Geology and Soil Mechanics
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Lecture - 24
In-situ Stresses - A

Welcome. Welcome back to the course Geology and Soil Mechanics. So, in the last lecture we just talked about different types of stresses, in-situ stresses, right and there we have cleared our conception regarding the total stress, effective stress, and the pore water pressure which are related okay. So, that means the if you know the total stress if you know the pore water pressure you can find out the effective stress which is nothing but the stress which is getting developed at the contact point of the soil grains right. Similarly, if you know the pore water pressure as well as effective stress you can find out the total stress. So, these relations already we have seen and we discussed.

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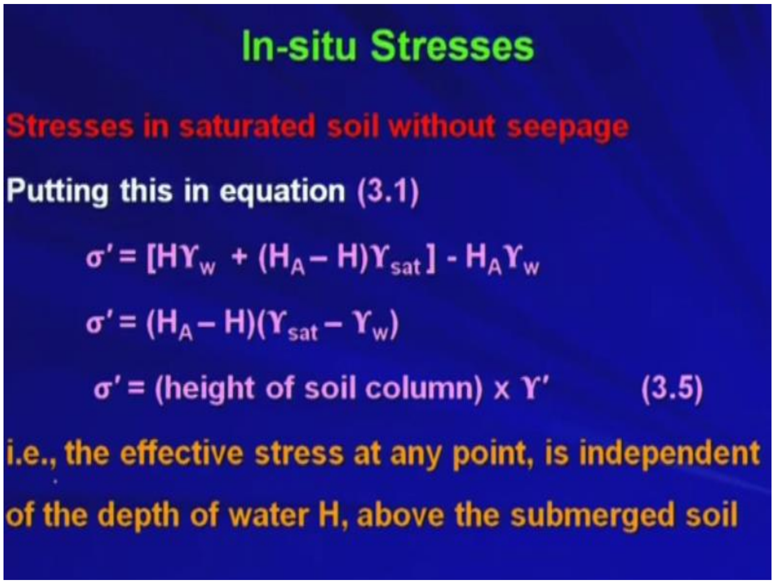

And we derived the equation or the expression of the effective stress and we have seen that the effective stress at any point is independent of the depth of water okay above the submerged soil. So, if you have the submerged soil or the saturated soil right so basically the effective stress is not dependent on how much water you have on top of the soil deposit. So, that is completely independent of that kind of water level or the water depth. So, effective stress is basically the sole property of the soil grain contact point stress right.

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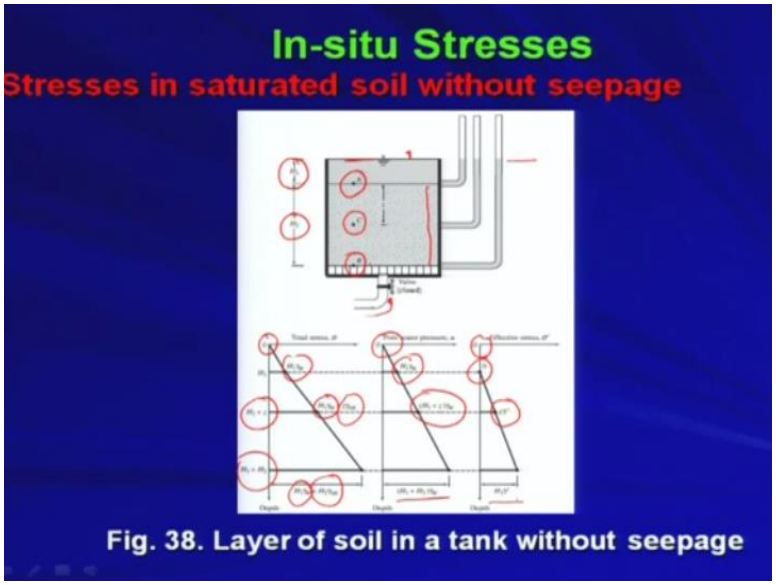

So, now we will be seeing that if you have I mean the saturated soil and if you want to find out the stresses developed in the saturated soil and there is no seepage happening in the soil deposit or the soil sample then how we can find out the different component of stresses. Now let us see this problem. In this problem, basically you have one soil I mean this is the soil deposit so this is your soil deposit and you are connecting one pipe so this is your connecting pipe okay.

