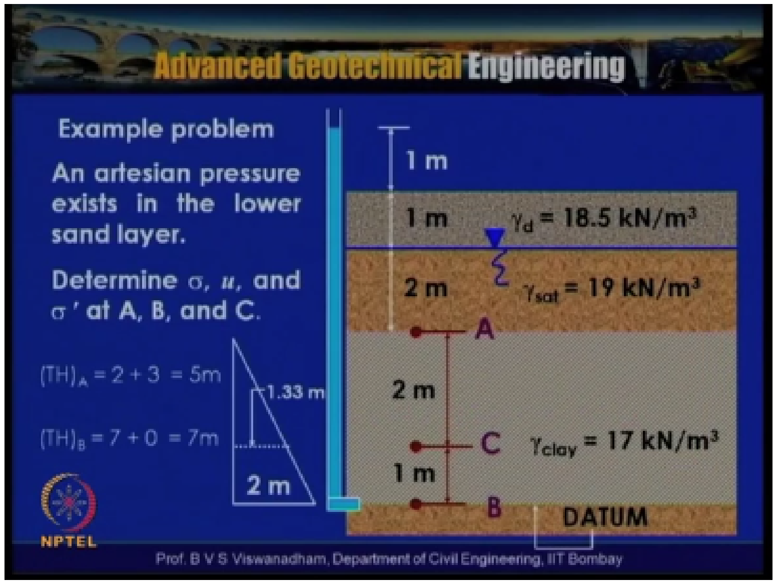


So that is what actually what we have understood the artesian pressure exuberance in the lower problem lowers and layer at a B and C and B is look C is located 1m above the datum, so in this given problem and this particular surface is assumed as a datum this is actually a zoom rise datum and here this particular point is 1m above the datum that is C and  A is actually 3m above the datum that is a D this point and then we have here there is a sand layer saturated and layer and here it is a dry soil layer.

And so here we need to determine σu and σ - at Point A B and C in the previous problem this solution need to be worked out based on the given data here however this problem solution we can actually look into it this problem is different from the problem statement which Is given in the previous slide in this is also subjected to artesian pressure, but what exactly happens is that the head actually loss occurs from point when the flow actually takes place from point B to point A so the total head at A which is nothing but total head at A is nothing but 2m of water that is elevation head is 3m.

And pressure head is 2m that is 2m of the hydrostatic pressure is there and because of that the total head at point A is 3 5m and total head at B which is because here it is subjected to this 3 + 2 5 + 1 6 +1 7m so 7 + alumina this being the datum what we get is the total headed B = 7m so because of these the Δ H which is actually available the head loss here is nothing but 2m occurring or a the last the flow is a claim or a length of 3m at C is a point which is actually 1 meter from the data, so at point B that is σ can be obtained as 18 . 5 x 1.

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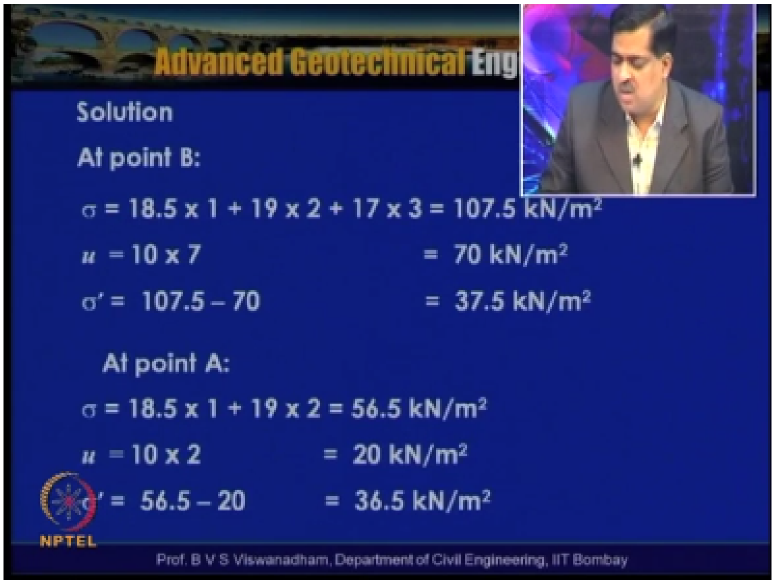


That is the D into 1m thickness +19 x 2 that is saturated unit weight of the sand layer below the hydrostatic water table + 17 x 3, so with that I have got 107.5KN/$m^2$ and at point B U = 10 x 7 so 70 KN/$m^2$ so α – is nothing but 107.5 – 70 which is nothing but 37.5k/$m^2$ and at Point A we can actually obtain the above the that is at Point A is at this point α is nothing but 18.5 x 1 + 19 x 2 = 56.5k/$m^2$ and u = 10 x 2 which is 20KN/$m^2$, so α- = 56 .5 – 20 is nothing but 36 .5KN/$m^2$ so at Point A the effective stress is this much at point B the effective stress is this was almost of the same order.

