**Geology and Soil Mechanics**
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**Lecture - 58**
**Tutorial on Shear Strength**

Welcome everyone. So, this is the sixth tutorial section on Geology and Soil Mechanics. Now today we are going to discuss the last chapter regarding the tutorial section the shear strength of soils. So, we are going to start with a problem that was given for assignment and then we are going to proceed to the next problems in the chapter.

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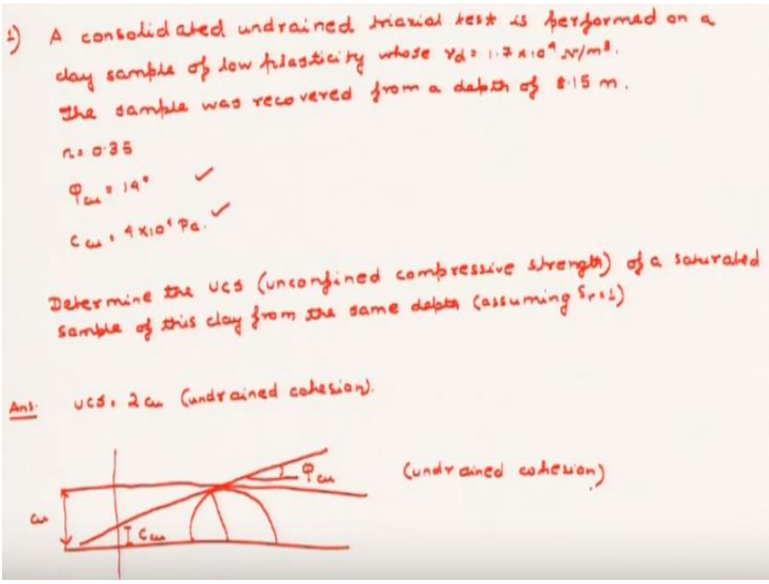


So, the problem that was given in the assignment was a consolidated undrained triaxial test, is performed on a clay sample of low plasticity whose gamma d or the dry unit weight is given as 1.7 into 10 to the power 4 N/m cube. Now the sample was recovered from a depth of 8.15 m. The porosity of the clay sample is given as 0.35 and the consolidated undrained triaxial test, gave the value of phi Cu as 14 degree and C c u as 4 into 10 the power 4 Pascal.

So, it is asked determine the UCS or also known as the unconfined compressive strength of a saturated sample of this clay from the same depth assuming S r or the degree of saturation e to 1 and that no moisture was lost during the process of handling. Now we all know that the unconfined compressive strength or UCS is generally given by 2 into Cu where Cu is generally given as the undrained cohesion.

Now you have to find out this parameter Cu from the given phi Cu and C c u. So, first let us find let us draw the Mohr circle condition for the consolidated undrained test,. So, this is how the Mohr circle looks like. This obviously is C c u. This is phi Cu.

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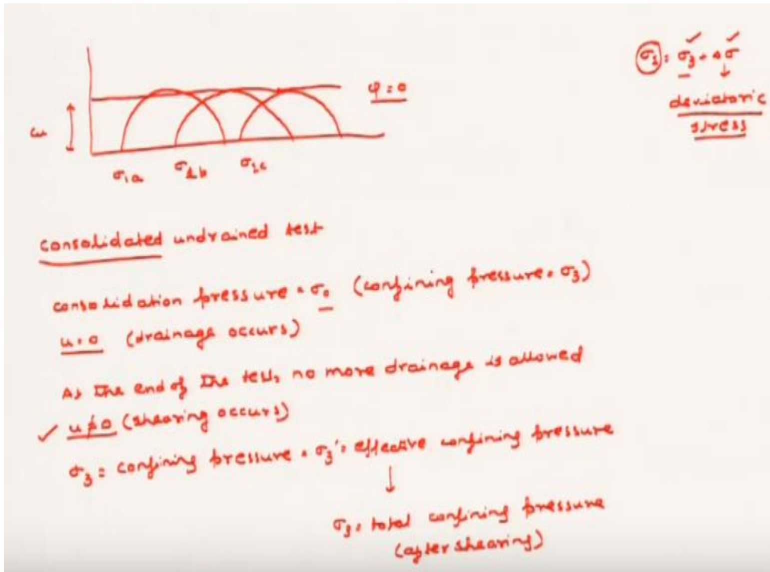


This point is touching and we all know that this value is Cu or value of undrained cohesion because as you all know that during a U u test, irrespective of whatever the pressure is let us say that the pressure here is sigma 1 here the pressure is sigma 1a this is sigma 1b and this is sigma 1c. So, irrespective of whatever the pressure is your Mohr circle your the failure line is always a horizontal line and it has a phi equivalent to 0 and this value is equivalent to Cu.