Initially it is the valve is closed so that means initially you are saturating the soil and the actual water level is here. So, this is your actual water level and once it is reaching there you are stopping the valve. So, you are closing the valve. So, that means the small h 1 is the depth of free water which is lying above the top surface of the soil deposit or the soil sample and h 2 is the depth of soil sample or the soil specimen.

So, because of I mean this there is no water flow I mean actually I mean the flow is not happening so the complete the soil deposit as well as the water is in the stagnant phase so that is why you will be getting the same level of water at each and every location in the soil sample. So, now in this situation I would like to find out the stresses okay. Let us see how we can find out the stresses at different location.

Now first for example if we consider the point the top surface that is the surface here. At that time what is the total stress? The total stress is 0 right. So, there is no issue for that. So, I mean and then what is the pore water pressure at that location? Of course, the water head is not there. So, that is also 0 and eventually you do not have effective stress concept because the soil grains are not occupying the top surface of the (()) (3:42) okay.

So, that means at top point you are having total stress 0 as well as pore water pressure 0 whereas there is no information about the effective stress because effective stress is the sole property of the soil grain as I told you. Now if you travel from the top surface to the depth say h 1 and you come to point a say. Not at that point what will be the total stress? Total stress will be h 1 into gamma w. Am I right?

So, that will be the total stress because still you do not have any soil grain which will be giving you some component of the effective stress. So, the whatever stress is getting developed that is solely due to the I mean the free water which is coming on top of the soil specimen. So, that total stress is nothing but h 1 into gamma w and that is solely due to the pore water pressure. Therefore, your pore water pressure is also h 1 into gamma w whereas your effective stress is simply 0 right.

So, I hope that you are following this thing right. So, now if you travel from point a to point say some point c which is situated at some depth z from the top surface of the soil okay soil specimen. So, that means you are travelling to point c which is having the depth equal to h 1 plus z so that point. So, at that point the total stress will be h 1 into gamma w because of the free water plus z into gamma saturated right.

So, your soil is completely saturated so z into gamma saturated will be your will be I mean z equal to z into gamma saturated plus h 1 into gamma w will be the total stress. If you try to find out the pore water pressure at that location that will be simply h 1 plus z into gamma w because the water depth or the water level or the water level height is h 1 plus z so the pore water pressure will be simply h 1 plus z into gamma w. So, that you are getting here right and the relation is linear so of course so you are connecting all the points with the linear line or the linear curve. Now what about the effective stress?

So, now you will be getting some effective stress because now you are within the soil specimen and so you can expect some effective stress which is getting developed in the soil matrix right. So, the effective stress will be z into gamma prime so from our earlier discussion or the earlier knowledge whatever we have discussed so far regarding effective stress, total stress, as well as pore water pressure.

So, effective stress will be z into gamma prime. How we can get it? So, we can simply get it the total stress minus the pore water pressure that will give me the effective stress right. So, similarly if you travel to point b okay so at that time if you want to find out the different component of stresses then at that point your total depth is h 1 plus h 2 okay and you are getting the total stress as h 1 plus gamma w due to the free water.

That will be remaining constant right because you are not varying the depth of the free water surface okay during the say study. So, h 1 plus gamma w plus h 2, h 2 is the total specimen depth into gamma saturated as we have done for point c the same thing is coming here. So, h 1 plus gamma w plus h 2 into gamma saturated will be the total stress. Now what about the pore water pressure at that location?

That will be simply h 1 plus h 2 into gamma w so that is given here right. So, if you subtract the pore water pressure from the total stress you will be getting simply the effective stress which is nothing but h 2 into gamma prime or that is nothing but your gamma submerged right. So, if you do not have any seepage flow or the flow is not happening in the material so that means everything you are saturating it and you are trying to find out the stresses under rest condition.

So, there is no flow no disturbance in the soil matrix happening. So, in that situation so these are the different stress components and in that way actually you need to find out the stresses at different location of the soil to obtain the information about how the stress zone is getting developed inside the soil deposit right.

