Soil Mechanics
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Lecture – 18
Effective Stress-I I

Welcome to lecture on effective stress. This is the part 2 lecture and the continuation of the effective stress which we did in the previous lecture. In the previous lecture we have introduced the concept of effective stress. We said that total stress is equal to effective stress plus pore water pressure and this is an important equation in geotechnical engineering.

In this lecture we will look into much more details of this concept of effective stress. Then we will try to look the effect of fluctuation of water table on the effective stress. What will happen if the water table ranges within the ground level? What will happen if the water level depletes within the ground level or if the water table ranges above the ground level, will it affect the effective stress or not? We will try to look into this concept in the form of some example problems. Finally we will try to look into another name of pore water pressure which is called neutral stress. So as we introduced in the previous class like effective stress principle which was forwarded by Karl Terzaghi in 1936 happens to be the very important equation in geotechnical engineering. This is valid only for saturated soils.

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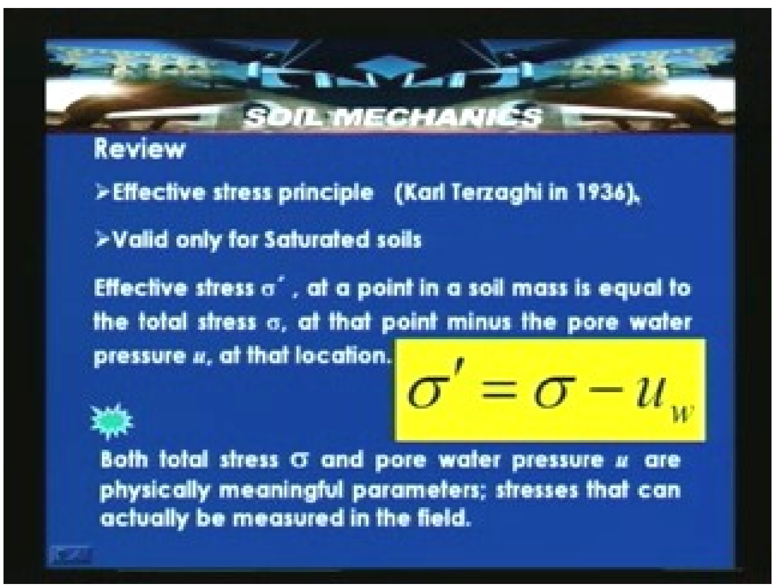

We can define the effective stress sigma dash at a point in a soil mass is equal to the total stress sigma, at that point minus the pore water pressure u, at that location. So here sigma dash= sigma- $u_{w.}$ We also discussed that how to determine sigma that is total stress in case of homogeneous soils as well as some stratified soil deposit and u_w is the pore water pressure. So both total stress sigma and pore water pressure u_w are physically meaningful parameters. These are the stresses that can be actually measured in the field. We define sigma dash= sigma- u_w. Sigma is the total stress which is the result of the overburden or the soil above that particular point under consideration. And u_w is the pore water pressure which varies from the top of the water surface to the point under consideration. So both total stress sigma and pore water pressure u are physically meaningful parameters and stresses that can be measured in the field. Where as in this slide, we are trying to give importance to the equation proposed by terzaghi. So terzaghi in 1936 proposed the relationship for effective stress. It was said that all measurable effects of a change of stress, such as compression, distortion and a change of shearing resistance are due to changes in effective stress. This effective stress is computed mathematically from the total stress and pore water pressure.

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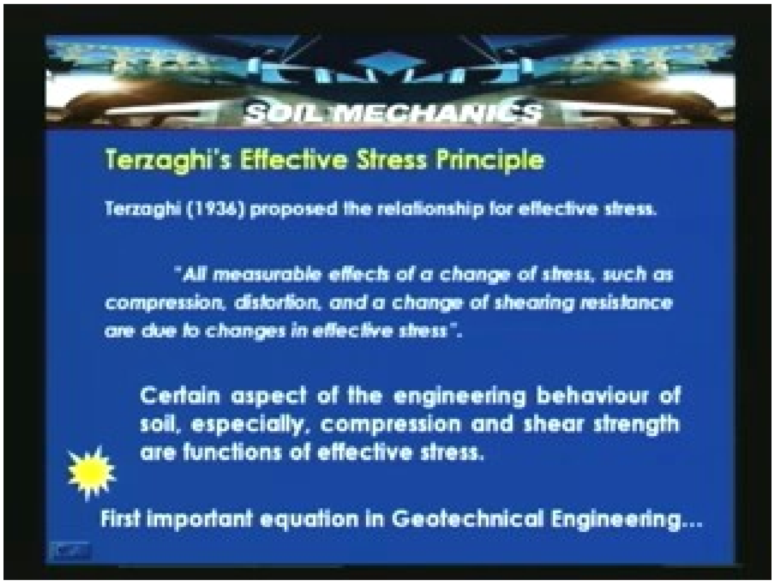

Certain aspect of engineering behavior of soil, especially, compression and shear strength are the functions of effective stress. If there is any change in the effective stress it affects this shear strength characteristic as well as the compression characteristics of a soil. So first important equation in geotechnical engineering. So we have introduced terzaghis effective stress principle. Then we are looking into the much more details about this concept of effective stress.

So effective stress sigma dash by definition can be determined only by arithmetic manipulation that is sigma dash = sigma- u_w. Unlike total stress sigma and pore water pressure u_w, sigma dash is not thus a physical parameter. So it is thus only a mathematical concept but obviously useful parameter since it has empirically been observed to be the determinant of the engineering behavior of the soil.

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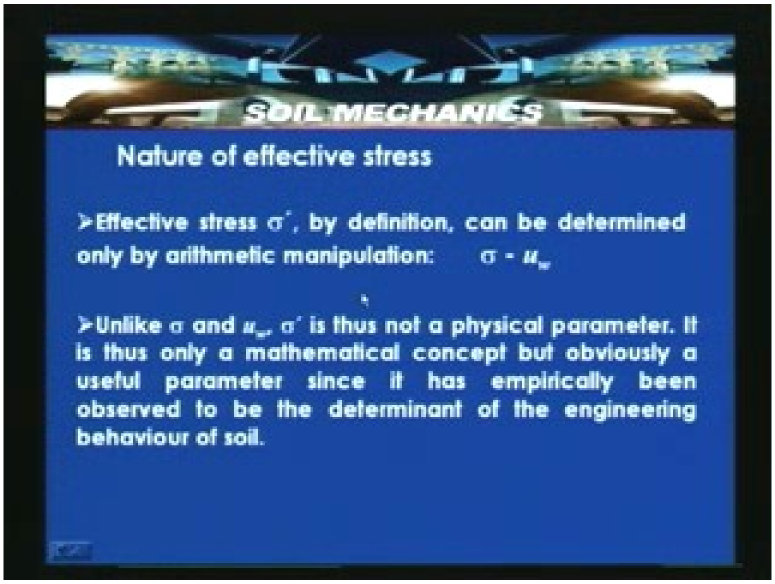

So though it is a mathematical concept which is obtained by arithmetic manipulation of total stress and pore water pressure. But as it is determinant to many engineering properties of the soil, this particular parameter is very important parameter in soil mechanics.

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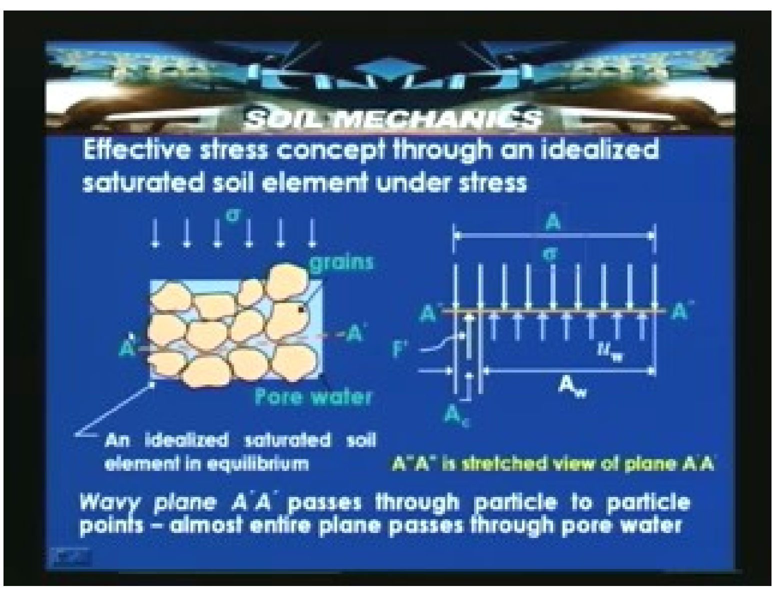

Let us consider this effective stress concept through idealized saturated soil mass under certain stress. In this slide, grains are shown covered with water indicates that all the voids within the grains are filled by water. A' and A' is the wavy plane which passes through the contact points of the grains and this A' A' plane can also pass through the pore water pressure. So if you see at this particular point where the contact is very less. This A' A' is passing through this contact points. So this is the pore water and these are the grains, sigma is the total stress applied to this. So this is an idealized saturated soil element in equilibrium. What you are seeing is an idealized soil element in equilibrium.

