NPTEL

NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

CDEEP IIT BOMBAY

ADVANCED GEOTECHNICAL ENGINEERING

Prof. B.V.S. Viswanandhan

Department of Civil Engineering

IIT Bombay

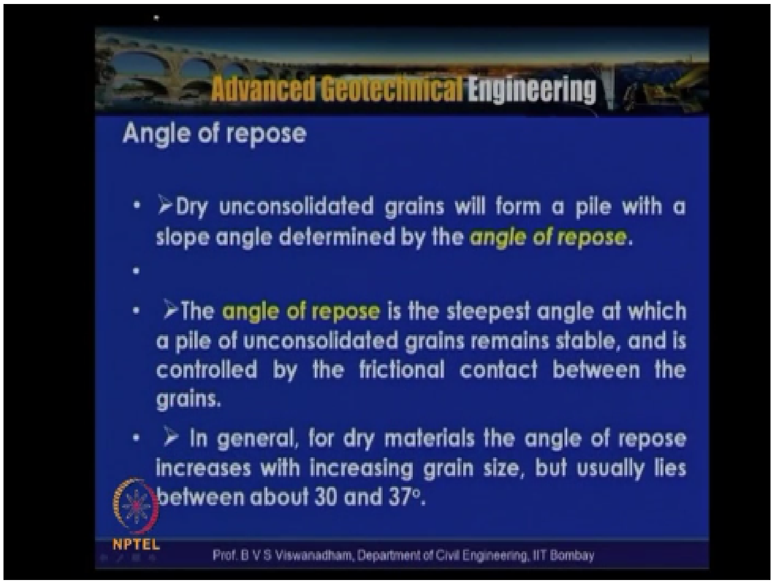
Lecture No. 011

Module-1

Effective stress and Capillarity

So welcome to module one of the course of advanced geotechnical engineering and lecture number 11 in the previous lecture we have understood about the effective stress and capillarity in this lecture we will try to look into some problems and also role of water played on the particularly when you are interactive in a soil water is interacting with the sign so we have a particular angle which is actually called as angle of repose drying unconsolidated drains will form a pile with a slope.

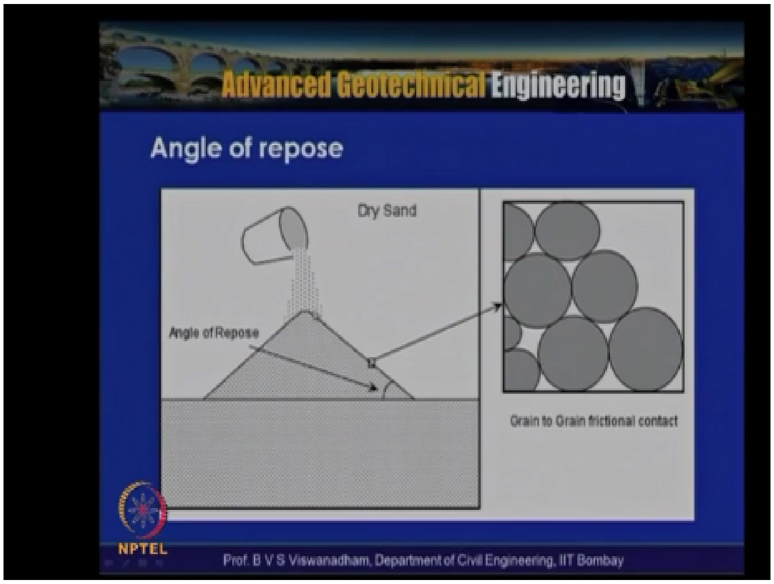
(Refer Slide Time: 01:01)



Angle determined by the angle of repose suppose if you take a dry sand when a heap is formed when sand is completely dry the angle subtended with the horizontal is actually called as angle of repose that is maxim angle what the sand can make the angle of repose is the steepest angle at which heap or pile of unconsolidated grains remains stable and is controlled by the frictional contact between the grades this is controlled by the frictional contact between the grains in general for dry materials the angle of repose increases with increasing grain size.

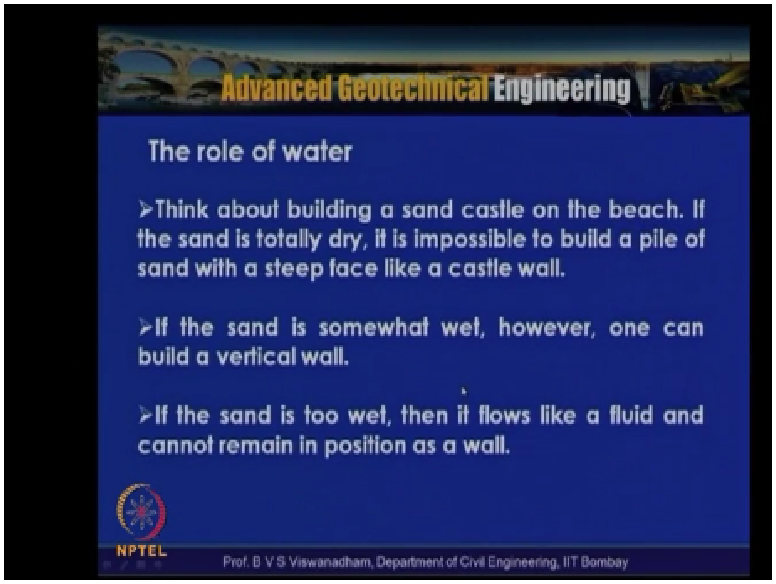
But usually lies between about 30 to 37degrees for example if you take a sand having classified as SP uniformly graded sand and which is having a average particle size about 0.15 2.2 mm this particular sand in Tri State exhibits an angle of repose of about 28 to 29degrees so in general for dry materials the angular proposed increases and increasing grain size with increasing grain size but usually lies between 32 that is not degrees that means that the sand cannot actually stand vertical or steeper than this angle of repose. So here in this slide what you see is a pile of sand.

