Soil Mechanics/Geotechnical Engineering I
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Lecture - 20
Effective stress application

So, in last 2 lectures, I have given the effective stress concept; how to find out effective stress at a depth of soil and also effective stress for different condition; like whether flow condition and or flow condition and again when there is a flow condition, whether flow is an upward direction and downward direction, how this effective stress is changed changes and sometime this change of effective stress will be sometime is dangerous also in some situation.

So, you have to consider all aspects and we have shown; how to calculate for different condition and now I will show the application of those through a few problems and I will take problem one by one. How to find out effective stress and of the problem is taken in such way, I will be able to the show the application also, right from beginning whatever we have covered like weight, volume, relationship, 3 phase diagram, etcetera because if you again use those things again and again it is easy to remember.

So, I am trying to keep their those things also instead of giving unit weight at same unit weight at different place, exact unit weight of say different places; I am giving in terms of some parameter so, that first step will be to find out the unit weight then you have to calculate depending upon the situation there and so I will take the first problem.

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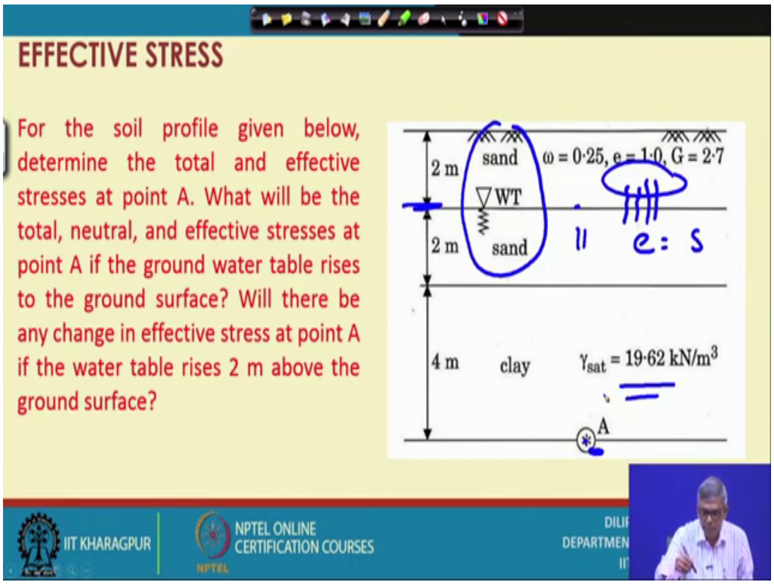

The first problem was there for the soil profile given that is the soil profile given here below determine the total and effective stress at point A. So, point A is shown here and soil profile is how; this is the ground mark this 1 and from 0 to 2 meter; actually 0 to 4 meter. In fact, is a sand; this is the sand layer and in the middle of this sand layer, the water table is there.

So, water table at exactly at 2 meter from the ground surface. So, out of 4 meters that to 2 meters, actually not saturated and 2 meter is saturated. So, below water table, when soil is below water table always saturated and above water table, it can have 3 different situation, it can have dry, it can be partially saturated, it can be also saturated without water table, how this will saturated without water table.

Generally as I have mentioned that soil will have a very fine particles and through the interconnected particles, white spaces the water can flow and that is the capillary action. So, because of this capillary action, the water can go up and saturate some amount of soil so; that means, above the water table there are 3 situation possible that is saturated that is by capillary rise partially saturated; that means, some water is detained by the soil or completely dry. So, here actually above water table what are the things given, e is given, water content also given, since water content is given, is must be partly saturated that is some amount of water is there. So, by using that I will calculate the unit weight for this that is bulk unit weight as it is and below this water table this to this that is below the water table always soil will be saturated.

So, for this water content is known void ratio is water content. So, void ratio is known and e is known and it is saturated. So, assuming this condition, I can find out the unit weight of this and clay saturated unit weight already given. So, these things first to be calculated after doing that I can find out different quantities; that means, total stress at this point and then pore pressure at this point and then difference of these 2 will become the effective stress so that we will find out.