Assume let us consider that this A' and A' wavy plane is stretched and made something like A' and A', a plane passing through pore water as well as passing through some grains also. This is an imaginary plane passing through solid grains as well as passing through pore water. So if that imaginary plane is having area and if total stress is acting over that imaginary area A. Then that can be given here as, if you look into this A'' and A''is a stretched view of the plane A' and A'. The total stress when it is applied is apportioned between the intergranular stresses. That is the stresses which are taken by the grains or solids in the soil mass plus water.

A_c is the area occupied by the solids and A_w is the area occupied by the water. That means the difference of total area minus area of contact is the area of water which is the pore water area. So wavy plane A' and A' pass through particle through particle contact point. Almost entire plane passes through the pore water. Because especially for a granular soils, if the contact area is very less it always tries to pass through the entire pore water. So if we look here we have got a force F' which is merely acting on the solid grains at the contact points and U_w which is acting in the pore water that is on the inner surfaces of the solid grains.

Let us look the static equilibrium of this particular condition. Since the soil element is in equilibrium, that is what we have considered. The algebraic sum of the forces must be equal to zero. Let us consider a summation of vertical forces sigma mv sigma fv is equal to zero. So if I do that I am having 3 forces one is sigma A that is total stress acting over an imaginary area A over which this entire total stress is acting. So area A is the one which resulted due to the stretched view or stretched plane of A' and A' which is passing through the contact points.

The sigma A is the total stress on the account of overburden, sigma multiplied by the area of the plane A. That is the one fourth which is acting downwards and U_w A_w is the pore water pressure multiplied by the area of the plane which passes through passes through pore water A_w . So U_w A_w is the total force resulting due to the pore water pressure which is acting over in the area of voids. Area of voids is nothing but area of water. F' is the summation of forces which act at particle to particle contacts through which the plane passes.

Let us consider the static equilibrium in the vertical direction. So from these applying the laws of statics to soil element in equilibrium $A_c+A_{w,}$ that is area of contact plus area of portion which is occupied by the water A_w is equal to total area A, that is area of the plane.

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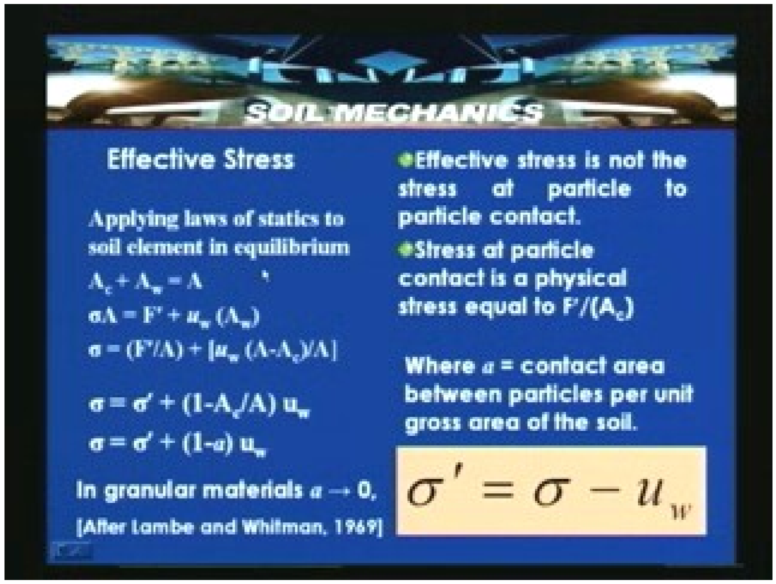

So here this can be written like this. Sigma A = F'+ $U_w(A_w)$. So by dividing with A this can be written as sigma = (F'/A) + [U_w (A-A_c)/A]. So this can be simplified like sigma = sigma dash+ U_w (1- A_c/A). So A_c/A is a, if you write like this where a is the contact area between particles per unit gross area of the soil. Then this can be reduced to sigma = sigma dash + (1-a) U_w. So for granular materials a that is this contact area between particles per unit gross area of the soil tends to become zero. In that case here this works out to be sigma = sigma dash + U_w. So for the granular material when a tends to zero then sigma is equal to sigma dash + U_w.

So from the spring energy we have proved that sigma is equal to sigma dash + U_w. So from this applying the law of statics in considering the equilibrium in saturated soil mass, we have deduced an equation called sigma is equal to sigma dash + U_w, where sigma is the total stress, sigma dash is the effective stress and U_w is the pore water pressure. So further if you look into this slide, the effective stress is not the stress at particle to particle contact. So this effective stress is not the stress acting at particle to particle contact that is required to be noted. This is acting over an imaginary area A passing through pore water as well as passing through solids as well as some contact points.

So stress at particle contact is a physical stress which is equal to F'/A_c. So it will be very high because sometimes minute contact areas can induce very high contact stresses. So here in this slide we tried to apply the laws of statistics to soil element in equilibrium and then we have deduced total stress is equal to effective stress plus pore water pressure. We can say from this slide and the previous discussion, in a saturated soil therefore effective stresses may be viewed as force transmitted at particle to particle contacts divided by the area of the wavy plane that passes to these particle contacts.

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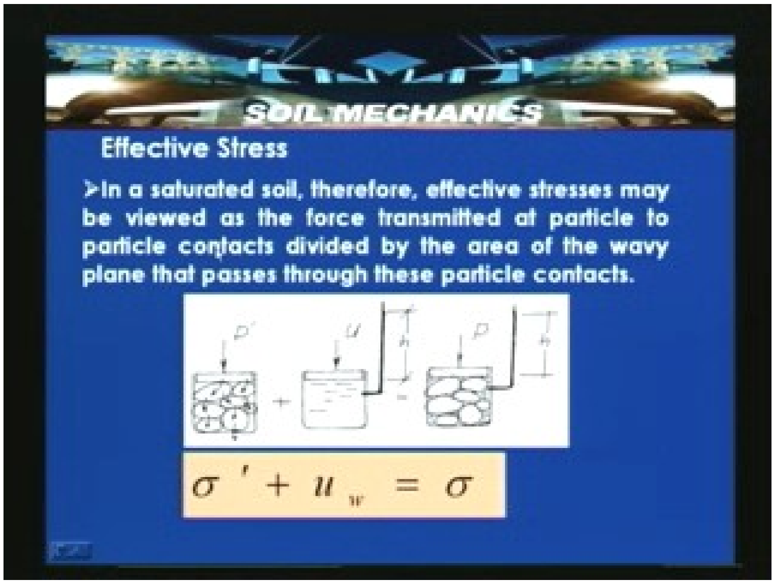

So here the effective stress equation is given in a pictorial representation. Where here sigma dash resulted due to the grain to grain interaction over an area a. Area a is the cross sectional area of the mould perpendicular to the application of the stress and u is the pore water pressure. So sigma dash + U_w is equal to sigma that is the total stress. What we have derived is that total stress is equal to effective stress plus pore water pressure.

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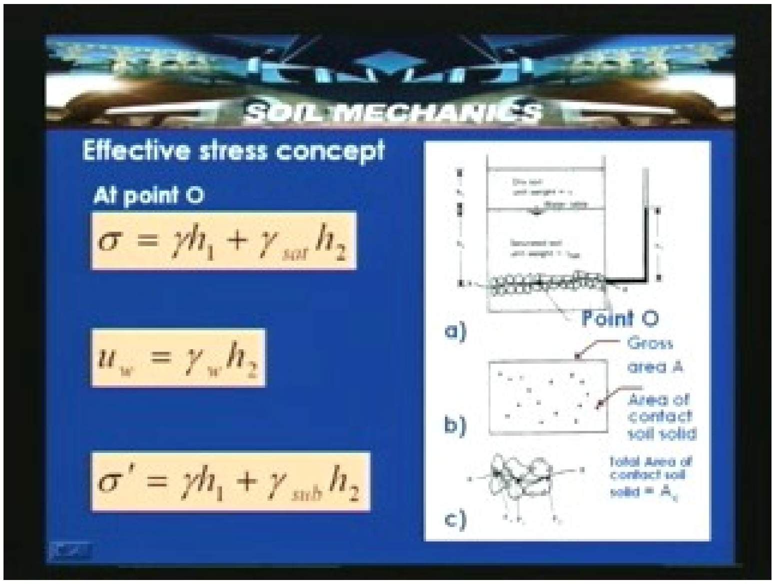

Let us consider once again at point O in this particular location, a strata or having saturated soil and x x is the wavy plane passing through the contact points. If we look into the diagram F_1, F_2, F_3 so on to F_n are the forces acting at the contact points.