So, that is what I have also drawn here that this value is actually equivalent to Cu. Now you have to derive the expression from Cu from the given C c u and phi c u. Now you have to know at first that what happens during a consolidated undrained test,. So, during a consolidated undrained test, the first process that occurs is consolidation. Now during the process when consolidation occurs the consolidation pressure is same throughout the test,.

So, let us consider that the consolidation pressure is sigma 0. Now this is same during the entire process of consolidation. This is also termed as the confining pressure or given by the term as sigma 3 in case of a specifically in case of a triaxial test,. Now at the end of the consolidation u is equivalent to 0 or the excess pore water pressure has been dissipated since drainage occurs. Now at the beginning of the shearing stage or the beginning of the undrained phase what will happen is that this confining pressure sigma 3 will remain as the same while depending on whether it is stress controlled or a strain controlled test, you are going to change the principle stress that is sigma 1 which is also known as sigma 3 + del sigma where del sigma is the deviatoric stress.

Now these are all covered in the lecture so I am not going to discuss them in very details. So, this sigma 3 is same as the consolidation pressure sigma 0 while depending on the stress controlled or the strain controlled test, you are going to increase the del sigma and you are going to achieve sigma 1 where basically different values of failure will occur. Now let us say that so at the beginning of the shearing stage so sigma 1 so at the beginning of the sigma shearing stage the confining pressure is sigma 3.

Now at the end of the test, no more drainage is allowed because during the entire undrained phase no more drainage is allowed. So, some amount of pore water pressure is developed. So, u is not equal to 0 at the end of the shearing stage and at this point what has happened is that this sigma 3 which was initially confining pressure at the beginning of the consolidation at the end of the consolidation phase as well as since u was equal to 0 or drainage has occurred this had this was equivalent to an effective stress as well.

So, this was this can be also termed as effective confining pressure has now moved to total confining pressure after shearing because u is no longer equivalent to 0. So, the effective confining pressure at the end of the consolidation stage has now become equivalent to total confining pressure at the end of the shearing stage because the pore water pressure is not 0 because of the undrained sample.

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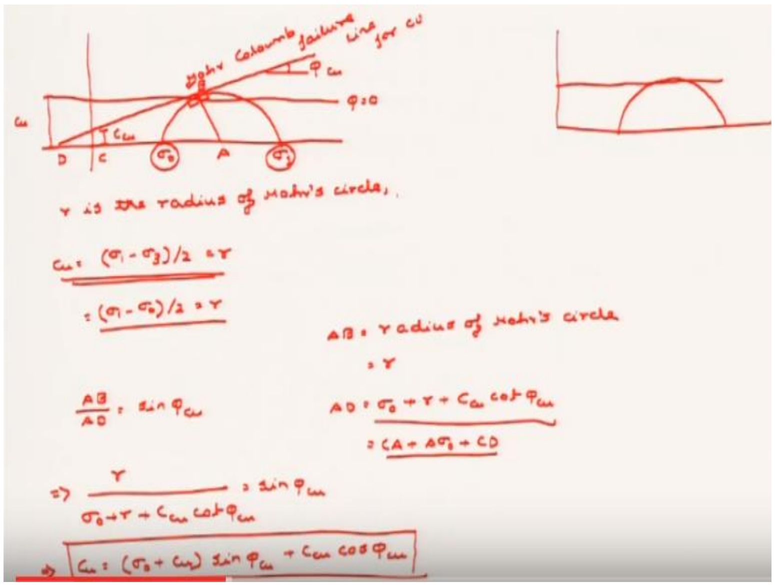

Now let us figure out that how do you find out this value of C. So, this is the failure line and obviously this is the Cu. This one is C c u, this one is phi c u. Now it will intersect the Cu will intersect at this point because this is the shear strength because this is the shear strength. You can see that this is the Mohr-Coulomb failure line for consolidated undrained and obviously this this Cu line which basically has a phi equal to 0 will intersect the circle at this point.