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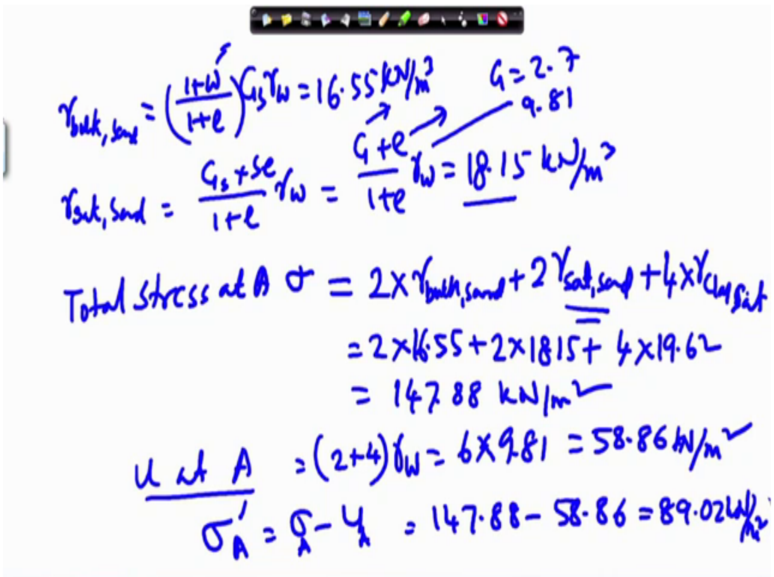

So, for this, I can take gamma, bulk, sand; gamma bulk, sand which will be equal to 1 plus W, this formula to be remembered; 1 plus e into G S gamma W. So, everything is given. So, if I put those things, then I will get the value 16.55 e value is given and water content is given. So, if I put all those this is unit is also important 16 kilo Newton per meter cube and then gamma sand gamma saturated again sand that is actually, you can say we have G S plus S into e plus 1 plus e gamma W is the formula when it is this and then in this, if I put S equal to 1 then.

So, it will be G plus e by 1 plus e gamma W and that it will give you that will give you your 18.15. So, e if I put G you can take 2.7 and G is 2.7 and e value is given and gamma W is 9.81, if I put, then you will get this is the 18 kilo Newton per meter cube, then total stress at a total stress at a that is nothing, but sigma. So, sigma will be how much? So, 2 meter depth was gamma bulk so; that means, gamma bulk sand plus 2 meter of gamma saturated sand plus you have 4 meter of gamma clay and that is saturated. So, this will be 2 into how much it is 16.55 plus 2 into this is how much; 18.15 plus 4 into 19.62.

So, this gives you 147.88 and what is the u at A; you have 2 meter plus 4 meter 6 meter into gamma W. So, 6 into 9.81 that gives you 58.86; every time kilo unit is important, kilo Newton per meter square, it is kilo Newton per meter square. So, sigma dash will be sigma minus u sigma dash A. So, sigma A sigma u A. So, that will become 147.88 minus 58.86.

So, that becomes your 89.02 kilo Newton per meter square. So, this is the first question asked that is what is the effective stress at point A because of the given condition. Now I will see once again effective stress at point A, if the ground water table rises to the; what will be the total neutral effective stress at point A, if the ground water table rises to the ground surface; that means, water table now from here, it goes here, then there will be no gamma bulk, only gamma saturated will be 4 meters and gamma saturated for clay also all 8 meter will be gamma saturated. So, this one again let us see this part when you will do when water table water table at the ground surface.