Now if we consider the seepage flow. Now in the same problem now if we consider the seepage flow that means I am now opening the valve. Instead of closing the valve I am now opening the valve and I am allowing the water to move inside or to pass through the soil matrix and it will come to the top surface. So, if it is happening that means upward flow upward seepage flow if it is happening then how the stresses are going to change that we will now see.

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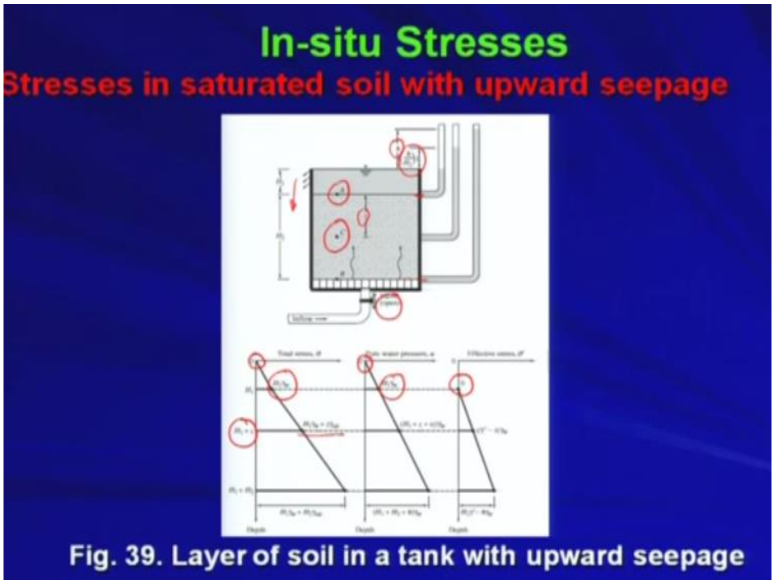

Fig. 39. Layer of soil in a tank with upward seepage

Now in the same problem as I told you now we are considering the upward seepage that means we are opening valve that means water is moving upward. So, in that situation see at the head difference so this is the top surface top surface of the water because after that water will be spilling out okay. Now the head loss happening for the water when it is travelling from the bottom surface to the top surface to this surface say that is happening with small h right so that is your head loss.

Similarly, at any depth z your head loss is h by h 2 that is the linear relation into h so that is the head loss right at different so if you consider so this is your say initial head and this is your say final head. So, that is the head loss which is causing the seepage flow which is causing the passing of the water through the soil matrix. Now say now I would like to find out the total stress, pore water pressure, as well as the effective stress under this kind of seepage flow or under this situation where the flow is happening in the upward direction.

So, now we will like to see at different locations how we can find out the total stress. So, at the top surface the total stress will be 0 so there is no issue whether it is whether seepage is happening or not because you do not have any head on top of that right. So, no stress is happening no stress is acting at the top surface or the free surface of the water. So, that is 0. Now what about the pore water pressure? That will be also 0 because there is no water level or the water depth on top of the top surface right. So, that is also 0.

Now what about the effective stress? It is not coming into the picture at all because you do not have the soil grain okay at the top surface because the top surface is occupied by the water only.

So, if the soil grain is not there you cannot have the effective stress because that is the property of the soil grain or the contact between the soil grain okay. So, now coming to point a which is at h 1 depth below the top surface.

So, at that time what is your total stress, h 1 into gamma w as I as we have seen in the last problem also when there was no seepage, so h 1 into gamma w. So, therefore your pore water pressure is same h 1 into gamma w. So, therefore your effective stress is 0 at that point okay. So, that means you are just on top of the soil specimen so your effective stress is 0. Now if you come to some point c okay. At that time, what will be your total stress okay.

So, c is located at a depth h 1 plus z from the top surface. So, that is here. So, your total stress is h 1 gamma w plus z gamma saturated which was same. So, h 1 gamma w is coming from the free water depth and the z saturated z into gamma saturated is basically coming from the soil participation or the soil contribution okay. So, if you look at this problem and the previous problem so then basically your total stress is not getting changed, that is remaining constant. That is the beauty but that is the main important thing which I want to emphasize at this particular time okay.