So, from here we can find out if r is the radius of Mohr circle then Cu is equivalent to sigma 1 - sigma 3 by 2 which is equivalent to r. This is known to everybody because this comes from the basic relation of performing a UU test, which basically UU test, is the peak point of the Mohr circle. So, obviously this is equivalent to sigma - sigma 3 by 2 equal to r. Now for our condition since you considered that sigma 3 is equivalent to sigma 0 so we will take sigma 1 - sigma 0 by 2 equivalent to r.

Another important point is that this r let us consider this point as A this point as B and this point C this is D. So, we can write AB by AD is equivalent to sin of phi c u because obviously this is the sin of phi cu because this is perpendicular always so this point is also so this point is also perpendicular. So, obviously perpendicular by hypotenuse is equivalent to sin phi so that is what you have written. Now what is AB? AB is nothing but actually the radius of Mohr's circle.

So, you can write this as r. What is AD? AD as you can see this point is sigma 0 because this is at the end of the shearing stage. So, this point is sigma 0. This point is sigma 1. If this is true then AD is equivalent to sigma 0 + r + C of c u into cot of phi c u. Now this can be also derived this can be also derived from the basic relation so I am not going into the details but if you can see from the geometry you can easily get this relation because sigma 0 is sigma 0 is the point from C to A CA, r is basically A sigma 0, and C c u cot phi is nothing but this length CD.

So, obviously if you add all together you will get sigma 0 + r + C cu cot phi. Now we put back in the original relation. So, r by sigma 0 + r + C cu cot phi c u is equivalent to sin phi c u. So, Cu from here is sigma 0 + Cu into sin phi c u + C c u into cos phi c u. Now this is what is the relation of the UU test, with the CU test, or basically this is the relation of the undrained cohesion with the consolidated undrained cohesion or consolidated undrained friction angle.

Remember that it should not cross you should always remember that when basically you are drawing the Mohr circle for a CU test, it should never cross the Cu line or the failure line should never cross the P because the same Mohr circle may not apply for an unconsolidated undrained test,. It is obvious that all these lines will intersect at the common point of failure but it is always advised that the Mohr circle may not be same in each one of the test,.

For a consolidated drained test, it may be different. For consolidated undrained test, it may be different. For an unconsolidated undrained test, it may be different or a UCS it may be different but they will always have the same common failure point so that is what I have drawn here. I have just let it pass this common failure point and I have derived this relation between Cu and phi c u.

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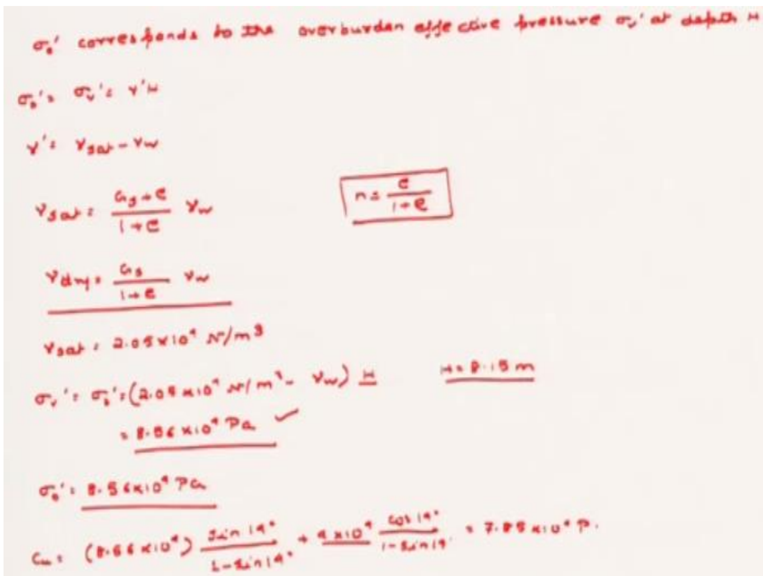

So, once this relation is derived now you have to find out what is the value of sigma 0 dash. Now obviously sigma 0 dash corresponds to the overburden effective pressure sigma v dash at depth H. So, sigma 0 dash is then equivalent to sigma v dash which is equivalent to gamma dash into H. No gamma dash is obviously is known as gamma sat - gamma w. So, gamma sat you can easily find out from the relation of gamma dry because gamma sat is G S + e by 1 + e into gamma w while gamma dry is equivalent to G s by 1 + e into gamma w.