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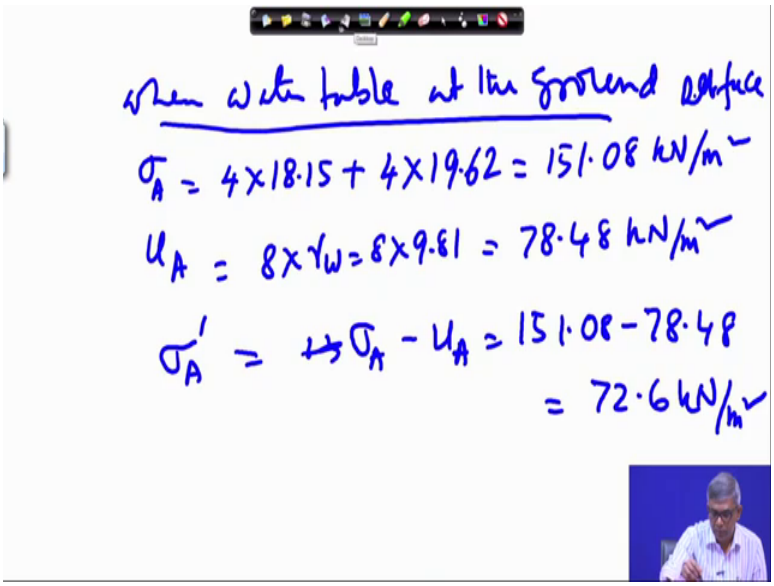

So, you have sigma B. Sigma A will be equal to 4 into 18.15 because entire 4 meter of sand will be saturated plus 4 into 19.62. So, that gives you 151.08 kilo Newton per meter square and u A will be 8 into gamma W. So, 8 into 9.81 that gives you 78.48 kilo Newton per meter square. So, sigma dash A when water table at ground surface will be equal to 151 or sigma A minus u A equal to 151.08 minus 78.48. So, that gives you the value equal to 72.6.

So, this is the second condition that is water table when it rises to the ground surface, this is one part. Now I will go back to again the next the problem that is your third part, you see will there be any change in effective stress at point A, if the water table rises 2 meter above the ground water so; that means, water table was here water table was here.

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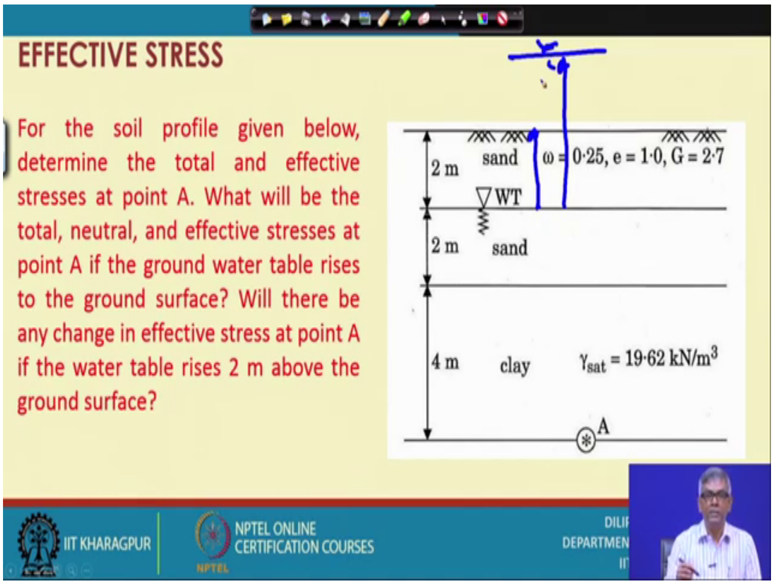

Now, it has gone here; now it is going here somewhere here water table. So, will that be any change in effective stress this is the thing we will see now and so, third case when water table when water table 2 meter above ground surface.