And at Point C which is in between point A and B where total stress is given as 90.5 and pore water pressure is given as 10 into pressure head at C, so here based on the discussion here the head which is actually available here the full head is had to be the head drop is actually available which can take place is 2m and this is the length of the, so hydraulic gradient here is nothing but 2/ 3that is 2 / 3 0.67 is the hydraulically the slope of this line so here at 50% of the plate thickness that is 1.5m will have the head of only 1m, but here because of this head which is actually available is 1.33m.

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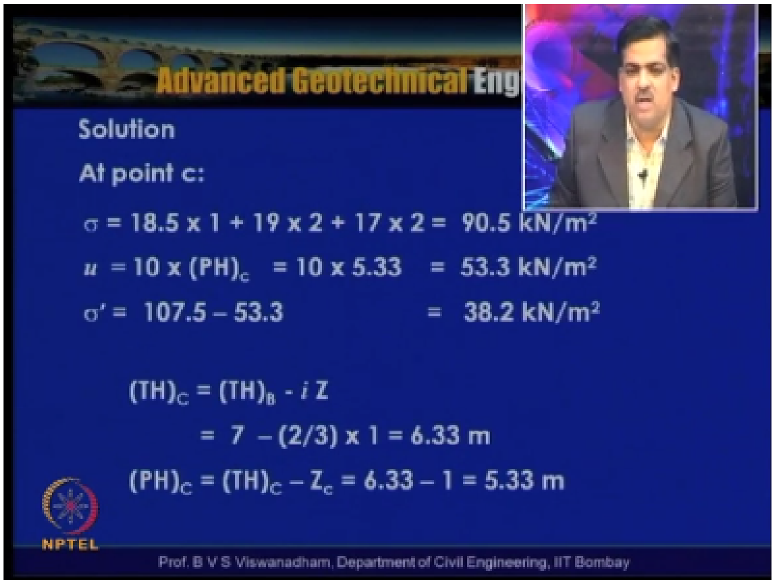


So we can actually write the pore water pressure is nothing but 10 x 5.33 which is nothing but 53 0.33 current per meter squared the effective stress is nothing but water stress minus pore water pressure which is nothing but 38.2KN/$m^2$, so the total head rate C is nothing but total headed B m - I into z which we can write it as 7 - 2 /3 is nothing but the hydraulic gradient that is nothing but A2m had lost or a length of the soil layer as 3m that is 2 / 3 into z = 1, so with that 6.33m the pressure head at C can be obtained like this total head at C is nothing but 6.33 - elevation head is 1m.

So because of that the pressure head at C what we consider is 5. 33 is explained here so with this for the given problem what we discussed in the previous slide.

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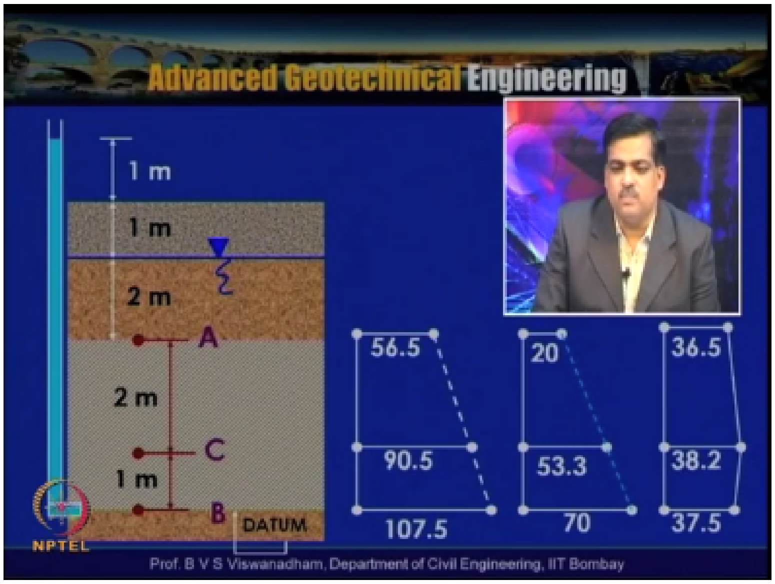