(Refer Slide Time: 02:34)



Which is actually formed with a dry sand in contrast if you look into a micro picture here what will actually happen is that you have the grain to grain contact between these two places for example if you take a magnifying view the grain to grain frictional contact will ensure that two halves obtain an angle of that you know the Magnus of steepest angle that what we call it as the angle of repave repose.

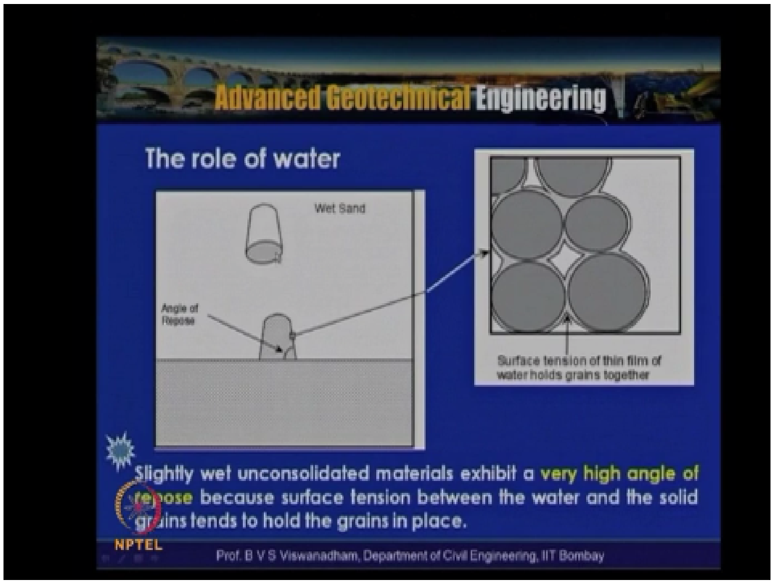
(Refer Slide Time: 03:03)



So what is the role of water suppose if you add little amount of water what we have discussed earlier is that it forms a thin film makes this you know appear like it can take the so-called steeper angles than angle of repose this is because of the capillarity action so think about building a castle on the beach if the sand is totally dry it is impossible for you to build a pile of the sand with a steep face like a castle wall but if you make the sand somewhat wet however it is possible that you can actually build a vertical wall.

So if the sand is too wet again then it flows like a fluid and cannot remain in the position as a wall so if the sand becomes too white it cannot actually stand vertical so this can be explained here for example.

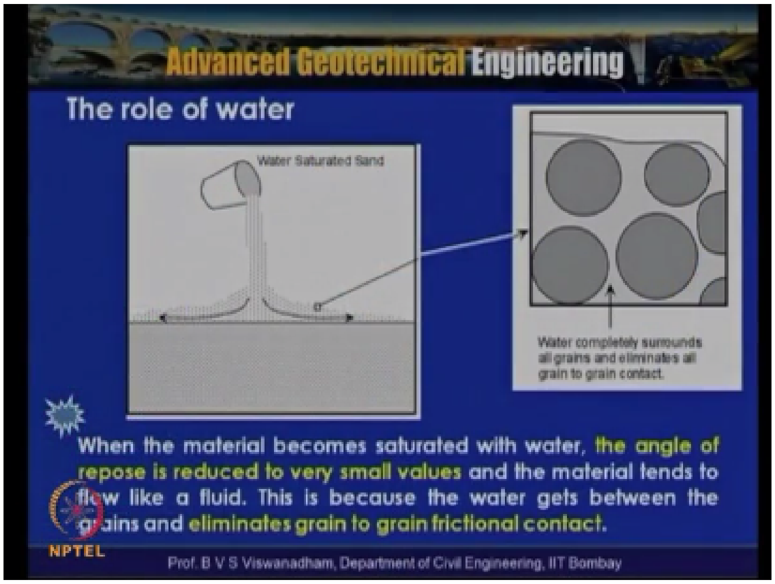
(Refer Slide Time: 03:59)



If you take a particular mould and you take a shape here and in this case when you have got water in contact with the sand grains and when it is actually formed like a thin film which is that this film is actually caused because of the surface tension of the thin film of the water is actually holding the grains to that you can see here the grains are actually held together by you know this particular action of soil water that is solid water and air interaction.

What you see is the solid is nothing but the sand grains and water and air interaction so here in this particular case is slightly wet and unconsolidated materials exhibit very high angle of repose so slightly wet and unconcern dated grains exhibit very high angle of repose the reason is that the surface tension between the water and the solid grains tends to world the grains in place so in case of dry state the angle of repose which is very less in case of a slightly wet state the insane un -conservative sand grains are unconcerned dated materials exhibit very high angle of repose because the surface tension between the water and the solid grains tends to hold the grains in place now on the other hand we have discussed.