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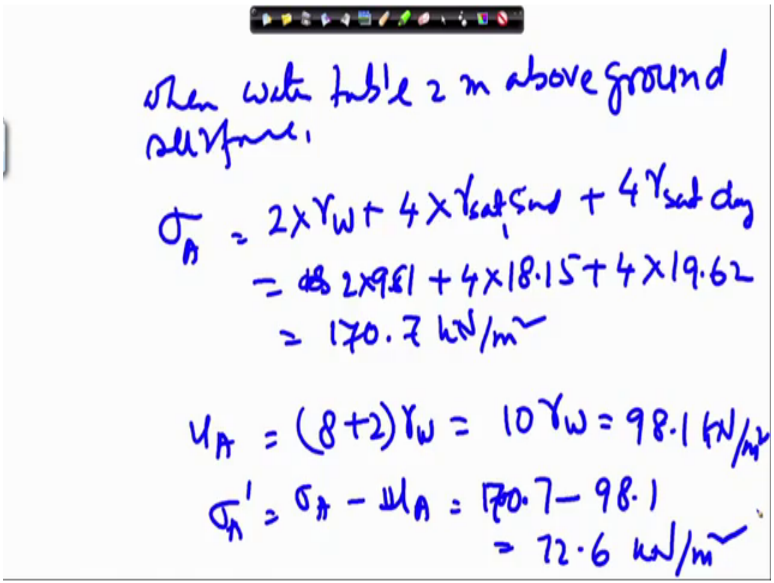

So, sigma A; the same point, I will consider, sigma A will be equal to now 2 into gamma W plus 4 into gamma saturated sand plus 4 into gamma saturated clay. So, that gives you 18.15; 18, sorry, this is 2 into 9.81 plus 4 into 18.15 plus 4 into 19.62. So, that gives you 170.7 kilo Newton per meter square and what about u A will be now to be 8 meters. Soil was there plus 2 meter above into gamma W. So, 10 into gamma W; so, that is equal to 98.1 kilo Newton per meter square.

So, now same point; now sigma A dash will be sigma A minus u A. So, it will become 170.7 minus 98.1 that gives you 72.6 and you can see; now the compare with the previous case when water table was the ground. Now it has gone above 2 meter. Now there is no change, it is the same value we have. So, that is what conclusion I have done in the last previous last to last lecture that when water table changes above ground water level there is no change in the effective stress at point. So, that is the thing we have shown here through this application.

So, next I will go to the next problem.

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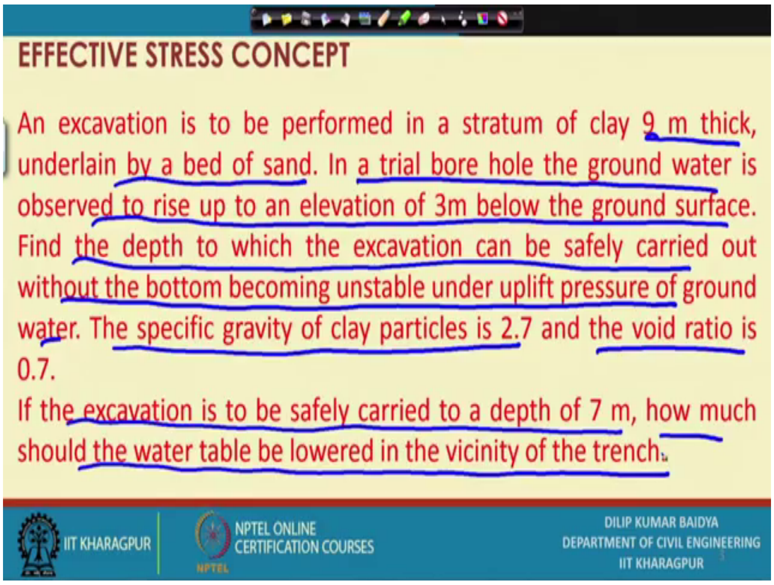

Next problem is something is that an excavation is to be performed in a stratum of clay 9 meter thick underlain by a bed of sand in a trial bore hole the ground water is observed to rise up to an elevation of 3 meter below the ground surface. Find the depth to which the excavation can be safely carried out without the bottom becoming unstable under uplift pressure of ground water the specific gravity of clay particles is 2.7 and the void ratio is 0.7, if the excavation is to be safely carried to a depth of 7 meter, how much should be the water table be lowered in the vicinity of the trench.