So, from these 2 relations you can easily find out because the because e is given in terms of porosity and you know that n is equal to e by 1 + e. So, e is obviously given to you so from this relations it turns out that gamma sat is equivalent to 2.05 into 10 to the power 4 N/m cube. So, sigma v dash or sigma 0 dash is actually equivalent to 2.05 into 10 to the power 4 N/m cube - gamma w equivalent to 8.56 into 10 to the power 4 Pa.

So, this is basically the sigma v dash or the stress at that point into H sorry the height. So, this is basically equivalent to the stress at that point. So, the sigma 0 dash now you have found out as 8.56 into 10 to the power 4 Pa. The depth is already given as 8.15 m. So, H is equivalent to 8.15 m. So, if you put this all these values in this Cu is equal to sigma 0 + Cu sin phi c u C c u cos phi c u then we will get Cu as 8.56 into 10 to the power 4 sin 14 degree by 1 - sin 14 degree that is phi sigma 0 + Cu sin phi c u + C c u cos phi c u. So, plus 4 into 10 to the power 4 cos 14 degree by 1 - sin 14 degree. Now obviously this number is the C cu 4 into 10 to the power 4 Pa. So, from here you get that Cu is equivalent to 7.85 into 10 to the power 4 Pascal.

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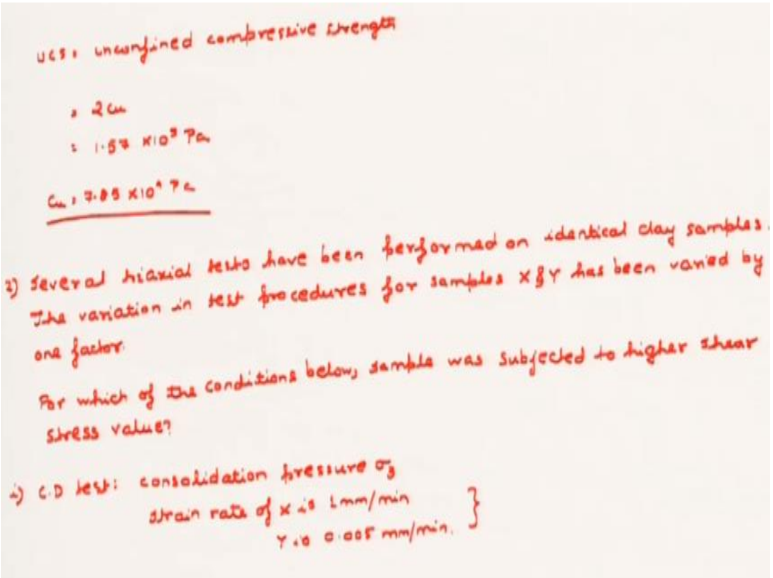


So, obviously the UCS or the unconfined compressive strength is 2 times of Cu which is 1.57 into 10 to the power 5 Pa given that Cu is equivalent to 7.85 into 10 to the power of 4 Pa. So, this is a simple derivation that how basically you can connect one triaxial test, with another like let us say a Cu with a UU or you can also connect CD with you can also connect a CD with a CU. But it is very difficult to connect a consolidated drained test, with a UU test, because an UU test, in case of a UU test, you see that all the Mohr circles are almost the same.

So, that is why the effective stress the effective Mohr circle is actually absent in all those cases. Now a general relation that basically describes the unconfined compression test, or UU test, and a CU test, has been derived in this formula. Now let us move to the next let us move to the next problem where basically we will discuss something about the about how the strain rate and in a strain controlled test, let us say the strain rate or basically in an over-consolidated soil how the over-consolidated soil will affect the behaviour of the Mohr circle. So, the second problem says that several triaxial tests have been performed on identical clay samples.