(Refer Slide Time: 05:29)

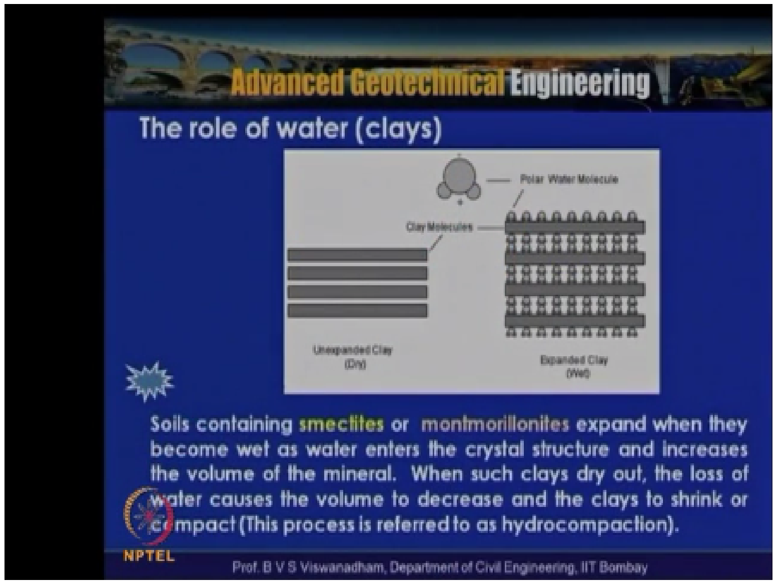


That if we are actually adding more amount of water than what it desire for example a water saturated sand it actually flows like this water saturated sand force like this and here what you see is that the grains are actually floating along in the water and water completely surrounds the all grains and eliminate at grain to grain contact so whatever the frictional interaction.

Which is actually generated because of the grain to grain contact will remain of sin if you have got actually more amount of water surrounding the grains and in addition to that the surface tension whatever which is actually accumulated that the films which are actually formed because of the solid a water interaction get washed out so the role of water is explained here when the material becomes saturated with water the angle of repose is reduced to very small values and the material tends to flow like a fluid here the material tends to flow like a fluid.

And the grains actually float along with the water this is because the water gets between the grains and eliminates the grain to grain frictional contact so almost like the grain to grain frictional contact comes to zero so in case of clays for example if you have got a clay the role of water is again peculiar so in this particular slide you have on the left hand side.

(Refer Slide Time: 06:55)



An expanded clay that particularly some expansive clays which are having multiple light when they come in contact with water the increase in volume so when the polar water molecules areincoming contact with the spirit particles the what a quarter accumulates between the particles are platelets and there is a possibility that these this is the it will form a status like expanded clay. so this is in the dry state and this is in the wet State the same time when this water you know evaporates because of the exposure to the temperature there is a possibility that you know the clay is subjected to shrinkage which is in terms of for this type of soils.

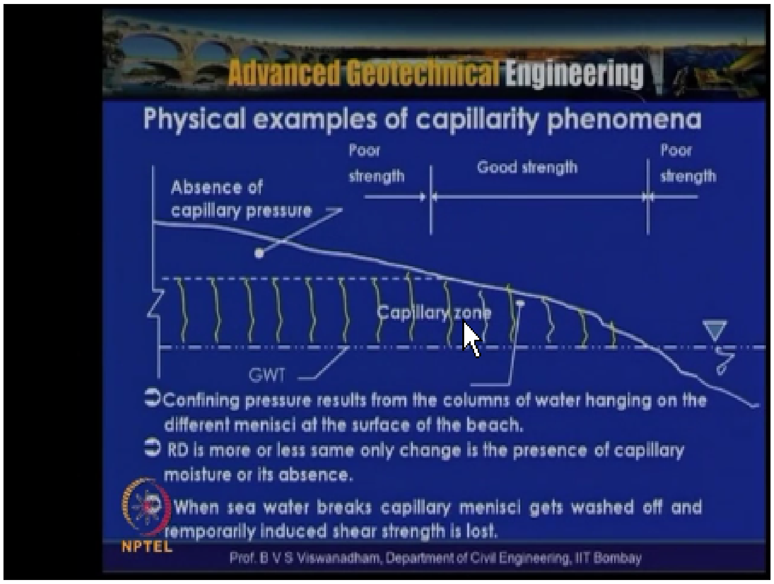
It is also called as hydro compaction so soils containing spec tights or mountable light expand when they become wet as the water enters the crystal structure and increases the volume of the mineral it increases the volume of the mineral because the water accumulates between the platelet particles and makes the private particles push apart and because of that the volume of the soil mass increases the volume of the soil mass increases means that the soil mass is subjected to an increase in the swelling potential and it is also you know when it water gets evaporated it is also subjected to the so called shrinkage when such clays dry out.

The loss of water causes the volume to decrease and the Clay's to shrink and are compact so the clay particles will be pulled together and this process of you know an operation of the clay evaporation of the water out of these you know particles which are actually formed with the spectators are metabolite minerals is actually called as the process called as hydro compaction so hydro compaction generally occurs in case of soils having minerals.