The total stress diagram which is actually shown like 56.5 the units are in $KN/m^2$ the units are in $KN/m_2$ 56.5$KN/m^2$ 90.5 and or not 7.5 and the water pressure is the thing about 20 and at this point it is 53.3 and 70 and here the effective stress is nothing, but that 6.5 38.2 and 37.5 is having an a constant effective stress of about 37. 5 average effective stress of about 38KP.

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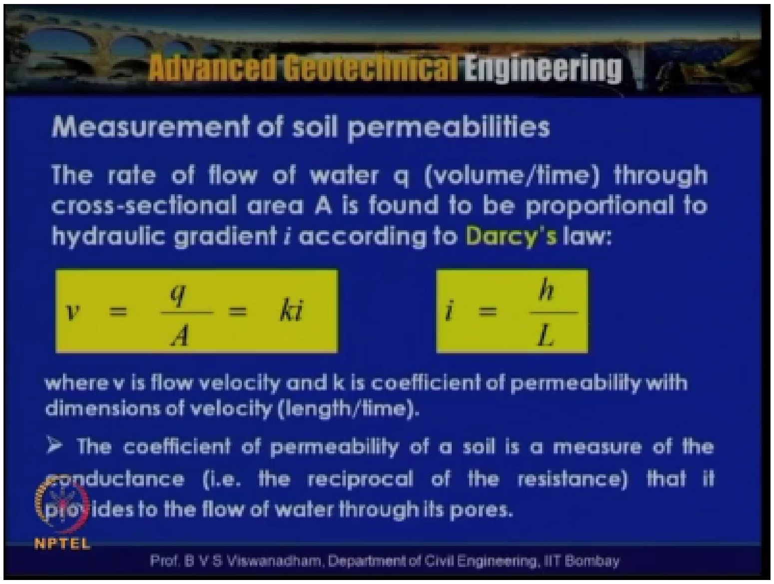


So the measurement of soil permeability is so we have said that permeability is a property of the soil where different types of soils exhibit different values and this is actually used for four different conditions different applications in civil engineering construction and it is very it will be interesting to know how this permeability is actually measured the permeability can be measured from either from the indirect methods or it can be measured from the laboratory tests or through the field tests.

So the rate of flow of water Q that is volume or time T through a cross section area is found to be proportional to the hydraulic gradient I according to Darcy's law so which is nothing but V is equal to Q / A = $K_i$ RQ is nothing but the $K_i$ a so discharge over a cross section area which is nothing but Q is equal to $K_i$ A where I is nothing but the hydraulic gradient or a length L that is nothing I is nothing, but head loss or a length yell I thought a gradient is equal to head last for a length L where V is the flow velocity and K is the coefficient of permeability with the dimensions velocity or length - over time C.

The coefficient of permeability of a soil is a measure of the conductance that is the reciprocal of the resistance that is provided that provides the flow of water through its pores, so it is a property of the soil which actually determines which actually tells the ease with which the water can flow through the soils as that has been mentioned in the in the previous discussion the value of the value of the coefficient of permeability.

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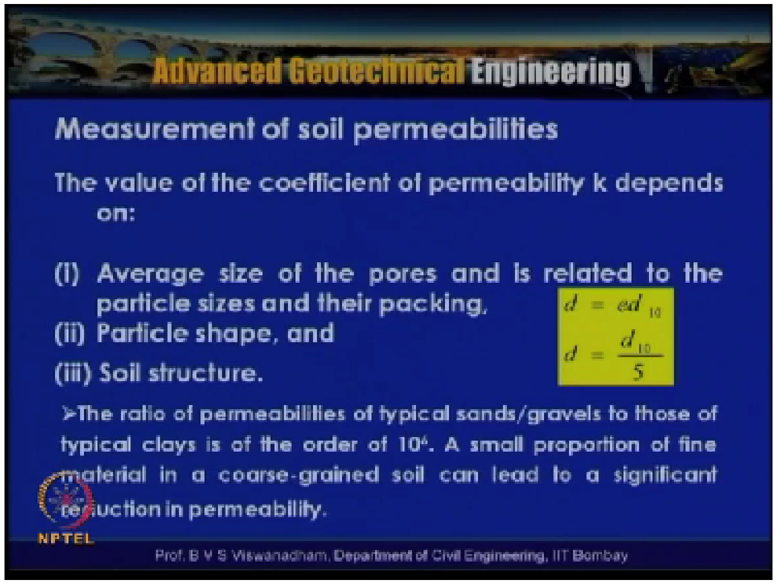