The variation in test, procedures for samples x and y has been varied by one factor. Now this is a more kind of explanatory problem rather than a solving problem so we would discuss this problem and it is asked that for which of the conditions below sample was subjected to higher shear stress value. Now the first question is that a consolidated drained test, is performed.

Now a you all know in a consolidated drained test, it is entirely a effective stress test, and it is a very slow test, so a consolidated drained test, consist of a consolidation phase and a drainage and a drained phase. In both the cases the total test, is the total stress is always equivalent to the effective stress because in each of these cases the total the pore water pressure or the excess pore water pressure is always equivalent to 0.

So, it is said that the consolidation pressure is sigma 3 and the strain rate is varied in this test,. So, this is a strain controlled test, Now a discussion about strain controlled test, and a stress controlled test, has already been discussed in the lectures in the lecture slide so I am not going to discuss all these things. The first thing is that here the strain rate of x is 1 mm/min while that of y is 0.005 mm/min. Now in which of these cases you will see that the sample is subjected to higher stress value. So, how do you find out this?

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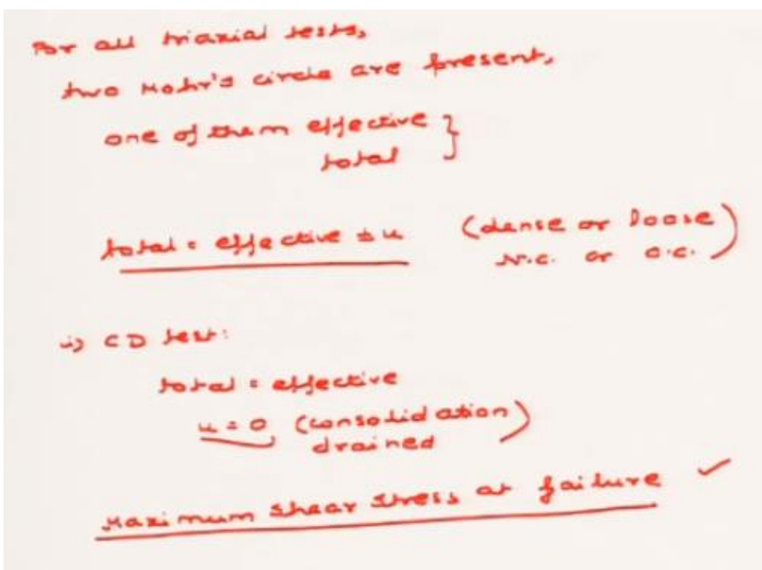


So, the first question is that now you all know that for all triaxial tests 2 Mohr circles are present. So, one of them is called the effective one of them is called the effective Mohr circle and the other one is the total Mohr circle. Now you also know this that the total is actually given by effective plus or minus u depending on whether the sample is dense or loose in case of sands or N C or O C in case of clays. So, depending on that if the test, is CD test, then just as I have said previously that the total is actually equivalent to effective because the u is always equivalent to 0 whether it is a consolidation phase or it is a drained phase and one important thing that what is the higher stress value.

Now in this case that higher stress value is basically which one has a maximum shear stress at failure is the one that basically has a higher stress value because you know this that a soil is always subjected or a soil sample is always subjected to only shear and in compression or tension in compression in compression it will never fail in tension it cannot take tension so obviously it fails whenever a tension is applied. So, only failure that you observe is basically in case of shear so that is why the maximum shear stress at failure or the higher stress value means the only stress that here is referred to is the maximum shear stress at failure.