So, I have mentioned that by lowering the water table some time the effective stress will be increased that is the thing required. So, that requirement is also mentioned here. So, I will case this one. So, 9 meter thick clay layer below that there is sand and sand layer is under pressure and how much pressure when you make a bore hole, we will see the water, how much height it has raised. So, that is what is shown the water table actually shown 3 meter below the ground level though while excavating through the clay the clay layer seems very highly impermeable.

It is not showing water table, but when you puncture that one go to the sand and make a bore hole you will see the water table up to the 3 meter below the ground surface. So, that is that can be considered as the water pressure at the sand layer at the top of the sand layer and clay layer of course. So, I will show this how to do this type of problem, once I have taken before, but once again with effective stress concept we are repeating once again.

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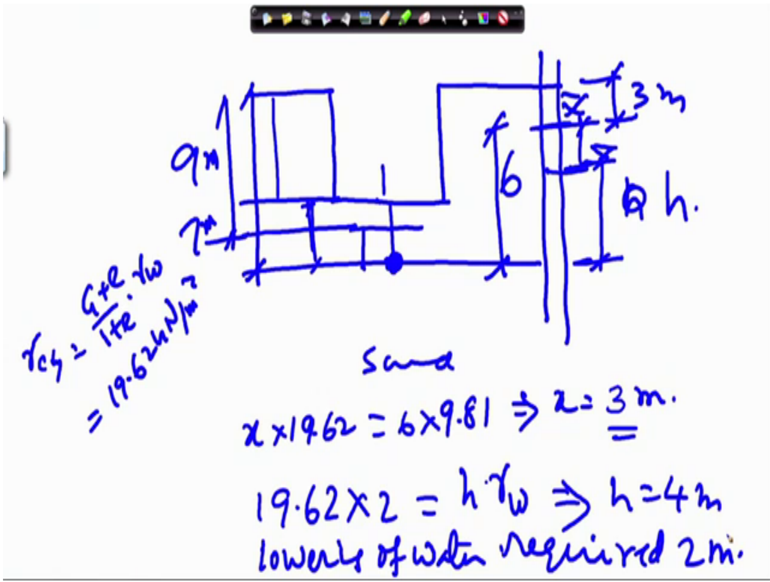

So, it will be something like this the; so, this is the excavation going on and this is the sand layer, when there is a bore hole bend water table came somewhere here and this depth is 3 meter and this depth is 9 meter and now the gamma clay is not given gamma clay is not given. So, we are considering G actually considering a saturated. So, it will be G plus e by 1 plus e into gamma W and if I do that that gives you 19.62 kilo Newton per meter cube and. So, how much depth to be; so, this one taken as x, I am taking this x as x actually.

So, x into 19.62 this is pressure from this side and how much water height at this point. So, I am considering equilibrium at this point that must be equal to 6 into 9.81 so; that means, this gives you x equal to 3 meter so; that means, out of 9 meter if this is 3 meter; that means, we can go up to 6 meter expression without any danger, but these are danger actually we are considering equilibrium upward and downward force we have just if it is of danger, but slightly less than that we can go stably; that means, up to 6 meter depth, we can with that condition, we can do excavation and second problem was that if you want to go up to some depth that is actually 7 meter if I want to excavate 7 meter then how much water table be lowered.

So, I am considering the water table to be lowered by some depth. So, in that case or suppose water table finally, I have to bring water table here to suppose here. So, these depth suppose I am considering h. H, if I consider, then 19.62; 19.62 into 2 7 meter is at excavation. Now I am going down to 7. It was 6, now it is further I am making 7 meter so; that means, soil will be above this will be 2 meter 19.6 into 2 will be equal to h into gamma W.