K depends upon the average size of the pores and is actually related to the particles I just sent her packing, so we actually have said that the pore diameter can be approximated as wide ratio times the effective particle size, so if you take effective particle size of a sand an effective particle size of a clay and clay is actually having very low effective particle size with that we can say that the pore diameters of the clay is very, very fine compared to s and so it is approximated that 20% of effective particle size is regarded as pore diameter.

So the value of the coefficient of permeability and a prima facie depends on average size of the pores and is related to the particle sizes and their packing and the particle shape particularly whether it is angular or whether it is rounded or sub-rounded the ship and the soil structure and that is nothing, but the arrangement of the soil particles whether it is a flocculated or whether it is a dispersed structure or whether it is bulk structure, so the depends upon the whether it is a lose bulk packing or a dense packing in case of a bulk particles the ratio of the permeability of typical sands and gravels to the rest to that of the Clay's is to those of the classes of the order of 1 million times that means that the ratio of the permeability of the typical sands and gravels to those of typical clays is generally of the order of 10 to power of 6 a small proportion of the fine material in coarse sand soil can lead to a significant reduction in the permeability.

That means that if you are able to add a small proportion of fine-grained soil to the coarse-grained soil and that can influence the permeability the number of tests can be used to measure the estimate of the permeability.

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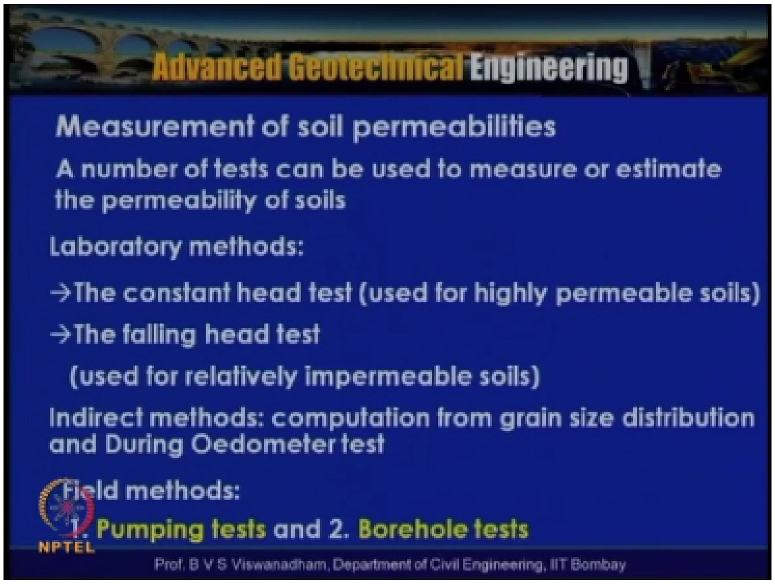


In the primer in primarily in the laboratory the 2 types of tests which are actually there they are called the constant head test used basically for hyperbole soils and the following 8 tests used basically for relatively in purple soils, so the constant rate test is actually basically used for hyperbole soils and following light test is used basically for relatively impermeable soils as it was mentioned earlier there are indirect methods some correlations which are actually available based on the grain size distributions that is based on the d5 d10 and other particle sizes basically for sandy soils.

Some correlations are actually available by knowing the effective particle size will be able to estimate the coefficient of permeability based on the grain size distribution also from the hydrometer test or a con Oedometer test when the soil is actually subjected to consolidate in a consolido meter test indirectly we can actually compute the permeability based on coefficient of consolidation and coefficient of volume compressibility and the unit weight of the water, and these are the you know possible laboratory methods in the field there are methods which are actually possible are called pumping tests and borehole tests which are popularly known as the packers tests.

Which are actually conducted with single packer or double packer systems so in determining the permeability of coarse-grained soil?