Through this wavy plane if I draw and if it is passing through the contact points, it results like this. Let us consider at this particular level if I stretch this, then the imaginary plane results and that can be called as x x (Refer Slide Time: 14:55). If I look into the computation of the total stresses and pore water pressures at this case with this example we can see. So h_2 is the height of the saturated soil mass above point O where point O located here which is shown in the above slide. And h1 is the dry soil unit weight which is having gamma as the dry unit weight. So water table is located h_1 meters below this ground surface. If I put a stand pipe here, the water will raise under hydrostatic conditions up to h_2. That is h_2 is the height that indicates the pore water pressure at this point is gamma w h_2.

So here if I look into the slide above, this is the total imaginary area passing through the plane x x perpendicular to the application of this stress resulting due to overburden in this case. Then area of the contact soil solid is some where here and total area of the contact soil is A_c. So A- A_c that is nothing but A_w which is again taken out by water which is filled with water. So here at point O, we can write total stress as gamma h_1 in principle it is gamma d h_1, gamma suffix d that is the dry unit weight of soil mass. Here gamma d is equal to gamma, so gamma h_1. The h_1 is the height of the dry soil and gamma sat that is saturated soil mass unit weight × h_2. So this is the total stress acting at point O. Pore water pressure at point O is gamma w h_2. So here the pressure is zero and here the pressure is gamma w h_2 (Refer Slide Time: 16:49). So the pore water pressure is gamma w h_2 at this point O. So effective stress is nothing but it is sigma- $U_{w.}$ So we can obtain like gamma h1+ gamma sub h_2. So gamma sub is nothing but gamma dash is equal to gamma sat minus gamma w. So that can be simplified and written as sigma dash is equal to gamma h_1 plus gamma sub h_2.

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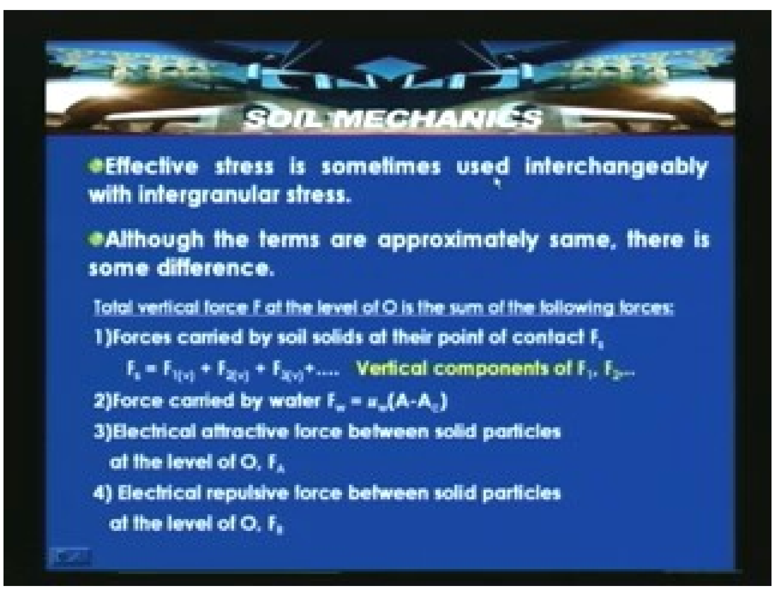

So let us look further into a fundamental difference of intergranular stress and effective stress by considering this particular diagram which is given in this slide.

Effective stress is sometimes used interchangeably with intergranular stress. Although the terms are same and yield same meaning but there is some difference that we will try to look through these 2 slides. Let us look the total vertical force F at the level O, is the sum of the following forces like forces which are acting at grain to grain contact points and forces resulting due to water or which can be some attractive forces or some referencive forces which can happen in soils particularly in clayey soils. So if you see here the forces carried by soil solids at their point of contact say, if I call that force as F solids. The F solids are equal to $F_{1[v]}$, $F_{2[v]}$, $F_{3[v]}$ summation. That means F_s is equal to $F_{1[v]} + F_{2[v]} + F_{3[v]}$ so on. So this $F_{1[v]}$, $F_{2[v]}$, $F_{3[v]}$ are the vertical components of F_1 and F_2. That means if we go to the previous slide and if you see here at the contact points you have got forces F_1, F_2 and F_3 are acting.

So the vertical components of F_1 is $F_{1[v]}$ and the vertical components of F_2 is $F_{2[v]}$ and vertical components of force F_3 is $F_{3[v]}$. So the force carried by water is nothing but U_w $(A- A_c)$. So A is the total area of the plane under consideration and A_c is the contact area. So now F_W is equal to U_w $(A- A_c)$. Then electrical attractive force between solid particles of level O that is F_A is the electrical attractive force between the solid particles at the level O and electrical repulsive force between solid particles at the level of O is F_R. So the total forces is the summation of these forces. We can write now, total vertical force F is equal to $F_s + F_W – F_A + F_R$. Keeping view of this sign convention, the negative sign for F_A was given. So F is equal to $F_s + F_W – F_A + F_R$. Now by dividing with area A, that is A is the imaginary plane area passing through that level at point O in the previous slide.

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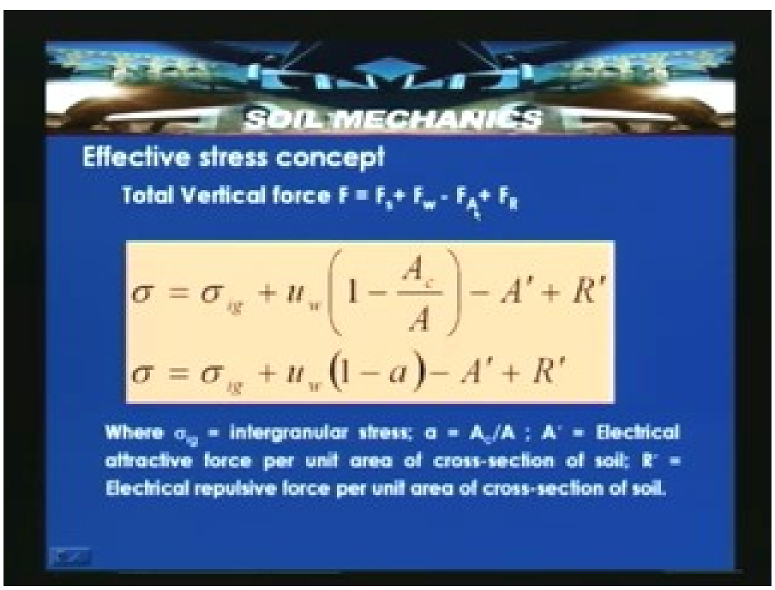

Sigma = sigma ig that is nothing but $F_s/A + U_w (1- A_c/A)$ - A’ + R’ where A’ and R’ are the electrical attractive force and repulsive forces per unit area of the cross section of the solid. So sigma ig is intergranular stress, A is A_c/A and A’ is the electrical attractive force per unit area of cross section of soil. R’ is electrical repulsive force per unit area of the cross section of soil.

So this can be simplified further by writing like this. Sigma = sigma ig + U_w (1-a) -A’+R’. This when you discuss further or when you write in terms of intergranular stress, we can write like sigma ig = sigma- U_w (1- a) +A’-R’. So the value of a is very small in the working stress ranges. So a tends to zero basically for granular soils. We can write like sigma ig = sigma - U_w + A’ –R’. So the value of a is very small in the working stress range. So a tends to zero.

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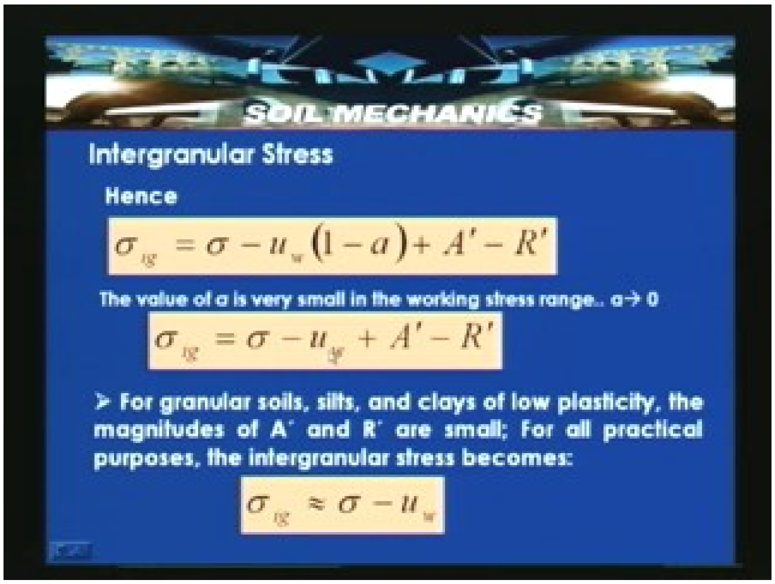

So in that case sigma ig = sigma – U_w + A’-R’. For granular soils like sand, gravels, slits and clays of low plasticity or that means clays of low plasticity indicates that lean clays, the magnitude of A’ and R’are small. For all practical purposes the intergranular stress becomes sigma ig = sigma - U_w. Here for granular soil, slits and clays of low plasticity the magnitude of A’-R’, the difference between A’ and R’ is negligible. So we can write sigma intergranular which is nothing but effective stress is equal to sigma minus the pore water pressure. So this particular deliberation we are discussing to look into difference of the two terminologies for effective stress called effective stress and intergranular stress.