So, final water table where it will be that is our h. So, from this if I get h become h become 4 h become 4 initially it was 6. So, initially this 3 meter from this side; that means, this was 6 now this is coming 4 that mean lowering of water table required lowering of water table required 2 meter. So, 6 to 4 we have to lower. So, this is another application.

And let me see the next problem this is a problem actually.

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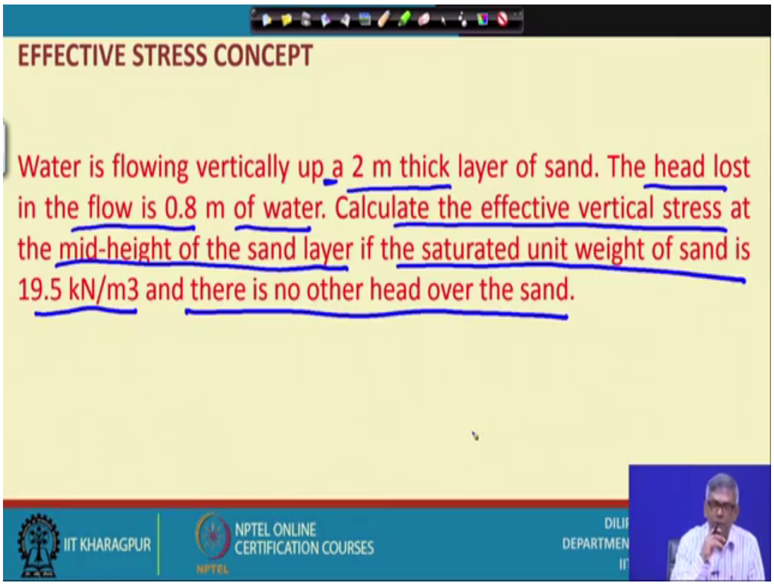

Water is flowing vertically up. So, when water flow vertically up we know that effective stress will be reduced. So, that is the thing I will come later for the time being let me read the problem water is flowing vertically up 2 meter up through a actually through a 2 meter thick layer of sand, the head lost in the flow is 0.8 meter of the water; that means, head how much difference in head to which passing the flow is 0.8 meter, calculate the effective vertical stress at the mid height of sand layer, if the saturated unit of sand is 19.4 kilo Newton per meter cube and there is no other head over the sand.

So, this is the problem. So, at the mid height of the clay, we can calculate; what is the effective stress normal, no flow condition and because of this flow condition with that much head what is the additional effective stress is coming that we subtracted, then I will get; what is the actual effective stress acting in it.

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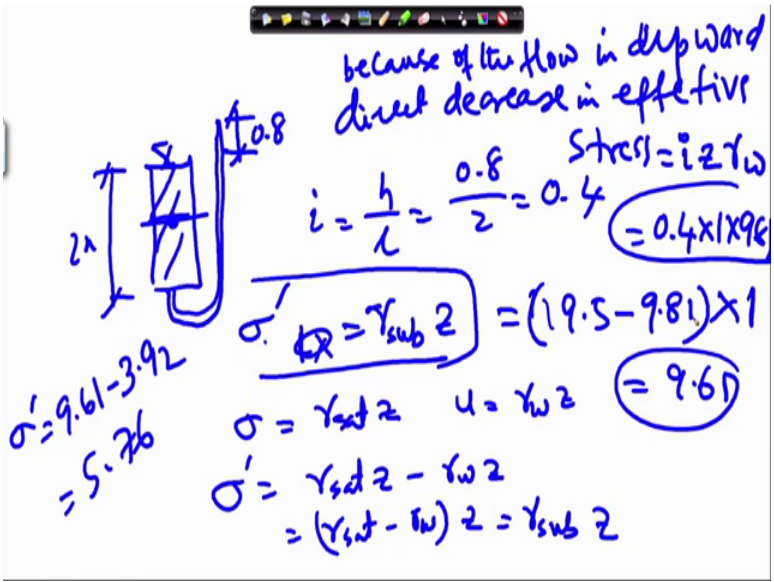

So, let me do that before that we can see suppose this is the soil and through which suppose we kept it something like this soil is this one is the soil, this is 2 meter and the additional head here actually 0.8. So, your hydraulic gradient will be I will be h by l. So, that is 0.8 by 2. So, 0.4 ; now if the water table is here at the mid height of the clay layer I have to find out the total effective stress the total effective stress will be how much. So, one meter into gamma saturated was given I think. So, 19.5; so, generally effective stress at the mid height of this gamma submerge gamma submerge into z is the effective stress.