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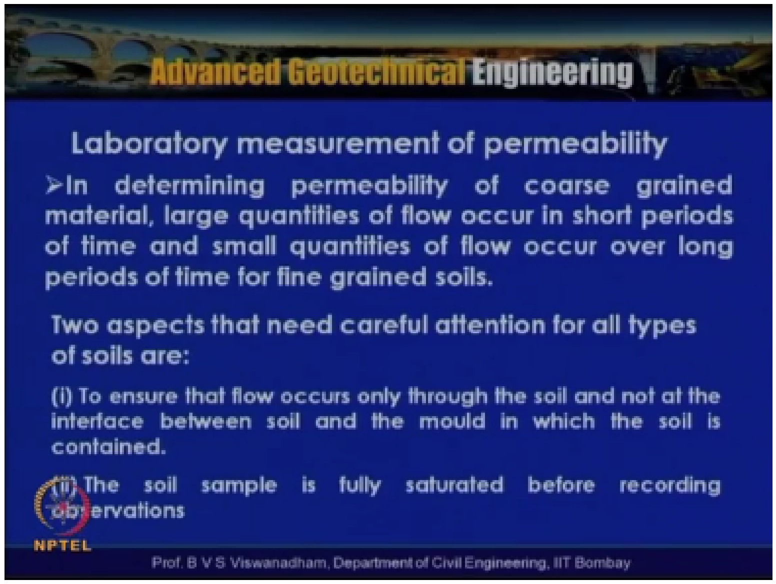


Particularly the large quantities of flow occurs in short periods of time and a small quantity of flow occur or a long period of time for fine-grained soil, so in case of fine-grained soils very small quantity of the flow occurs or a long period of time in case of a permeability of the coarse grained soils what will happen is that in a short span of time a large quantity of flow takes place so two aspects that need to careful attention for all types of soils are that to ensure that flow occurs only through the soil not at the interface between the soil and the mode in which the soil is contained so in the laboratory by determining the particularly the leakage from the edges are required to be our step that is that to ensure we have to ensure that the flow occurs to the soil not at the interface between the soil and the mold in which the soil is contained and the soil sample is fully saturated before recording observations.

So one is that the either is coarse dense soil or fine grained soil the soil sample need to be completely saturated, so for determining permeability of a soil sample by using constant head permeability test so in the constant test the setup which is actually shown here.

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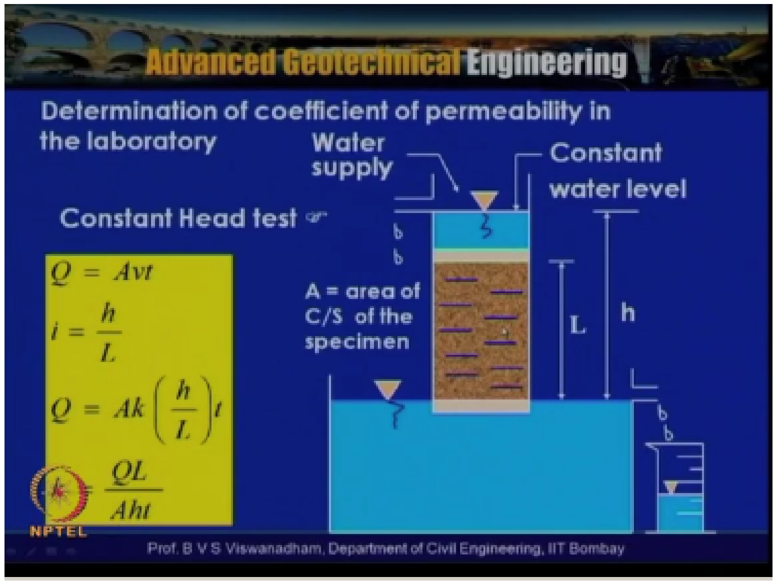


Has got a sample of length L and having some head of water which is actually maintained constant and so here the head of the water which is actually maintained is say H or a length L so the hydraulic gradient is nothing but the H / L, so any additional amount of water which actually flows through this one is actually collected as a discharge here, so in a given time or the cross section area of the sample perpendicular to the this direction of the flow, so the direction of the flow is in this direction so that is nothing but the a so the discharge which is actually connected in at time T is nothing.

But Q = A x V x T and V is nothing but D we can write it as K x H / L xT where K is the coefficient of permeability which is required to be determined, so by rearrangement of the terms here by measuring the discharge in time t and over a length of the sample A and A is the cross-section area and H is the head which is actually maintained with that we can actually determine coefficient of permeability of the soil through a by using constant test in the constant head test the one need to establish the steady state conditions after establishing the ensuring the steady state conditions.