So, total stress basically they that is remaining constant. If you recall that was also in the previous case when there was no seepage that I mean at that time also you were getting the total stress equal to h 1 gamma w plus z into gamma saturated and during the seepage also you are getting the total stress at that at z you are getting the total stress as h 1 gamma w plus z gamma saturated same. Now let us look at the pore water pressure distribution. Let us see what is happening at the pore water pressure due to the seepage.

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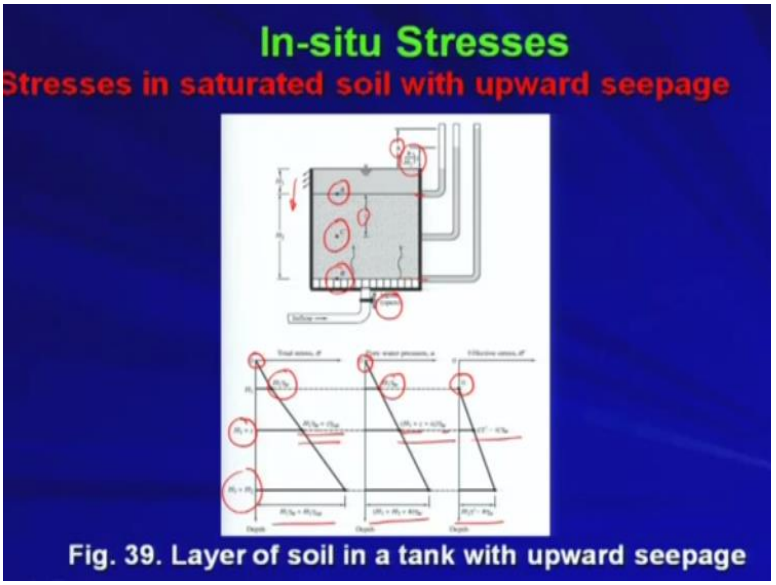

Now in the pore water pressure basically say basically h 1 plus z into gamma w that is nothing but the total pore water pressure at the depth agreed so which we have seen in the earlier case also when there was no seepage. Now because of the seepage happening you are getting some extra stress or extra pressure which is happening at the water body right. So, that is nothing but i z into gamma w right.

So, I mean from your seepage knowledge if you recall whatever we have seen in the seepage chapter that what is the seepage force you can calculate or you can find out the seepage force. So, now seepage force okay or the pressure we can find out and that is nothing but i z into gamma w. So, that component is nothing but the extra component or the additional component now it is getting added to the pore water pressure agreed.

So, now we can find out what is the effective stress. The effective stress is total stress minus pore water pressure which comes to z into gamma prime minus i z gamma w. Now what is happening. So, if you look at this, this is very interesting thing. What is really happening here? So, z into gamma prime that was the effective stress when there was no seepage. That you have seen in the earlier case right.

Now you are getting the effective stress as z into gamma prime minus i z into gamma w. So, this much the stress is getting subtracted from the effective stress due to the seepage only. So, if there is no seepage whatever effective stress you are getting now because of your getting some seepage your effective stress is going down or decreasing right. So, you have to remember or you have to really you have to be really careful when you are doing some design okay some geotechnical structure if it is under some static water right there is no flow happening in the water I mean soil body then whatever effective stress you will be getting okay you will you may get some increased effective stress or decreased effective stress due to the direction of the flow of course that is true. Now we are considering the upward flow that is why you are getting some reduction in the effective stress.

If it is the downward flow you will be getting some addition right, some additional effective stress. So, that but ultimately your effective stress is going to be disturbed due to the seepage flow. That is the only important thing. Total stress though I mean if you look at or if you design the problem based on the total stress that is not going to change, that already we have seen it. Total stress is remaining same.

Due to the change in the pore water pressure you are getting the change in the effective stress and so you must think about the effective stress when you are thinking of designing something okay. Now similarly, if I come back to point b okay which is the bottommost point, at that time the b is located at h 1 plus h 2 from the top surface. At that time, your total stress is remaining like that which is same as before when there was no seepage.