Which are actually having nothing but is MEC tight supply night and they expand when they become the wet as water enters the crystal structure and increases the volume of the mineral when such place dry out the loss of water causes the volume to decrease and a kales to shrink or compact so this process what we actually have discussed is called hydro compaction so we actually have seen you know a peculiar you know role of water in case of a sandy soil when the water is less it makes the sand to how very steep angles of repose.

When the water is high the angle of repose is reduced to zero in the sense that the sand with high water content starts elflowing in contrast if you have got higher amount of water the clay tends to expand its volume and when the water is lost out of the same clay because of the operation then it is actually the process which actually nooses onto the soil is called the hydro compaction so the physical examples of capillary phenomenon if you look into it this is a you know very clearly at the beaches beach which is available say for example if you have the place.

(Refer Slide Time: 10:10)



If you take a ground water table the soil below the ground water table is completely saturated that we have discussed and here the soil above the certain portion of the soil above the close to the ground water table depending upon the type of the soil which means one hundred percent saturated above that certain zone there is a partially saturated and here there is an absence of capillary pressure so if you look into here you if you take the soil here it actually poses the pore strength and in this zone.

It actually pushes the pore strength and again it process the pore strength so here what it actually happens is that the confining pressure results from the column of the water hanging on the different minks at the surface of the beach so real to density more or less for example if you take you know near the you know situation we are in the beach the relative density of a soil is more or less same that is greater density is nothing but e max =- e by E max - E max minimum E max -e minimum.

Where a relative density of a deposit is more or less same because the same process is actually it is getting happened only changes the presence of the capillary moisture or its absence so when there is you know a cap in the capillary zone when there is a inadequate when the water is actually less let us say that you know the all the sand molecule the sand particles is actually covered with you know a thin film of water and that makes.

The you know the particles you know the so called which is called as negative pore water pressure so this negative pore water pressure pulls the particles through there and makes actually you know you know if you look into this effective stress at this point here when the total stress is zero and the negative pore water pressure is- U and with that what will happen is that the total stress is nothing but σ which is zero - of -u it becomes σ dash = u that means that whatever the new two pore water pressure is there that much you know effective stress.

It actually generators that makes actually the soil to carry you know exhibit good strengths this allows us to you know for riding vehicles or one can jog very close to the place where you know the wave breaking does not take place but in case if there is a excess amount of water then what will happen is that the new two pore water pressure which is actually binding these particles will get diminish so in the process what will happen is that the same soil actually sensed and the reduces to zero with that the prompt the process.

Of what we get physically observe is that physically as inking feeling which actually comes because of the loss of this term which occurs in the phenomenon so when the seawater breaks the capillary menisci which are there surrounding this particles sand particles gets washed out and temporarily induced so shear strength is lost so the capillarity phenomenon weathered in the in the no the ground suppose if you even if you have got a you know the particular soil type.

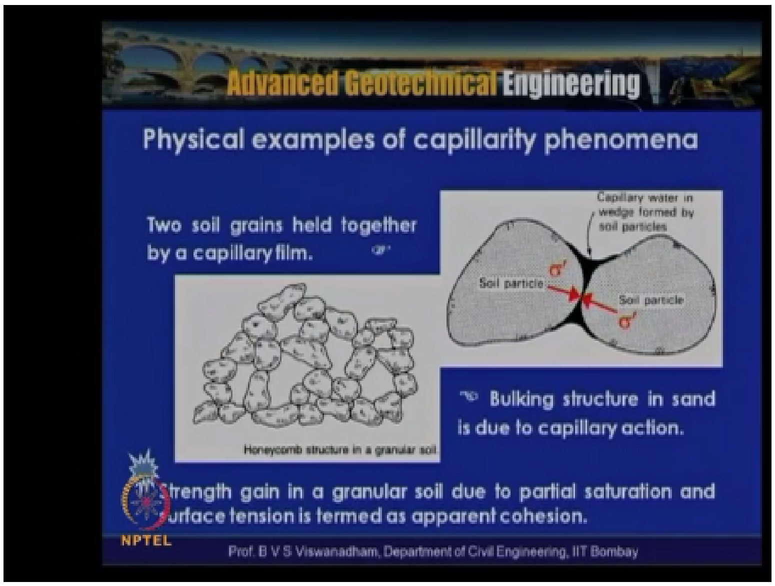
Which actually has got a capillary phenomenon capillarity phenomenon what it does is that the it makes because of the presence of capillarity effect there is a possibility that this effective stress will be high but you know this makes ever increase effective stress makes that you know temporarily the shear strength will be high but once this capillarity phenomenon effect diminishes then there is a possibility of the loss of the defective stress that means that the temporary shear strength.

Which actually exhibited over there soil will be lost so hence because of the because of this nature the effect which is actually due to because of the capillarity water is not really considered in the design so when the seawater for example in this particular phenomenon what we consider when the seawater breaks the capillary menisci gets washed off and temporary inducible shear strength is lost.

So this is an example for the observed behavior of the soil very close to the beach where there is a you know soil exhibits good strength that is because of the negative pore water pressure which is actually prevalent in the portion as you go away from the you know wet zone because of the you know partial capillarity that an to pore water pressure will not be there so because of that you know the soil actually position so it is very difficult to walk in this zone but very easy to walk in this zone.