Consequently in case of a highly plastic soils and dispersed clays the A’ and R’ that is attractive and repulsive forces are very large. Depending upon the environment under which this deposition is taking place it can be said that A’- R’ is very large. In such situation we cannot say that intergranular stress = sigma - U_w because the contribution of A’ – R’ will be there.

So if you consider in the slide which is given below, we have got clay particles which are represented as a platelet particles and surrounded by the electrical double layer water, absorbed layer and then this water surrounding the soil particles. So the clay particles and absorbed water are shown in the slide below. Depending upon the deposition and availability of the concentration of the salts, this type of arrangement can be there like face to edge and edge to face orientation.

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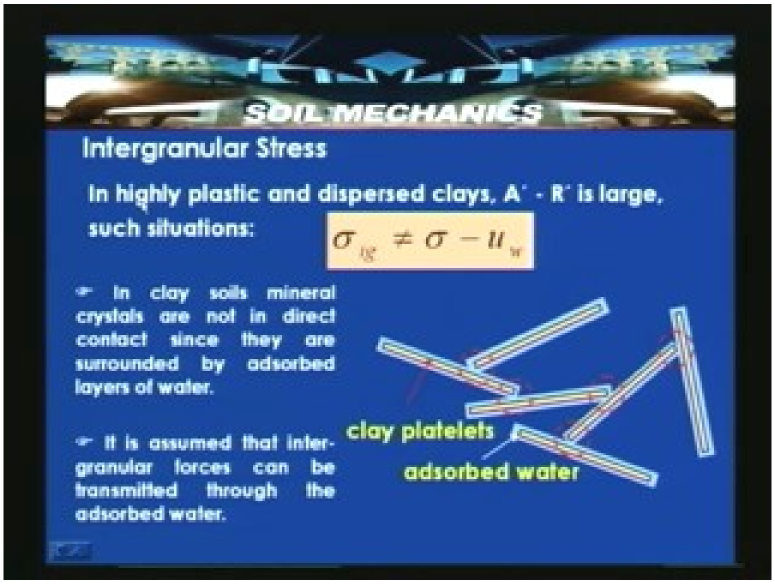

In the clay soils, minerals crystals are not in direct contact since they are surrounded by the adsorbed layers of water. The mineral crystals are not directly in contact to generate the stresses but they mobilize in tune with the adsorbed water surrounding the perplatted particles. It is assumed that intergranular forces can be transmitted through adsorbed water. This assumed that in this particular case of clayey soils where this difference of A'- R' is very large. So this type of arrangement is possible, in that case it is assumed that intergranular forces can be transmitted through the adsorbed water.

So intergranular stress for the case of sands, gravels and clays of low plasticity, we can say sigma ig is equal to sigma dash = sigma – U_w. Where as in case of highly plastic and dispersed clays where A' – R' is very large in that case we cannot really say sigma ig is equal to sigma dash = sigma - U_w. Because of the large contribution of the A' – R' that is difference of attractive forces and repulsive forces acting over cross sectional area of the soil. We have discussed as of now the effective stress under saturated soil conditions and we said that effective stress = sigma – U_w.

But as we discussed earlier, we have situations like partially saturated soils above the ground water table. In such situation how we define effective stress? Let us look through these slides. So partially saturated soils exist in a 3 phase state air, water and solids. The water in the voids is not continuous because it is intermittently disturbed by the presence of the pore air. Pore air occupies considerable volume in the system. So here in the slide below the grains are shown and water surrounding the grains is shown. And in-between trapped air can be seen that is the pore air pressure. So in such situation we cannot say that the equation which was proposed like sigma dash is equal to sigma - U_w is valid.

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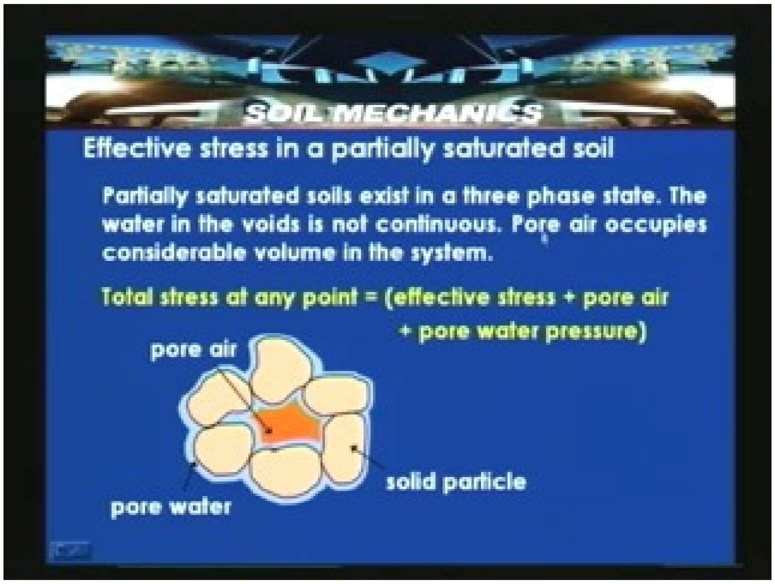

In that situation total stress at any point is equal to effective stress plus pore air pressure plus pore water pressure. In these situations like the total stress at any point is equal to effective stress which is mobilized in the form of an interaction from the grains plus pore air that is when the air is under the pressure, so pore air pressure and pore water pressure.

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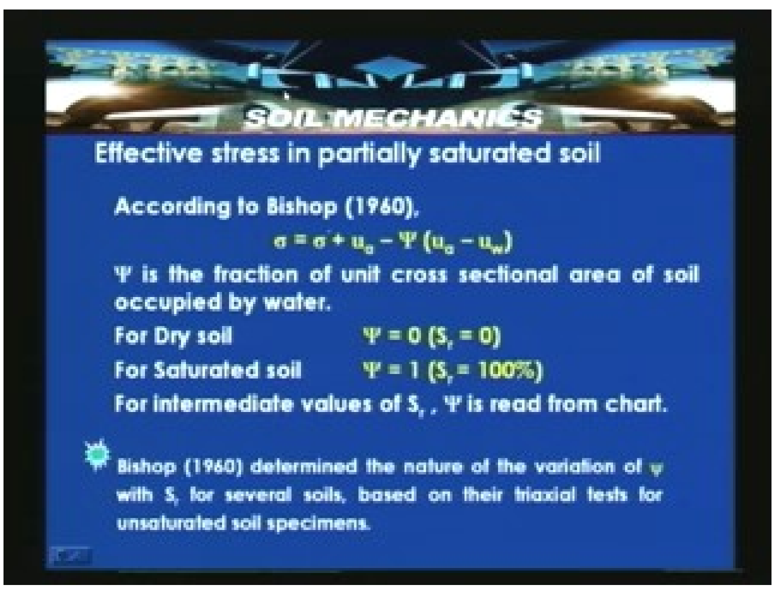

This was discussed and then proposed by bishop (1960). According to bishop (1960) we can say sigma is equal to sigma dash that is effective stress plus U_a that is pore air pressure minus sigh, a constant which is the fraction of the unit cross sectional area of the soil occupied by the water$\times U_a - U_w$.

This value of the sigh is equal to zero for dry soils. When the degree of saturation is equal to zero then sigma is equal to sigma dash plus U_a. That is the total stress = effective stress + pore air pressure. In case of saturated soil, when sigh =1, with the degree of saturation 100 % sigma is equal to sigma dash plus U_w that is pore water pressure. For intermediate values of S_r, sigh can be read from the chart based on the triaxial test on saturated soil samples. Bishop (1960) has proposed variation of sigh with degree of saturation. So this can be determined by the nature of the variation of sigh S_r for several soils based on triaxial tests for unsaturated soil specimens.