And three to four readings need to be one and the average of these readings can be reported as the average permeability and main features of the constant testing include it is suitable for soils having coefficient of permeability in the range.

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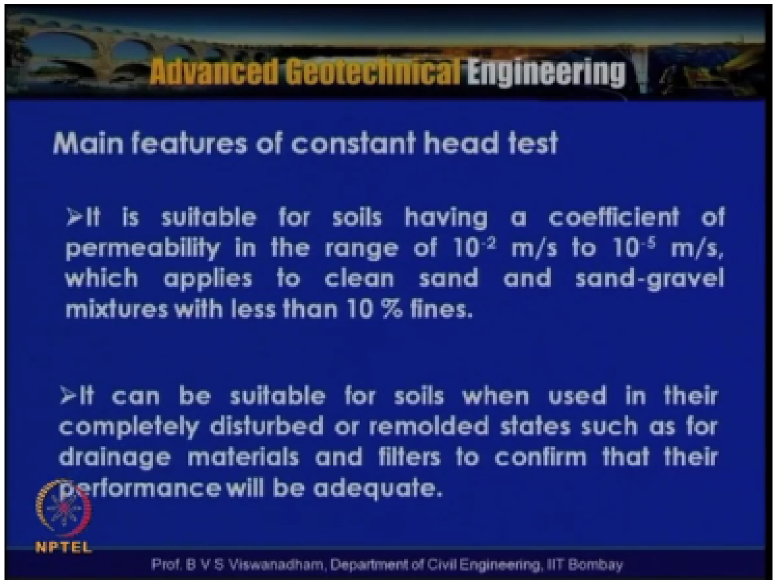


Of $10^{-2}$ 2 $^{-5\text{m/s}}$ which applies to clean sand and sand gravel mixes with less than 10 % fines and it can be suitable for soils when usually in their completely disturbed or remolded states such as for drain materials and filters to confirm that their performance will be adequate, so it can be suitable for soils when usually in their completely disturbed molded states such as for drain materials and filters to confirm that their performance would be adequate in this particular slide where the setup for the following head test or variable head test is actually shown.

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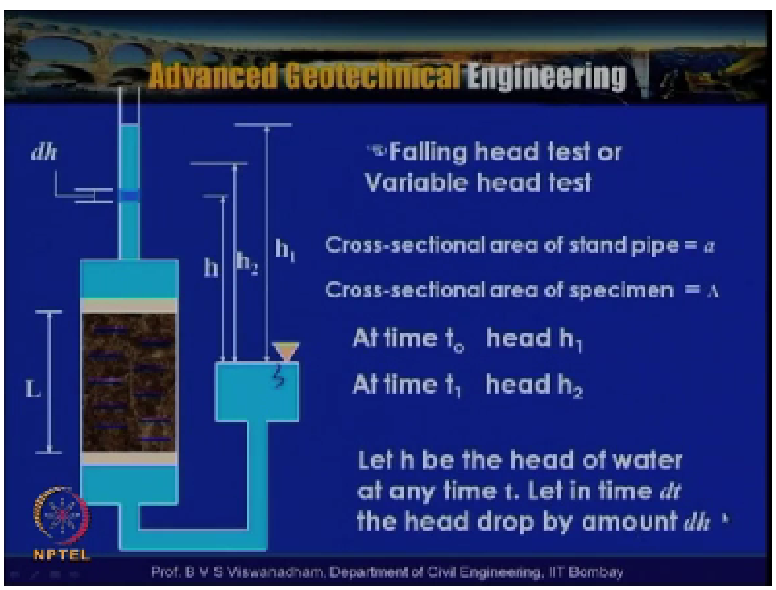

And here because at the amount of water which is actually flowing through the soil or entering into the soil is less, so a stem which is actually having a very small cross sectional area is actually provided on top and like the contest in a given amount of time the head drop from $h_1$ to $h_2$ is actually measured, so here the cross section area of the standpipe is say a and the cross section of the sample is say a so this is actually called as a rigid wall perimeter at time at time $t_0$ we are headed at head that head is h1 at time t1 the head is actually $h_2$.

So h be let $h_b$ the head of the water at any time t and let in time t that dt they had dropped by a motor the dh.