So because of this particular region this you know this capillary phenomenon can be explained another physical.

(Refer Slide Time: 15:00)



Example for the capillarity phenomenon is that the honeycombing particularly we have discussed that soil fabric in case of some sand particles when they are actually moist and then when there is a film which is actually surrounding the science and particles so what will happen is there this exhibits on carom structure can result in some granular soils or in some sandy soils because of this film which is actually solid the particles so here the larger soil particle which is actually shown here the capillary what capillary water in which formed by soil particles.

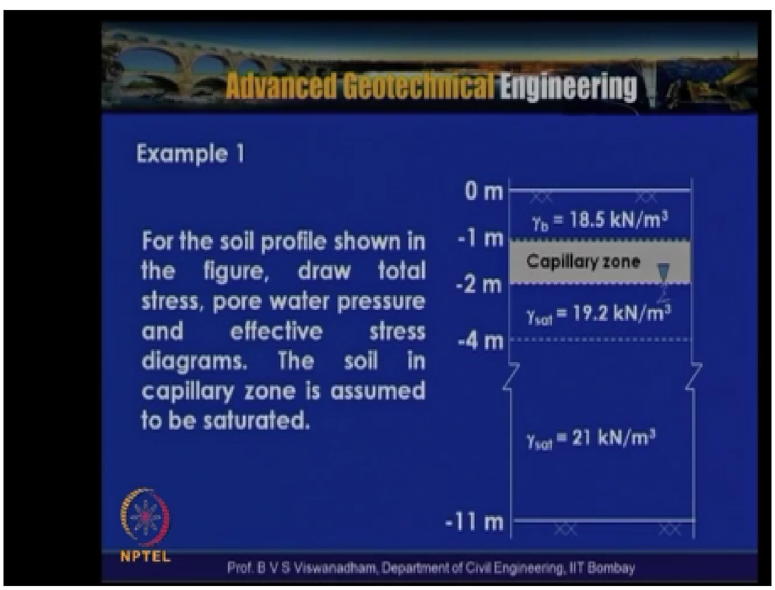
So the bulking structure in sand is due to you know capillary action so for example here what does it mean is that if the particles are actually appear like large volume but in between there are you know sand particles are actually filled with air so this is something like when you look the real you know moist sign it actually exhibits somewhat like onacombi structure that's why it is actually called as the honeycomb soil fabric structure in Grander son's this is because of the capillary action the strength the drain in granular soil is due.

To partial saturation and surface tension is actually this particular surface tension which is actually making the particles to bind together is actually called as a parent equation so this type of apparent cohesion is prevalent particularly above the groundwater table where there is you know the possibility of the evaporation and also in some ash deposits like coal ash deposits these particular type of you know Kellogg College deposits they exhibit very high apparent coefficient so the strength grain in the grain walls granular soil is due.

To partial saturation and surface tension and sub partial saturation and the surface tension and it is termed as apparent coefficient so this cohesion is actually a property of the soil which we will be discussing later but if you look into this here now there are two types of cohesions one is called a true cohesion which is generally referred with the which is actually is the property of the his file which actually can get because of the presence of type of the mineral for example carbonates actually can induce some cohesion in the soils insulates type of soils.

So because of that the salty type of soils can actually stand vertical top some extent where if they are actually having a prevalent carbonate deposits so in that case that particular type of soil set to actually exhibit a true cohesion but if a granular soil when it is actually partially saturated and because of the surface tension the particular nature which actually resulted with the is termed as the apparent cohesion.

(Refer Slide Time: 17:59)

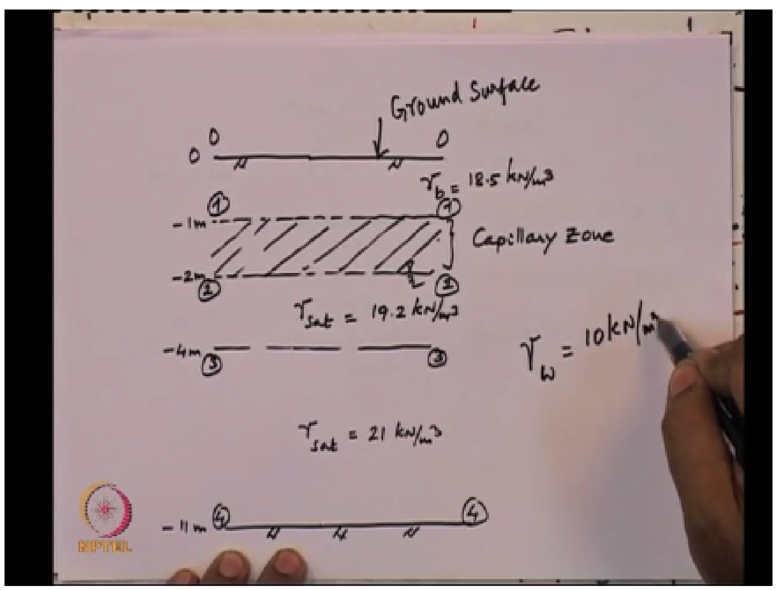


So let us look into some example in this particular example one a soil profile is actually shown in the figure we need to draw the total stress pore water pressure and effective stress diagrams and the soil in the capillarity zone a capillary zone is assumed to be saturated so here a soil profile is actually shown here and this is at the elevation zero meters that is at the ground surface.