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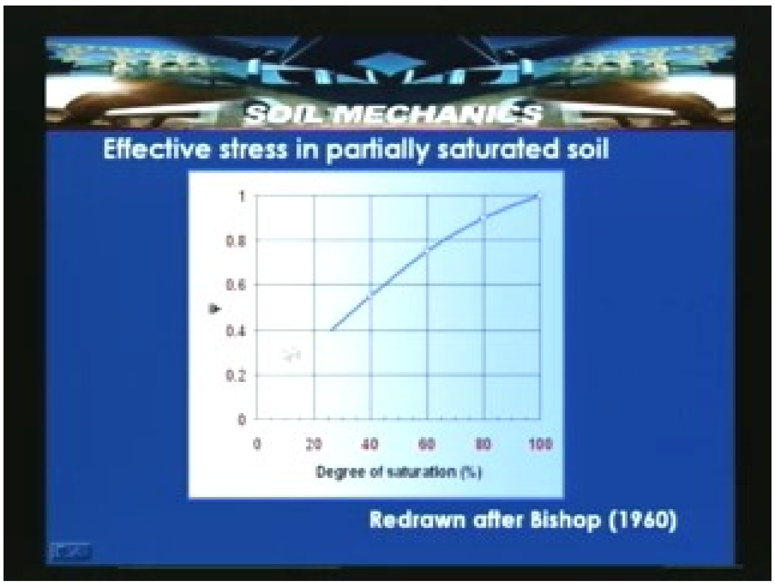

So this chart or this graph shows the variation of sigh, a fraction which is a constant with degree of saturation. You can see here for 100% saturation the value tends to be 1 and for the 30% saturation, the value works out to be around 0.4 or so. So for intermediate partially saturated condition this value can be obtained to compute the total stress which is equal to effective stress plus pore air pressure plus pore water pressure. Having seen the definitions of effective stress for saturated soil conditions and then the derivations based on the effective stress conditions, let us look into effect of the applications of water table on effective stress.

So water table at ground level means that is shown in the slide below. That soil surface and gamma sat is the saturated unit weight of soil mass and sigma dash is that vertical effective stress under consideration and the small element which is shown there. In this particular case the water table is located in the ground surface. So pore water pressure at any depth is hydrostatic. So at depth z, sigma v is equal to gamma sat z, because here at depth z we are interested in computing the total vertical stress, sigma v is equal to gamma sat z. U_W that is pore water pressure at depth z from the ground water table. At ground water table level it is zero and then at depth z it is gamma w z. So effective stress is equal to sigma v – w, which can be given as sigma v dash is equal to gamma dash z where gamma dash is the submerged unit weight of the soil or buoyant unit weight of soil which is nothing but difference of gamma sat minus gamma w.

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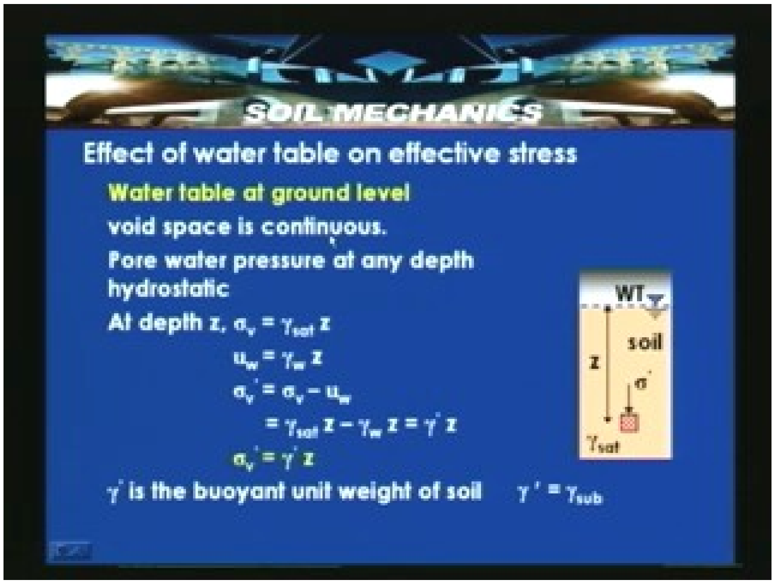

Another case like, water table above ground level. Previous case we have seen water table at ground surface now water table above ground level. Consider in this slide the water table z_w located above the ground level. That is the line marked above the soil which is shown in the below slide is the ground surface. So z_w is the water table located above the ground surface. So when we are interested to compute the total stress which is nothing but gamma sat z + gamma w z_w. And U_w is equal to gamma w (z + z_w). So effective stress when you simplify and write it like sigma v- U_w and it is nothing but sigma v dash is equal to gamma dash z. So if you look into it, in the previous case when the water table is located at the ground level, we have got effective stress as gamma dash z which is independent of the that location of the water table.

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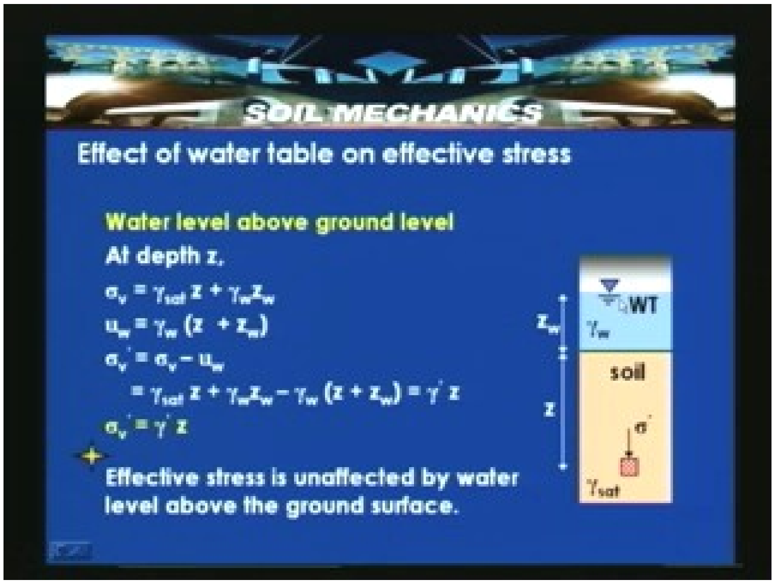

For example if it is at the ground surface we have got sigma v' which is equal to gamma dash z. In this case even with water table above the ground surface the effective stress remains unchanged. So effective stress is unaffected by the water level above the ground surface. As long as water table is located above the ground surface, the effective stress remains unchanged. Let us consider this example, water table above ground level. In this example gamma sat which is taken as 18 kilo Newton per meter cube and gamma w which is taken as 10 kilo Newton per meter cube and at depth z is equal to 3 meters and z_w is equal to 2 meters. This is the cross section of the profile which is shown in the below slide.

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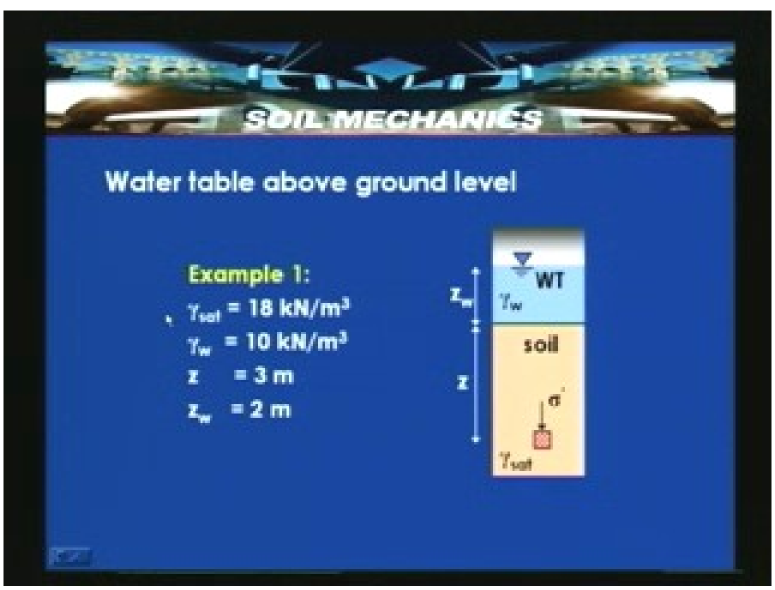

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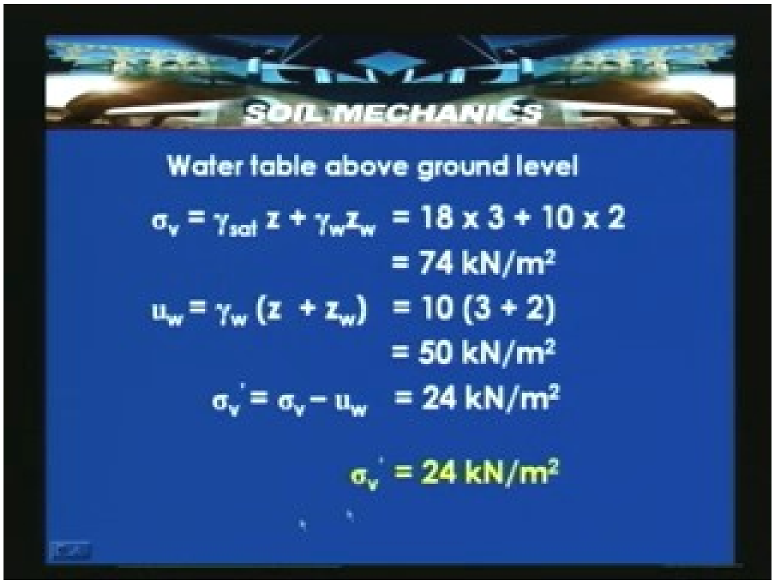

If you look into the water table above ground level, sigma v is equal to 74 kilo Newton per meter square and pore water pressure at depth 3 meters below the ground level along with 2 meter height of above the ground level which is around 50 kilo Newton per meter square. So the effective stress is around 24 kilo Newton per meter square.