This is the way you can do or you can do sigma equal to gamma sat into z and u equal to gamma into W into z and sigma dash equal to gamma sat into z minus gamma W into z. So, ultimately gamma sat minus gamma W into z and which is nothing, but gamma submerge into z. So, which we have shown; so, sigma dash is gamma submerge into z. So, gamma submerge is 19.62 is nineteen point five is given at saturated unit submerge you have to subtract 9.81 and z is since total depth is 2 meter at the middle of the layer.

So, at one you have to multiply. So, that gives you effective stress gives you 9.61 and when flow because of the flow because of the flow in downward direction sorry upward direction decrease in effective stress will be equal to I into z into gamma w. So, I z gamma W will be how much I is point 4 into z is 1 into 9.81.

So, this to be subtracted from this; that means, your effective stress will be 9.61 minus 3.92. This will become 3.92 and then finally, it will become 5.76. This is another application that is when flow is taking place; what will be the effective stress we have as we have mentioned that I z gamma W will be reduced. So, that we have subtracted from there. So, this is another application what we have just covered and next we will go to the last of problem.

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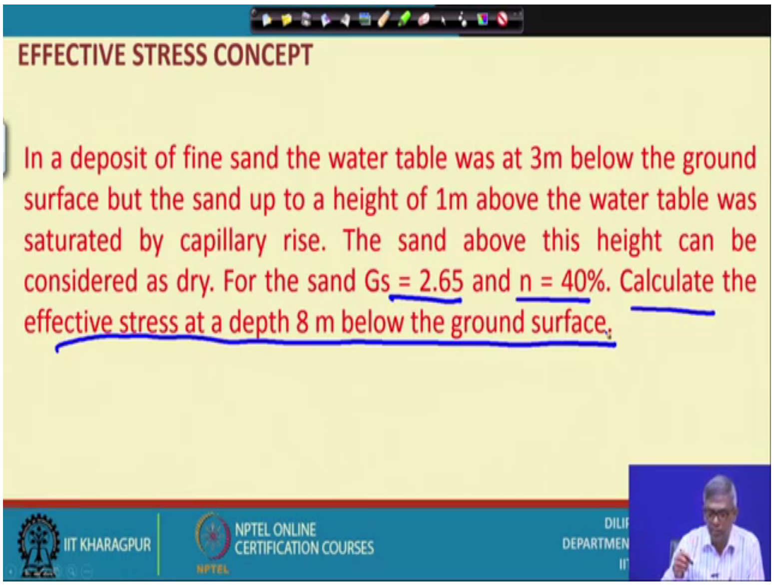

So, this way in a deposit of sand water table was sand the water table was at 3 meter below the ground surface, but the sand up to a height of one meter above the water table was saturated by capillary rise as I have mentioned that because of capillary rise soil get saturated the sand above this height can be considered as dry. So, beyond that for the sand G S is equal to 2.65 n equal to 40 percent calculate the effective stress at a depth 8 meter below the ground surface. So, this one, we can do whatever way we have discussed.

So, let we see that. So, I can do this oh sorry better this was deposit of sand. So, sand layer is not there water table was below 3 meter.