So this is the ground surface and here it is - one meter and this particular portion the soil is actually 0 - 1 meter the soil is partially saturated -1-2 meter by a chew of the presence of groundwater table here the soil is actually capillary this is called as a capillary zone and the water column is actually maintained above the that means that up to one meter above this distance there is a you know the saturation is actually prevalent and -2-4 meter that is again it is actually having saturation.

So there are two types of soils layer 1 0 to 4 meter and 4 to11 meters there is layer 2 that is here from that is about 7 meters so the solution for this can be worked out like this if you look into this particular figure what we have done is that.

(Refer Slide Time: 19:28)

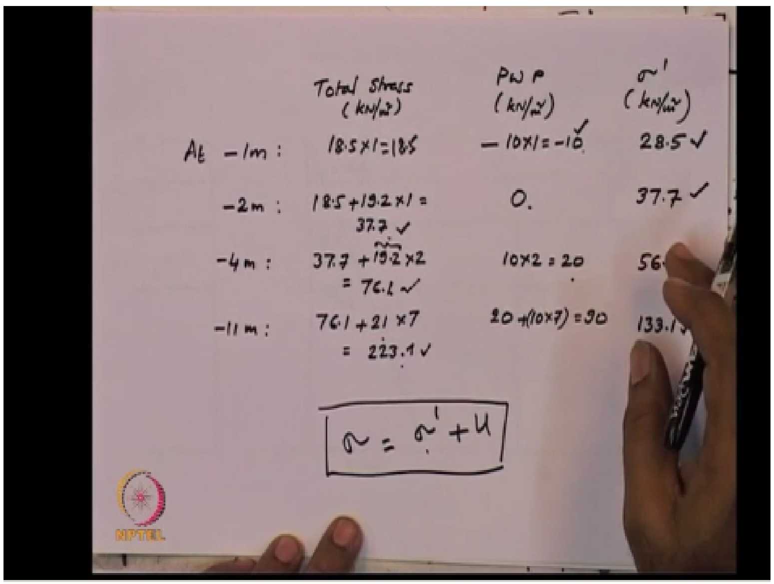


We actually have transformed the figure which is actually given like 0 0 meters that is elevation so this is the ground surface what we are calling this as ground surface and this is the - one meter we are actually indicating each SS 0 0 and 1 12 2 3 3 & 4 for the 4 4 is the place where the bottom of the strata and at 22 or there is a groundwater table and at3 3 the from 3 between 3 3 to

4 4 the layer 2 history starting between 00 2 level 3 3 there is a layer 1 so if you wanted to get the total stress and pour water pressure and effective stress diagram.

So in this example we have actually taken γ W the unit weight of water as 10 kilo Newton per meter cube okay now let us consider at - 1meter that is at level 1 1 the total stress.

(Refer Slide Time: 20:51)



Which is nothing but 18.5 that is the bulk unit weight of the soil into 1meter which is nothing but eighteen point five kilo Pascal's at -2 meters that is two meter below the ground the total stress is eighteen point five +nineteen point two into on.

So it becomes thirty seven points even at four meters that is at - 4meter level thirty seven point seven + nineteen point two into two because nineteen point two is nothing but the saturated unit weight of the soil two meter is the vertical distance between _2 meter to _4 meter with that what I have got is that seventy six point one kilo Pascal's or a kilo Newton per meter square as the hottest us at - loan meter saved six point one + twenty one the saturated unit weight of the soil is actually given as 21 Quran per meter cube into seven.

Which comes to two twenty three point one kilo Pascal's so what we have done is that at innovation - one meter that is one and eight elevation - - at elevation three and elevation for four we have actually determined trotter stresses the pore water pressure is actually obtained like this we actually have said that between the zone 1 1 & 22 so 2 2 is the level of the groundwater table now because of the capillarity effect what we have actually discussed is that in the zone of the capillarity there is a capillary height.

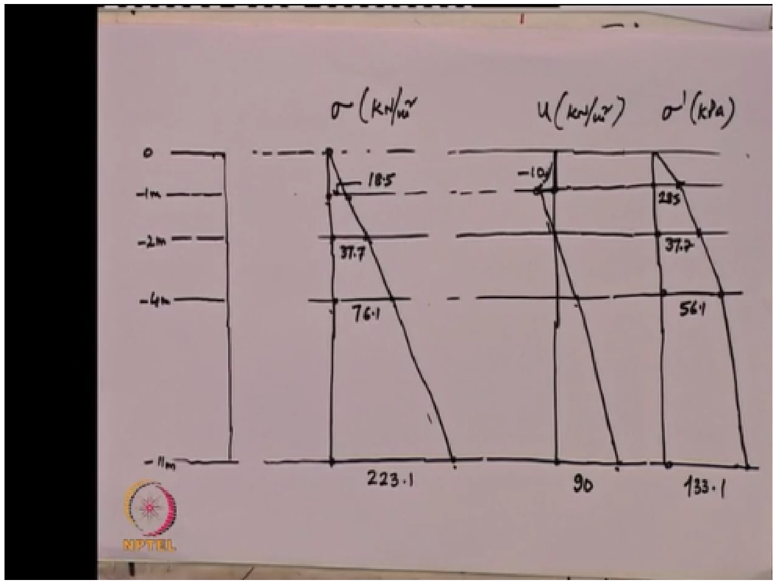
Which is actually called as h suffix Cit's C so in that case the -γ W into 1 that is - 10 into 1- 10kilo Newton per meter square is the native pore water pressure which is actually exhibited by the soil at level1 1 so at level 1 1 that is elevation - 1 meter the negative pore water pressure is minus 10 kilo Pascal's in principle for example if series there is no capillarity effect and if water table is actually not there means then there is no pore water pressure but because of the virtue of the capillarity effect the -10 kilo Pascal's per watt pressure is exhibited at this level.