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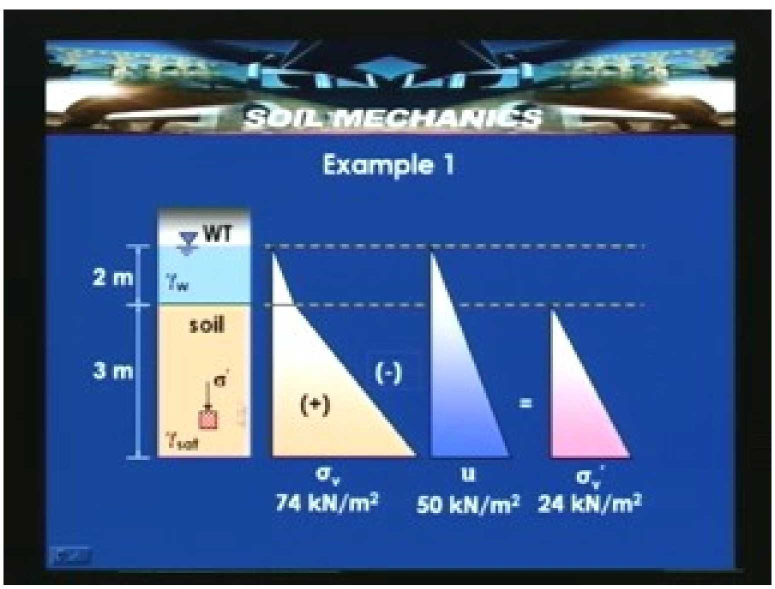

The above slide is the distribution of the total stress with the depth. This is because of the unit weight of the water, so the slope of this particular line is different (Refer Slide Time: 32:20) and here the slope is different because of the saturated soil unit weight. This blue color in the above slide is the pore water pressure and the one in pink color is the effective stress which is nothing but total stress minus pore water pressure. It gives us the effective stress zero at this point (Refer Slide Time: 32:40) and effective stress at this point is sigma v dash = 24 kilo Newton per meter square.

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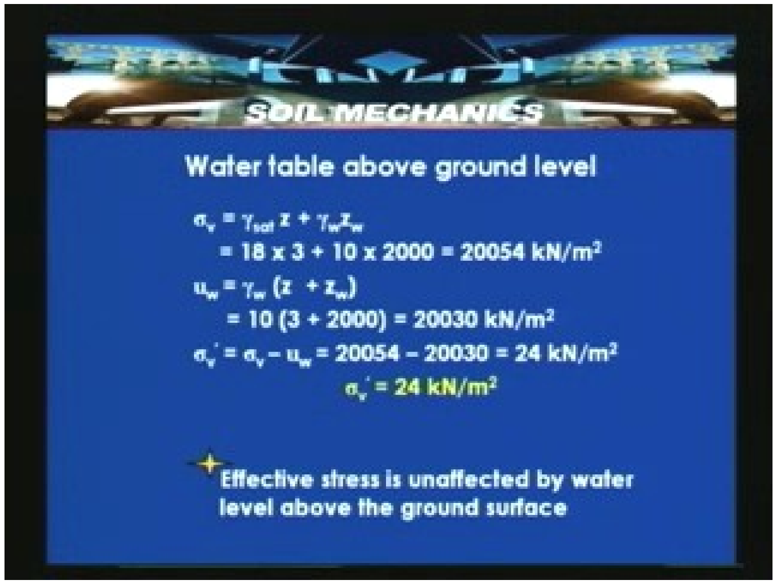

Let us consider another example like water table above the ground level where this Z_w is something like 2 kilometers or 2000 meters representing some deep sea sediment bed. In that case let us look how it changes. If you see here the total stress increased by equivalent amount, for example gamma w z_w is the one we changed. So 20054 kilo Newton per meter square is the total stress and pore water pressure is 20030 kilo Newton per meter square. The difference sigma v dash if you see, even in the case of deep sediments where the effective stress remains unchanged. So effective stress is unaffected by water level above the ground surface. This is just to demonstrate in case of estuarine bed and deep sea sediment. So as long as the water table is above ground level it fluctuates then the effective stress remains unchanged.

So this is that distribution which is shown for the problem what we considered in the example 2 where the z_w is equal to 2000 meters. This 20054 kilo Newton per meter square is the total stress and this 20030 kilo Newton per meter square is the pore water pressure and then 24 kilo Newton per meter square is the effective stress. So this tells us that effective stress in a submerged soil mass is independent of the depth of the water.

Let us consider the fluctuations of water table within the ground level. So this is possible every year because of the onset before monsoon or after monsoon or during rain or immediately after the rain and sometime after the heavy rain fall. These fluctuations of ground water table are also possible because of the depletion of the water table and because of the construction activities or dewatering of this ground water table.

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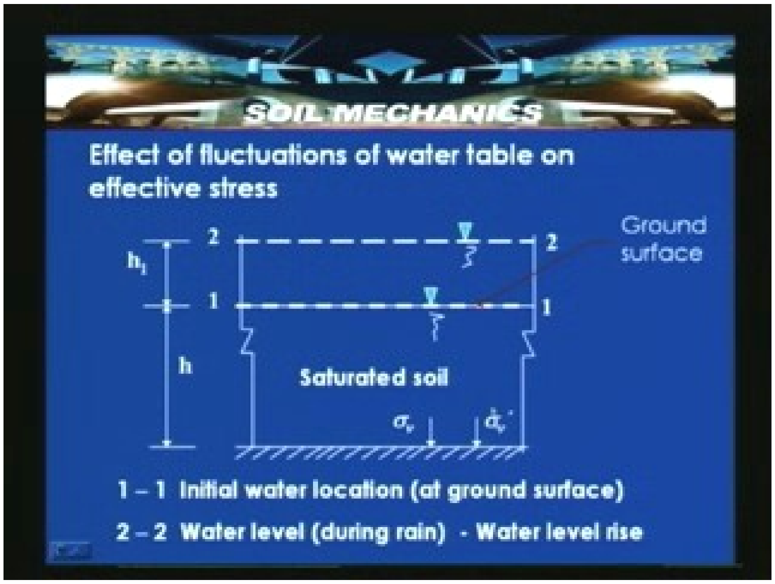

Let us consider a saturated soil mass of thickness h and height of water table above the ground surface is h_1. This h_1 resulted due to heavy rain, the water table rose from ground surface to the height h_1. So this level 1-1 represents initial water table location at ground surface and 2-2 is the water level location during rain that is the water level rises because of the insistent rain.

Let us see how this can change the effective stresses. We are discussing the effect of fluctuation of water table on effective stress. At level 1-1 that is initial water table at the ground surface, so before rain sigma v is equal to gamma sat h and U_w is equal to gamma w h. So sigma v dash is equal to gamma sub h or gamma dash h which is the effective stress before rain. This water level location changed because during rain, there is an increasing in the height of water level and rose from ground surface to height h_1 to go up to level 2-2.

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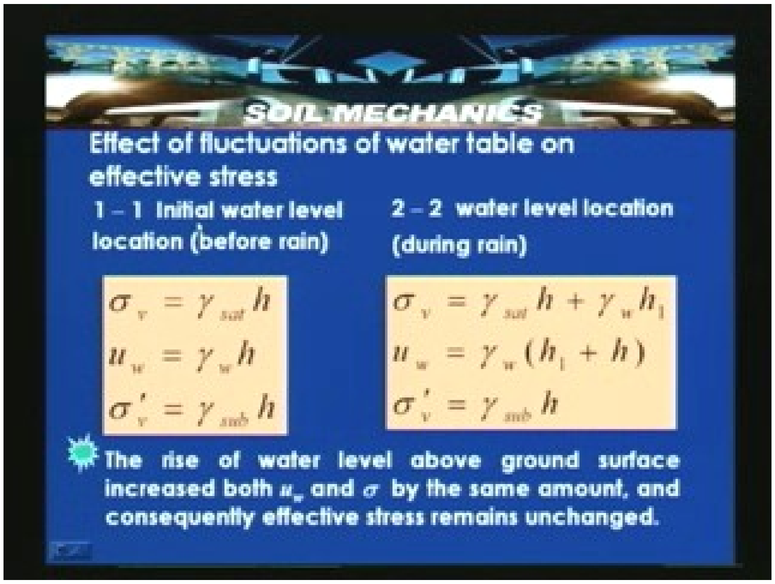

So 2-2 is the water level location. In this case sigma v is equal to gamma sat h plus gamma w h_1 and U_w is equal to gamma w (h_1 + h). So sigma v dash is equal to gamma sub h or gamma dash h. The rise of water level above ground surface increased both u_w and sigma by the same amount, and consequently effective stress remains unchanged. Because of the raise of water level above ground surface, both total stress and pore water pressure their magnitude have increased by the same amount. Because of this the effective stress remains unaltered.