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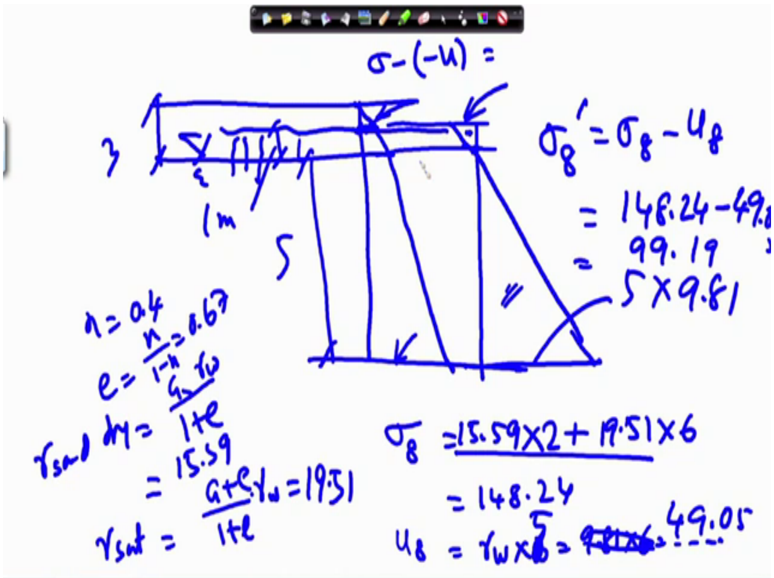

So, water table was below 3 meter water table was somewhere here and then later on by capillary rise it got saturated. So, this is this one is 3 meter and this one is 1 meter and n is given equal to 0.4. So, e will be equal to n by 1 minus n. So, it gives you 0.67 and from there gamma sand dry you can find out gamma sand dry you can find out that is G S gamma W by 1 plus e that gives you 15.59 and gamma sat gamma sat can be obtained G plus e by 1 plus e into gamma W and that gives you 19.51. So, different condition, we can find out; now if I do the total stress diagram like this. So, you will get up to 2 meter. So, at 8 meter depth, you have to find out sigma total height it will be equal to 15.59 into 2 plus and 19.51 into 6.

So, it will give you 148.24; whereas, you will have u at 8 will be though water by capillary rise water soil got saturated here, but water table will be here only water table cannot be changed. So, it will be gamma W into 6. So, that will give you 49 point; no it will be 9.81 into 6. So, whatever value it comes here 49, actually, I have done mistake perhaps. So, actual your pressure diagram; so your total stress diagram will be something like this and when you draw the pore pressure diagram water pressure diagram it will be something like this.

So, from here, oh this is not 6, it is 5 actually, this is 2 and 6 and this will be 5 because water table below 5 meter. So, it will be 49; 49.05 and so this depth is 5 meter. So, this is 5 into 9.81 and this one will be this one and so, at this depth; what is the sigma 8 dash, it will be sigma 8 minus u 8, it will be 148.24 minus 49.05 and that gives you 99.19. So, this is what point to be remembered here though it is mentioned that because of the capillary rise the one meter above the water table soil got saturated. So, we are taking the saturated unit weight only, but water table location is not changing. In fact, pore pressure instead of becoming negative those portion.

So, at this depth if I want to find out effective stress effective stress there will be increase here at this point effective stress will be increased because sigma here whatever sigma whatever at this point minus u because at this point, it is u minus. So, at this point, effective stress will be increased and at this point effective stress there will be change because of this saturation.

So, that to be remembered that though water table above sorry soil above water table is getting saturated by capillary rise, but water table is not changing water table is when you consider hydrostatic pressure below the water table it will be same height multiplied by z whatever gamma W do, but when you want to do pore water pressure above water table because of capillary rise because we have shown that this is because of tension only it is going up. So, that one to be negative and at that point if I calculate effective stress there will be increase.

So, that 2 points that is that here finding calculate hydrostatic pressure it will be water table will be the unchanged there should not be increase taken 6 that is one thing to be remembered and hydrostatic pressure above water table it will be negative and if I calculate effective stress at this point that will increase it will show then these 2 point important point has to be remembered. So, with this I will just close here.

Thank you.