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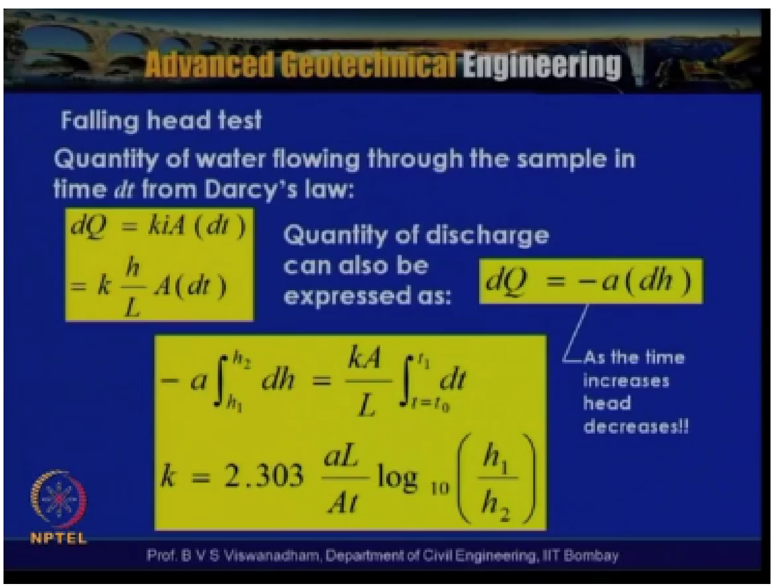


So we can actually write the quantity of water flowing to the sample in time dt from the Darcy's law can be obtained as we can write it as dq = k x I x a dt, so which we can write it as k x h/l x a x dt so the quantity of the discharge can also be expressed as because in the in a small cross section of pipe when there is a drop of water from h1 to h2 when h1is greater than h 2 well what will happen is that there is a the dq = - a x dh we can write as the time increases the head decreases.

So we can actually write – A x h1 to h2 x dh with that we can actually equate this these two discharges and integrating from t is good $t_0$ to $t_1$ we can by simplifying that we can write it as k = 2.03 A/ At log to the base 10 h1/ h2, so this is actually expression which is required to be used for a falling head test the main features of the constant head and following a test basically include in the constant head test the permeability is computed.

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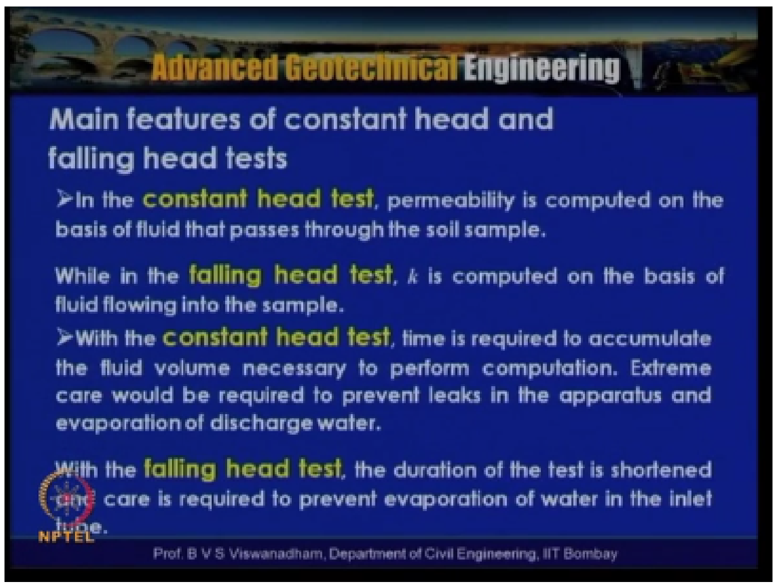


On the basis of fluids that passes through the soil sample while in the following way test k is computed on the basis of the fluid flowing into the sample, so in the case of fine-grained soil the what we in fact is measured is what entering into the specimen in case of a constant interest is that the permeability is actually computed on the basis that flow which is actually occurring through the sample, so the main distinct difference between a constant head test and following a test is nothing but.

In the constant head test the water flows to the soil in the following a test water flow C to the soil B here in the case of a falling a test the type of the soil which is actually being discussed are being determined for permeability is a fine-grained soil which is actually highly influenced by the you know which is actually having a fact of the soil structure and particularly the mineralogy which actually plays a bigger role, so well in the constant test the time required to accumulate the fluid volume necessary to perform computation.