Let us now assume that fluctuations of water table within the ground surface, like it can rise during monsoons or it can deplete because of any construction activity, because of the dewatering of the ground water table which is taking place or depletion of the water table. So in this case let us consider the same soil profile where total thickness of the soil here is h_1 and initially the ground water table is at the ground surface. Now it dropped down to level 2-2 by h_1 meters below the ground surface. So h –h_1 is the saturated soil and this can be dry or partially saturated or it can be completely saturated depending upon the gradation and particle size and then pore spaces. So that will be discussing in the next lecture. But here 1-1 is the initial water level location that is at the ground surface and 2-2 is the water level after rain. After rain in the sense long time after rain, so depletion of the water table can take place. The water table can raise and it can affect the effective stress. In this case what we are discussing is that after long time after heavy rain there will be a depletion of water table. So the 1-1, the initial water level location before rain so as we discussed earlier the sigma v dash is equal to gamma dash into h. For this case when the water table drops down by h_1 meters below the ground surface. Then if you see the sigma v is equal to gamma d h_1 assuming that the soil above that new ground water table level that is 2-2 is dry then gamma d h_1 + gamma sat (h- h1). So u_w is equal to gamma w (h- h_1) because now the ground water table is h_1 meters below the ground surface. The pore water pressure at depth h below the ground surface that is from the ground water table is gamma w (h-h_1).

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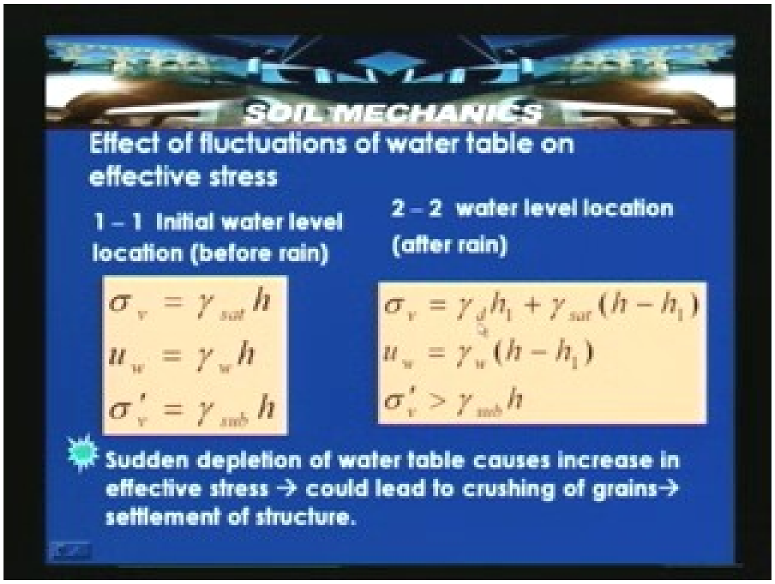

If I look into the difference of this sigma v – $u_{w,}$ definitely the sigma v dash is greater than sigma v dash which we computed for location of water table at the ground surface. So this indicates that when the water table drops down within the ground surface there is a chance of increasing the effective stress. So sudden depletion of water table causes increase in effective stress. But this transfer of effective stress is something like which is not an instantaneous phenomena. For clays where water flows very slowly and it takes long time, for sands it can occur rapidly. In case when there is a sudden depletion of water table and causes increase in effective stress, when this is happening all of a sudden, then it could lead to crushing of the grains because increase in effective stress can put this contrast stresses very high.

So this can lead to crushing of the grains. And crushing of the grains is nothing but rearrangement of the soil particles which is nothing but volume change or resulting into some settlement of a structure or a collapse which can take place. So this particular case when the water table depletes then we have shown that the effective stress can increase. Similarly within the ground surface, if the water table increases what it happens is that this effective stress decreases. So a case like when the water table raises within the ground surface then there is a chance of decrease in the effective stress.

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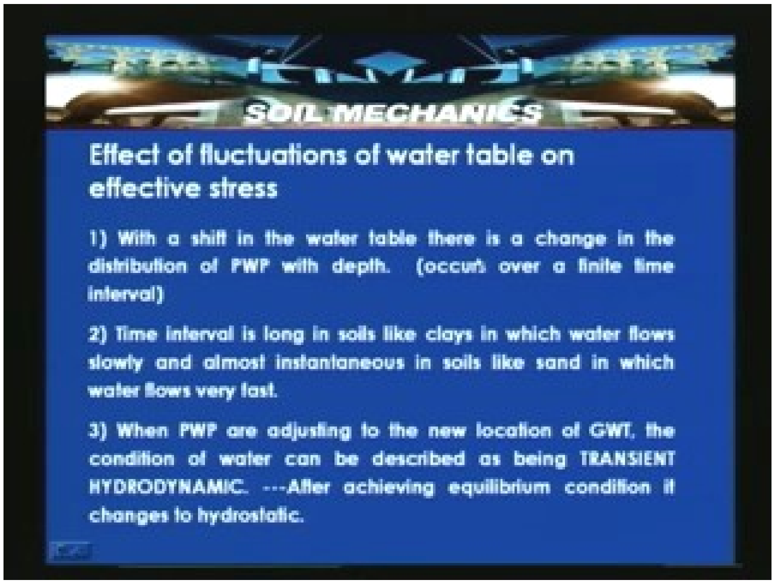

Let us look the effect of fluctuations of water table on effective stress. With a shift in the water table there is a change in the distribution of pore water pressure with depth occurs over a finite time interval. So this finite time interval varies from type of soil. Time interval is long in soils like clays in which water flows slowly and almost instantaneous in soils like sand in which water flows very fast. Why the water flows very rapidly in sands and why it is slow in clays, that will be discussing later. But at this point we can take the time interval is long in soils like clays in which water flows slowly and almost instantaneous in soils like sand in which water flows very fast.

When pore water pressure are adjusting to the new location of ground water table, the conditions of water can be described as being transient hydrodynamic. This is water table fluctuation taking place, when this adjustment to the new water table is being taken place in the soil mass those conditions are called transient hydrodynamic condition. After achieving equilibrium condition it changes to hydrostatic again. When the pore water pressure are adjusting to the new location of ground water table, the condition of water can be described as being transient hydrodynamic.

We can summarize like that effect of fluctuations of water table on the effective stress. If you summarize then we can say like for water table below ground surface, a raise of water table causes a reduction in the effective stress and a fall in the water table produces an increase in the effective stress. That means we have seen a case like fall. If you consider a case like raise of water table within the ground surface, you will observe that effective stress decreases. So for water table above ground surface the fluctuation in the exposed water level does not alter the effective stress in the soil.

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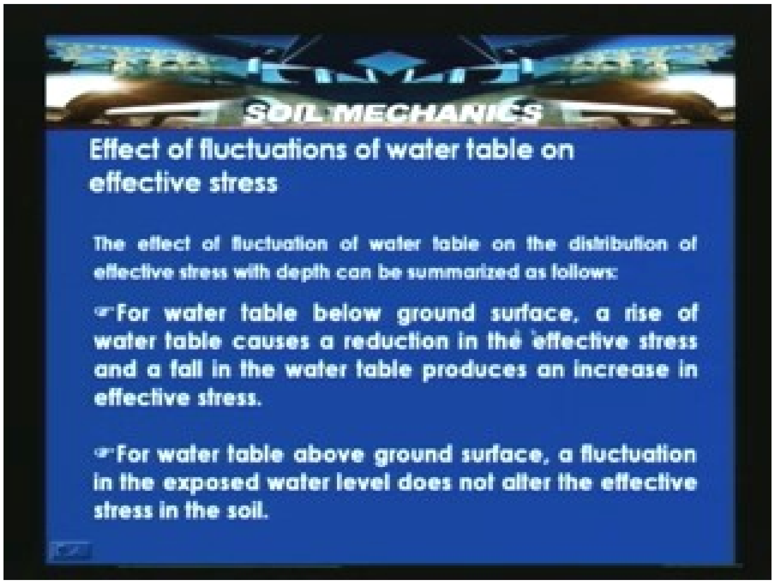

For water table above ground surface, if the water table ranges to 2 meter to 2000 meters as it is independent depth of the water, so the flow for the water table above the ground surface, a fluctuation exposed water level does not alter the effective stress in the soil. So these two conclusions like the variation of the ground water table within the ground surface like when it drops then there is increase in the effective stress. When it ranges because at the onset of monsoon water table can raise that leads to decrease in the effective stresses.