Now your what about your pore water pressure that is nothing but h 1 plus h 2 into gamma w plus h, h is nothing but the head loss okay h into gamma w okay. So, i into z instead of i into z you can write down i into h 2. So, i into h 2 is nothing but small h right. So, that is coming into the picture. So, that is your pore water pressure okay. Now what about the effective stress. That is h 2 into gamma prime that was there earlier right minus this much h into small h into gamma w is the reduction happening in the effective stress. Now we will see those things in the equation form and we will try to find out or try to derive those things.

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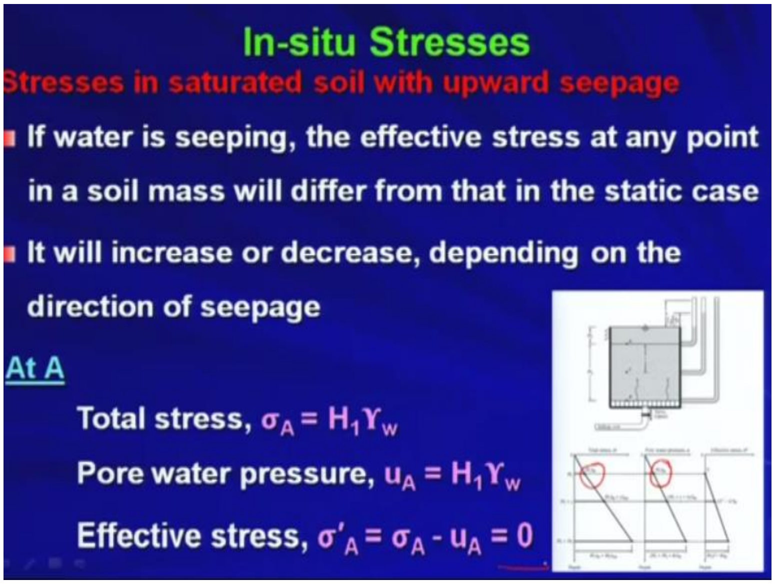

Now if water is seeping the effective stress at any point in a soil mass will differ from that in the static case right already we have discussed so far I mean whatever we have seen okay in different problem when there is no seepage when there is some seepage. So, depending on that basically you are getting some change or the variation in the effective stress okay. It will increase or decrease depending on the direction of seepage.

As we have seen in this case when the seepage is happening in the upward direction you are getting some decrease or the reduction in the effective stress but if you have the flow in the opposite direction that means the seepage or the flow is happening from top to down in the downward direction then your effective stress will be getting increased though your total stress will be remaining same but because of the direction of the seepage you will be you may get some decrease or increase in the effective stress.

So, effective stress is very important. So, that means if you consider I mean there is there could be a possibility that if you consider the downward flow right and if you try to increase the seepage I mean this flow I mean seepage pressure right so that will basically increase the effective stress but if you consider the upward flow then there must be some situation where basically your seepage flow or seepage pressure will be making the effective stresses 0. Do you understand?

Basically, I mean your effective stress you have h into z into gamma prime minus some part that is nothing but the seepage force or the seepage pressure. If that seepage pressure is going on increasing because of the increase in the flow right if the seepage pressure is going on increasing at certain point it may happen that the soil grains will lose the contact that means there is no contact force or the contact pressure is getting developed at the interphase of the soil grains so therefore your effective stress could be 0. So, we will come to that point later on what could be the consequence for that.

Now we will see whatever we have discussed or we have talked about that thing we will be talking in the equation form. So, at A the total stress sigma A is equal to H 1 into gamma w that already we have seen it so that is nothing but here. Then pore water pressure u A that is at point A okay is H 1 into gamma w because of the free water as I told you. Now effective stress will be sigma A minus u A that is the total stress minus the pore water pressure that will be coming as 0 fine.