And basically extreme care would be required to prevent leaks in the apparatus and evaporation of the discharged water and with the following head test the duration of the test Is actually shortened and care is required to prevent evaporation of water in the inlet tube.
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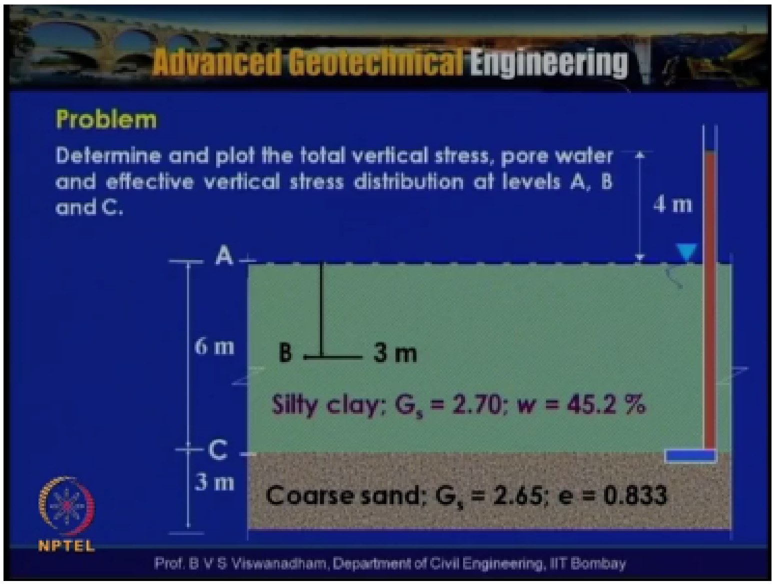


So another problem which is actually which we have given discussed in the in the slide which is shown here the problem is again shown here, so this problem can be treated as an assignment problem where here the soil strata which is actually having 6 meters and the silty clay which is actually having $G_S$ = 2.7 and water content is given as 4. 45.2% and coarse sand which is nothing but $G_S$ = 2.65 and A = 0.833 and this particular layer actually has got an artesian condition so with that it is the problem statement is actually like determined and plot the total vertical stress pore water pressure and effective vertical stress distribution at levels A and C and B is at a point.

A midpoint of this that is actually at the at this point that is 6m is the thickness of the clay layer so this silty layer, so be is at a bit mid distance from the this particular point so in this particular lecture what we try to discuss is that we have introduced the you know see pace force how it can be measured how it can be calculated one is we said then CPS force J = I γ wv and the CP pressure is nothing but CP is force per unit volume which is nothing but iγW which is the units of the CP pressure are KN/m3.

And which is actually resulted in the array this see both cps force and seepage pressure occur in the direction of the flow then we have introduced ourselves to a couple of practical problems where when there is a soil status subjected to artesian condition show we can actually compute these total stresses pore water pressures and effective stresses because of the resulting upward flow because of the artesian conditions and then we have actually discussed the methods for measuring permeability of the soil particularly we have actually have got two methods one is constant head permeability test and foreign debt variability test these are actually widely used for in the laboratory.

In the following head permeability test there are also like two distinct apparatus which are actually used one is called rigid wall parameters other one is flexible parameters in case of rigid wall parameters these stresses cannot be applied on to the soil sample, but however in case of flexible parameters the confinement stresses can be applied and then the permeability test can be done by using the similar concepts of falling head permeability test, so with this the effect of the confinements tresses on the perimeter of the soil.

Being tested can be on time and the main distinct difference between a constant test and following a test what we discussed is that in the case of a constant test the water actually flows through this foil and in case of a following it is the water actually enters into the soil and however what is actually measured is that the small amount of change of texture occurs.

And we also said that the for a typical sand and clay the distinct difference is actually about you know the prim bill to the sand is $10^6$ to times more than the a typical clay that means that distinctly different the permeability is the reason and the factors affecting the permeability of soils and the some field testing methods along with the some testing data we will be discussing in the subsequent lectures.

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**NPTEL**
**Principal Investigator**
**IIT Bombay**
Prof. R. K. Shevaganokar
Prof. A. N. Chandorkar

**Head CDEEP**
Prof. V. M. Gadre

**Producer**
Arun Kalwankar

**Project Manager**
Sangeeta Shrivastava

**Online Editor/Digital Video Editor**
Tushar Deshpende

**Digital Video Cameraman**
Amin Shaikh

**Jr. Technical Assistant**
Vijay Kedare

**Project Attendant**
Ravi Paswan
Vinayak Raut