So let us consider some facts noted each year during monsoon through personal observations or news paper reports. During monsoon we always see that ground water table is known to rise and hence the effective stress reduces. That is what we have discussed in the previous slide and summarized. So does the shear strength. What will happen is that when the effective reduces then that means that the grains are being deprived from generating this contact stresses. So with that the shear strength reduces, the more details we will be running in the due course of the lectures. But here the shear strength decreases. When the shear strength reduces below the magnitude of the shear stresses in soil, there are some stresses which are there to support the external load which is created in the form of total stress. When shear strength reduces below the magnitude of the shear stresses in soil then soil slides and collapses occur.

So increase in sigma occurs instantaneously, so one thing which we should notice is that increase in total stress sigma occurs instantaneously. Where as increase in effective stress is not instantaneous. Since particle adjustment and readjustment is not instantaneous. Since the particle adjustment and readjustment is not instantaneous we can say that this change in effective stress is not an instantaneous phenomena.

Where as in case of total stress which is resulting either due to the accumulation of water above the ground surface or due to the manmade activities like construction of fields or construction of structure, wide area fills or reaccumulation of the ground can change the total stress which is an instantaneous phenomena. So increase in effective stress occurs instantaneously where as an increase in effective stress is not an instantaneous, since particle adjustment and readjustational particles depends upon the type of the soil it takes place.

Now as we discussed in the previous lecture, we said that pore water pressure has got another term called neutral stress or neutral pressure. Why the pore water pressure is called neutral stress or neutral pressure? Let us look through the slides.

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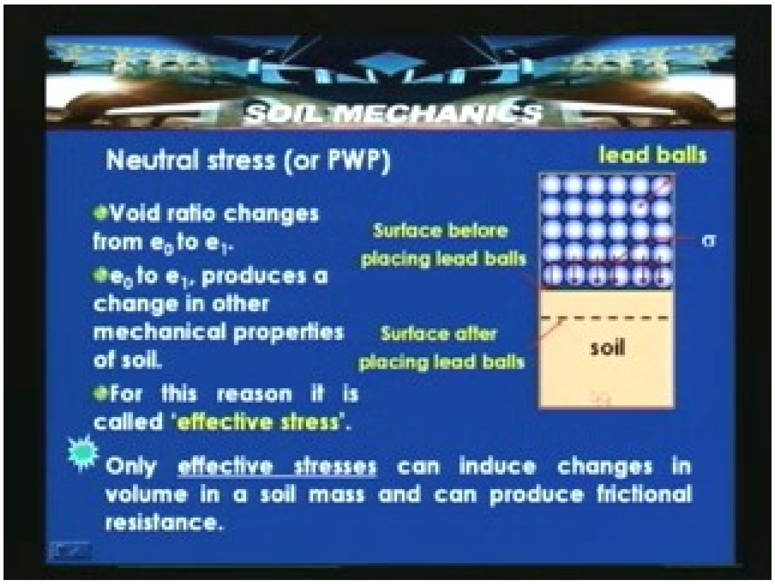

Consider a soil mass of certain thickness and assume that this is the surface before placing lead balls. So here the lead balls are loaded on the soil mass in such a way that they induce the vertical stress sigma. So surface of the soil mass after placing lead balls that means depleted here so changed down to small h, it got inserted. So because of this the void ratio changes from e_0 to e_1. The e_0 is the initial void ratio before placing the lead balls with an intensity sigma and e_1 is the void ratio which resulted after placing lead balls. So e_0 to e_1 produces a change in other mechanical properties. So change in void ratio means, change in other properties like mechanical properties of the soil.

For this reason, because the soil is being dried, whatever the total stress applied is sigma which is equal to sigma dash u_w is equal to zero. So we can say that for this reason, when this effective stress can induce changes in the volume in the form of changes in the void ratio. That is the reason why the effective stress is called effective stress which we have discussed in the previous class.

Only the effective stress can induce changes in the volume of the soil mass and can produce frictional resistance in the form of changes which can be produced. Contrary to this for example if the same mould which is filled with same soil but it is subjected to water level of height equivalent to the stress intensity given by these lead balls.

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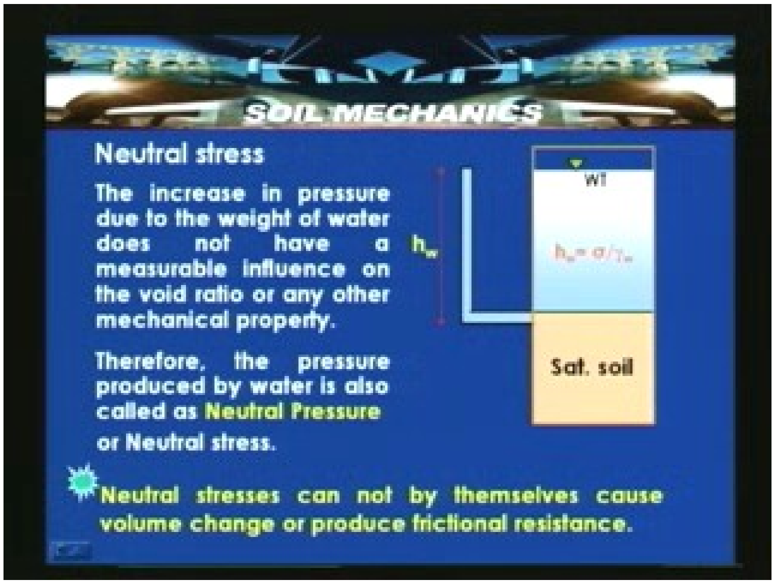

So let us consider here. Suppose if I consider same soil but it is saturated and then this height of the water level is maintained in such a way that h_w = sigma/ gamma w. So if I do this then what will happen is that increase in pressure due to the weight of water does not have a measurable influence on the void ratio or any other mechanical property. Therefore the pressure produced by the water is also called as neutral pressure or neutral stress. Neutral stress cannot by themselves causes volume change or produce frictional resistance. So neutral stress that is water pressure which is acting on the voids of the soils by themselves cannot produce any volume change. When there is no volume change then there is no change in the properties of the soil mass.

So keeping this point in view, generally this pore water pressure also called as neutral stress. So here in this slide what we have seen is that same soil mass which is saturated is subjected to a stress intensity equivalent to sigma by gamma w, where sigma is the stress intensity which we have given in the previous slide to the dry solid soil mass. Then we say that sigma is equal to sigma dash, because of this placement of the lead balls there is a change in void ratio that is decrease in void ratio $e_0 - e_1$ induces some change in the mechanical properties of the soil that can change the shearing resistance. So here in this case, though it is subjected to equivalent stress as that in the previous case. But the increase in pressure due to the water does not have a measurable influence on the void ratio or any other property. So the properties remain unchanged. When the properties remain unchanged by virtue of this water pressure, because this neutral pressure cannot by themselves cause volume change or produce any frictional resistance. Because of this pore water pressure is also called as neutral stress.

So in this lecture we tried to understand about the concept of the effective stress and then we tried to discuss about this fluctuations of water table above the ground surface. We have summarized that as long as the water table maintains the level above ground surface even if it changes its level above ground surface something like example like 2000 meters that means 2 kilometer above the ground surface like in deep seed sediments does not alter the effective stress. The effective stress remains unaltered. Because here the change in total stress and pore water pressure occurred by the same amount. Because of this the effective stress remains unchanged. Because we said that effective stress is equal to total stress minus pore water pressure. Contrary to this if the water table fluctuates within the ground surface that is if there is a depletion of water table, if there is a drop in the water table say after heavy rain then there is a chance of increase in effective stress.

But increase in effective stress is not an instantaneous phenomena. It occurs over a finite interval of time, it depends upon the type of soil. For the soils like sand where the water flows quickly then this changes can occur rapidly. Where as in case of clays then we said that it can occur over a period of time. The total stress is an instantaneous phenomena. Then we discussed that when the water table rises within the ground level then there is a decrease in the effective stress. So these two important discussions we made and then we also discussed some examples like water table at the ground surface and water table variation within the ground surface. Then we tried to understand this concept of the effective stress through examples. Then afterwards we have defined the difference between or terminologies like effective stress and intergranular stress. Then we also tried to discuss about another name of pore water pressure which is popularly known as for the pore water pressure also called as neutral stress. So that is discussed through a simple example then why the neutral stress is called pore water pressure. We have introduced and then we have tried to discuss.