When it comes to the - 2 meters that is the level where the ground water table is there so here the zero you know the pressure is actually here zero when you go when you go down below the groundwater table that is say 2 meter below at -4 meter which is nothing but level 3 3 what we see here is that 10 into 2 that is 20kilo Pascal's or 20 grand per meter square when we actually have minus 11meter that is nothing but 20 plus 10into 7 that is 90 kilo Pascal's or kilo Newton per meter square so this we have actually got total stress and this.

We actually have got pore water pressure now the effective stress which is actually nothing but σ total stress is equal to σ dash +u that is what actually we have actually discussed so effective stress is equal to σ-u so in this case the at level one the total stress is eighteen point five minus of - 10which comes out to be twenty eight point five kilo Newton per meter square or kilo Pascal au Pascal's and that at level two to the pore water pressure is zero so hence thirty seven point seven -zero you will get that seven point seven and at level three that is at the point evaluation of - 4 meter seventy six point one that is total stress - pore water pressure is positive here.

Which is -20 which comes to fifty six point one kilopascal’s and in case of minus 11 meters so 223 -1- 90 is 133 point one kilo Pascal's so we actually have done is that proto stress pore water pressure and effective stress has been calculated at each levels and the diagrams are actually obtained like this so here what we have actually indicated again the soil profile at zero that is the ground surface.

(Refer Slide Time: 25:16)



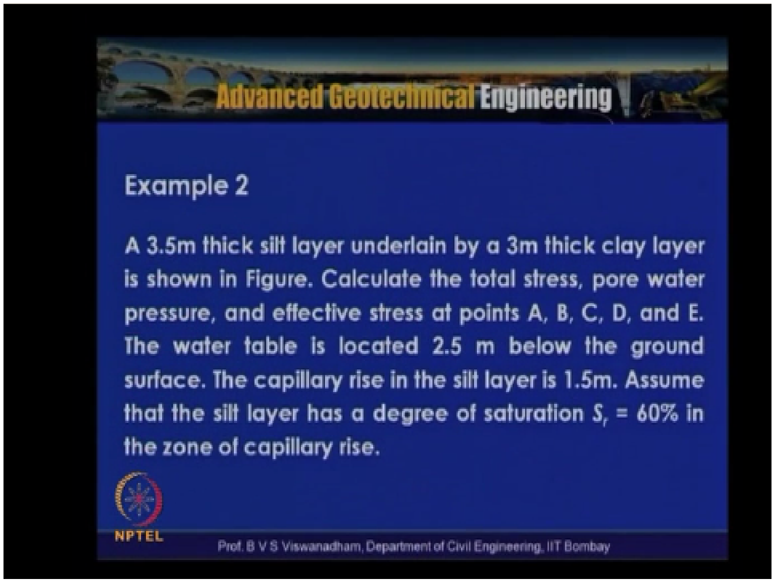
So the total stress is zero at this point has this Arden it is actually obtained and at this point it is eighteen point five so the pressure is actually represented here and this is thirty-seven point seven and here it is articles even six point one and here.

It is twenty two twenty three point one though the unit weights are little bit different but the minor variation will be there in the gradient and here in the case of pore water pressure for example here what we have discussed is that this is if this is subjected to you know completely saturated zone or this is the capillarity since this is the capillary zone saturated capillary zone so minus ten kilo Pascal's is obtained so what we have discussed in the previous lecture this indicates that you know as the comes to the ground surface.

The pore water pressure reduces to zero that means that here the soil actually tends to be in the partially saturated state that means that different depending upon the degree of the saturation the soil actually you know has the decrease in the pore water pressure and here what we have is that zero here and then here it is 20 and here what we have the pore water pressure is 90 kilopascal's so when we take this one σ dash that is nothing but σ- u σ dash is equal to σ-u we actually get the effective stress diagram.

So in the given problem what actually has been asked is that for the soil profile that draw the total stress pore water pressure and effective stress diagrams so we actually have used the concepts what we have discussed and then we try to draw with the effect of the can with the effect considering the groundwater table that is which is actually having a capillarity effect now let us try to one more example from the slide which is actually shown here in this example a3.5 meter thick silt layer underlined by a 3 meter .