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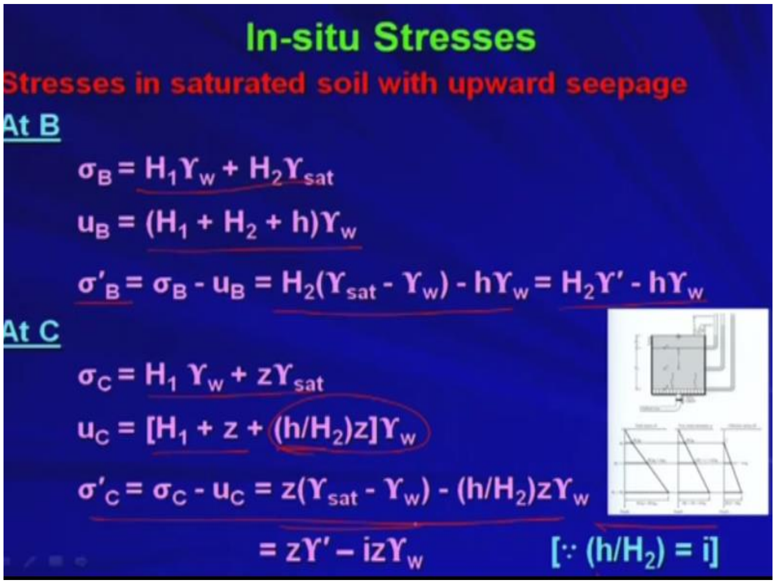

Now for point B your sigma B is nothing but as I told you H 1 gamma w plus H 2 gamma saturated. So, that will be remaining same. That is your total stress. Now this is your what is that? That is your pore water pressure. So, if you subtract the pore water pressure from the total stress you will be getting the effective stress which is nothing but H 2 gamma prime minus small h into gamma w. So, that is related with this equation okay.

Now similarly I can find out the stresses at point c which is located at some depth z from the top surface of the soil. So, there sigma c is given by that means the total stress at point c will be given by H 1 into gamma w plus z into gamma saturated, there is no change in that. Then u c that is the pore water pressure at point c will be H 1 plus z that is the total depth into gamma w plus h small h by H 2 okay into z into gamma w.

So, that this term so this is basically coming due to the seepage pressure right and this thing already you have seen it when we discussed about the seepage chapter at that time we talked about the how much you are getting the seepage pressure how much you are getting the seepage force all those things we have discussed right. So, in this part what is h by H 2 do you recall? What is small h?

Small h is nothing but the head loss happening when the flow is happening from bottom point that is point b up to some point c right or rather say a that is top surface. So, when the flow is happening from bottom point b to top point a at that time the head loss is happening small h agreed? Now when it is travelling from bottom point to some depth H 2 minus z right. At that time what is the head loss? So, h by z small h by H 2 into z. That is the i that will give you i and z right.

So, iz into gamma w basically the seepage pressure. Similarly, I can find out the effective stress at point c which is nothing but z gamma prime into i z because h by H 2, h by H 2 is your i okay is equal to z gamma w z gamma prime minus i z gamma w. Is that clear? So, in that way you have to find out the stress components at different locations under different situation like whether seepage is happening or not whether it is static condition or not. If at all seepage is happening then in which direction seepage is happening so based on that you can find out the stresses.

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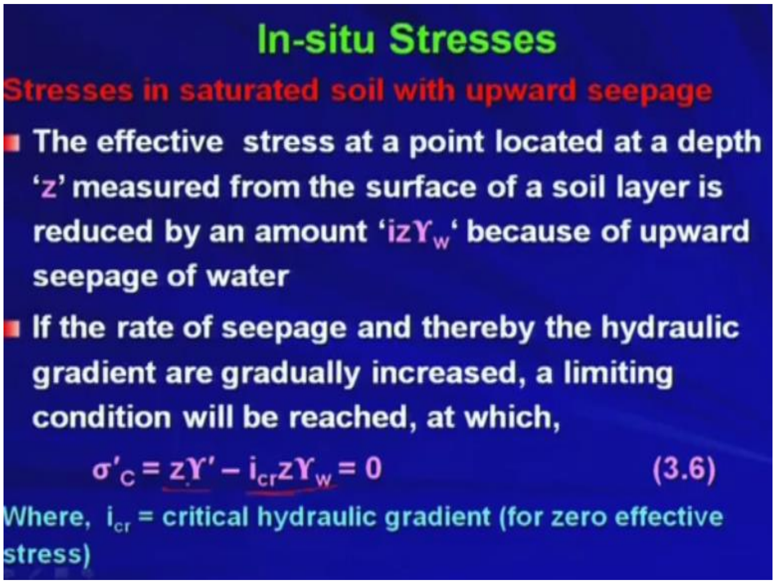

Now the effective stress at a point located at a depth z measured from the surface of a soil layer is reduced by an amount iz gamma w right. That much of reduction is happening in the effective stress because of the upward seepage of water. That already we have seen. That is z into gamma prime minus iz into gamma w. So, this much is reduction happening in the effective stress if the water is flowing in the upward direction that already we have seen.