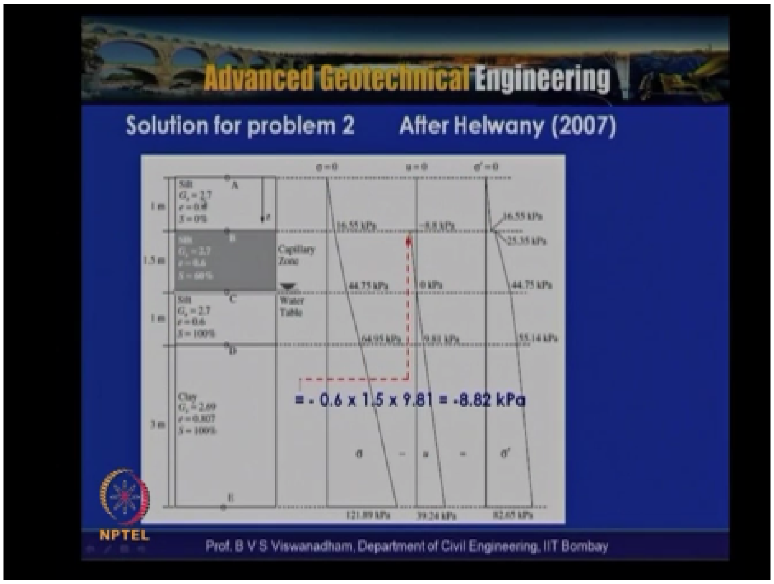
(Refer Slide Time: 27:19)



Thick clay layer is shown the figure will be shown in the next slid ewe need to calculate the total stress pore water pressure and effective stress at points ABCD and E the water table is located at 2.5 meters below the ground surface and the capillary raise in the sill silt layer is 1.5 meters assume that this silt layer has a degree of saturation of 60 percent only in the in the zone of capillary rise so here we actually have the partial partially saturated soil with a degree of saturation of only 60 percent so a3.5 meter thick salty layer underlined by a 3 meter thick clay layer is actually considered in this figure.

And we need to draw the total stress pore water pressure and effective stresses and points ABCD and E which we are going to see in the next slide and the water table is actually located two point five meter below the ground surface so the data which is actually given here.

(Refer Slide Time: 28:33)



Is the salty layer which is actually having the specific gravity of two point seven what ratio 0.6 and degree of saturation 60% degree of saturation is sorry this is degree of saturation here is zero that means that the soil is in almost in dry state and here the zone of the partial capillarity zone wherein the degree of saturation here is 60% the gray colored zone which is actually is the partially saturated capillarity zone and here below the groundwater table.

The soil is actually having 100%saturation and degree of saturation is same the specific gravity of the solids is same and the water table is actually located two point five meter below the ground surface and here the clay layer having a specific gravity of two point six nine and wide ratio of 0.807 and specific gravity 100% so we let us locate at this particular point and at this particular point a B C D and E so this is the partially saturated capillarity zone so with that total stress which is can be given like this base.

On the this data one can actually obtain the γ which based on that we will be able to get that is sixteen point five kilo Newton per meter cube so with that what we get is that this particular ordinate and by going further with this with the degree of saturation sixty percent by using the void ratio we can actually get the γ relevant to here and adding this you will able to get this ordinate as forty four point seven five kilo Pascal's and here below.

Which is sixty four point nine five and at this point it is 121 point eight nine kiloPascal so this we have plotted here total stress and here this is the porewater pressure diagram here at this point you here it is zero and when it comes to this point here as the soil is actually partially saturated what we can actually write is that- 0.6 intone point five into 9.81 here it is actually taken as 9.8 9.8 one kilo Newton per meter cube with that this ordinate water what we have written is a - 8.8 - kilopascal's and at this point it is zero and then we have here nine point eight one and then here it is ninety-knifepoint two four kilo Pascal's.

So when we take the draw the effective stress diagram here it is zero and then when we have what at this particular point just above this we have got 16 just above be the ordinate is sixteen point 5 5 kilo Pascal's just below be it is twenty five point three five kilopascal's and then we had this point forty four point seven five because this point is zero so what we have is that the total stress -pore water pressure it is party four point seven five and fifty five point four and then here it is eighty two point six five no Pascal so in this problem.

What we have done is that we actually have applied whatever actually we have learnt in this module to try to calculate total stresses and effective stresses and all the by knowing the pore water pressure distribution so in this particular module what we try to understand is that the particularly we actually have tried to understand the origin of the soils and then we actually also discussed about different types of soils and soil deposits which are actually prevalent in India and other parts of the world and then we also discussed about the soil classification particularly we have concentrated on the unified soil classification systems and before.

The soil classification system we have actually discussed about different you know weight based and volume based ratios and which are actually used for estimating the soil parameters and then we also have discussed about soil compaction and then we have discussed about how we can actually determine the particle size distribution or how we can actually determine the different physical states of fine-grained soils and we have actually given enough attention towards determining the Institute densities as well as the densities in the laboratory thereafter we try to discuss about the effective stress and capillarity you.

NPTEL
NATIONAL PROGRAMME ON
TECHNOLOGY ENHANCED LERNING

NPTEL
Principal Investigator
IIT Bombay
Prof. R. K. Shevgaonkar

Prof. A. N. Chandorkar

Head CDEEP
Prof. V.M. Gadre

Producer
Arun Kalwankar

Project Manager
Sangeeta Shrivastava

Online Editor/ Digital Video Editor
Tushar Deshpande

Digital Video Cameraman
Amin Shaikh

Jr. Technical Assistant
Vijay Kedare

Project Attendant
Ravi Paswan
Vinayak Raut