So, if the rate of seepage and thereby the hydraulic gradient are gradually increased, that you can do right, at any time you can do that rate you can increase the rate of seepage and thereby you are increasing the hydraulic gradient. That is in your hand right or maybe in the field that may occur also right due to the I mean increase in the seepage right. If it is gradually increased a limiting condition will be reached at which sigma c prime that means at any location that c, c is the point in I mean in the soil specimen.

So, at any location of the soil specimen right the effective stress could be 0 because this is fixed right. Fixed means at any depth this is the component which you will be getting from the if you know the gamma submerged right. Now if you are increasing the i, i that is the hydraulic gradient and thereby I mean the seepage is increasing, rate of seepage, then basically this is going on increasing. So, at certain point at the limiting condition you may get the situation when this that z gamma prime is equal to i cr z gamma w.

That means the effective stress at point at that point basically is becoming simply 0. Now in that equation i cr is known as the critical hydraulic gradient for 0 effective stress. That means if you want to obtain or want to gain or want to achieve the zero effective stress and if you want to know actually so that is the limiting condition. Now if the effective stress is 0 means soil grains will be losing its contact and they will be flowing like anything right they will be flowing like fluid so because you do not have the contact.

So, how the soil particles will be holding each other. So, there will be no contact. So, they will be flowing or they will be floating in the fluid or the water fluid right. So, this critical hydraulic gradient is very important or this phenomena is rather very important.

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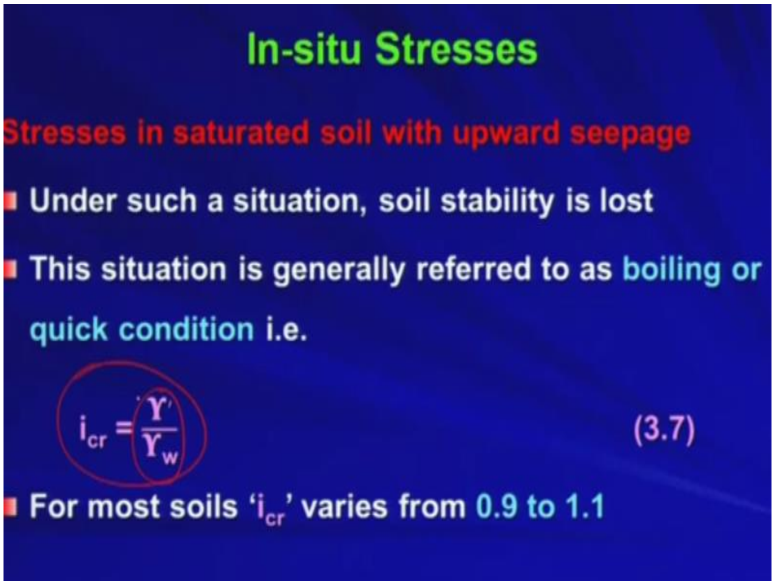

So, now when this condition achieved so under such a situation soil stability is lost because soil grain they are getting stick to each other because of their contacts. Now if this contact is getting lost then what will happen they will be floating right, they will be flowing in the water I mean soil fluid. Now this situation is generally referred to as boiling of soil or quick condition and that is given by i cr is equal to gamma prime then gamma submerged by gamma w okay.

From that equation if you look at this equation basically you will see that. From this you can find out i cr and from equation 3.6 you can find out i cr and i cr is given by this expression. Now for most soils i cr varies from 0.9 to 1.1 because I mean this I mean you have some generally you have the range of this gamma prime. Generally, it varies from this range to that range I mean for most of the soils and gamma w is of course known to you so i cr most for most of the soils i cr varies from 0.9 to 1.1 okay.

So, I will stop here today. So, in the next lecture we will be talking about the seepage force and other related issues. Thank you.