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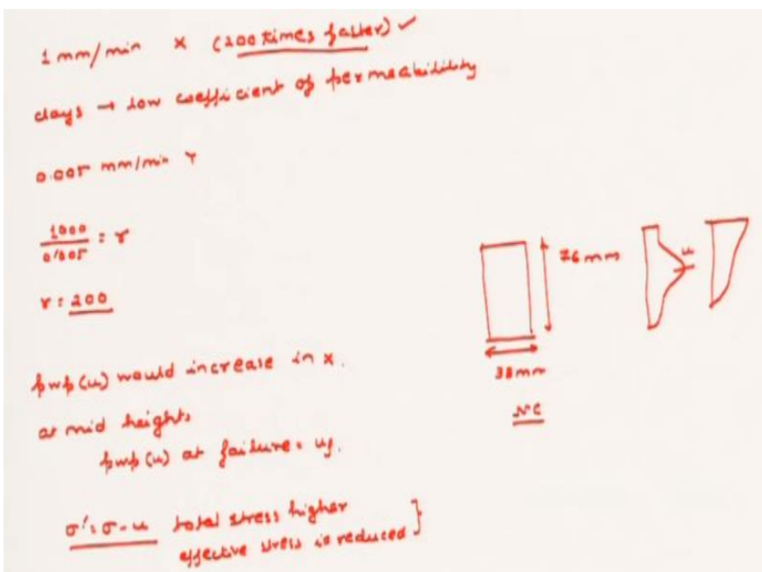


So, in the first case let us say a strain rate of 1 mm/min is applied to sample x. Now clays have a very low coefficient of permeability. We all known this from our permeability chapter so the sample y is 0.005 mm/min. So, 1 by 0.005 the ratio r it comes out to be above 200 times. So, the first test, goes 200 times faster than the second test, Now as the sample in case of clays has a very low coefficient of permeability so obviously a higher strain rate will not encourage the drainage rather it will prevent the drainage in this case.

So, clays have a very low coefficient of permeability so basically the pore water pressure or u would increase in x. So, generally what we do is that since the pore water pressure distribution may not be uniform so we will consider that let us say that this is a triaxial sample so this is let us say 38 mm and this is let us say 76 mm. So, the pore water pressure distribution along this sample may not be uniform.

It may be somewhat like this, it may be like this depending on whether the drainage is opened or that the drainage is closed so the pore water pressure may not be uniform. So, we will consider only at the mid height u okay. So, at mid height and we consider the mid height pore water pressure to be representative of the entire sample. So, at mid height pore water pressure or u at failure is let us say uf.

Now since basically you see that in case of x basically that the strain rate is much faster so in this case drainage is not supposed to occur. So, if drainage is not supposed to occur then obviously the sigma dash will be equivalent to sigma - u. So, in this case since it is sigma - u so the total stress even though may be higher the effective stress is reduced. Now this is considered this all things are considered considering that the sample is actually normally consolidated NC.

OC is just a special case so that is why we are considering only normally consolidated sample. Sigma dash is equal to sigma - u so obviously u have to plot the Mohr circle with a effective stress because you have to get the effective parameters. Effective parameters are more important rather than the total stress parameters.

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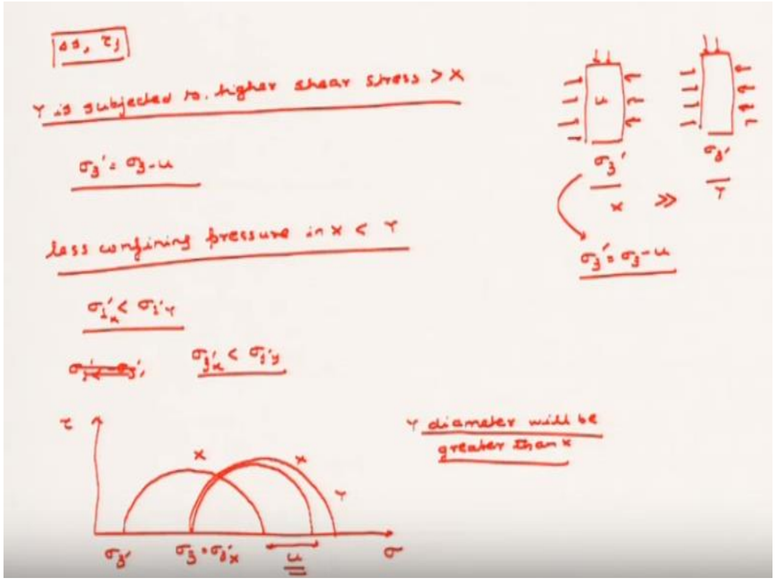

We have seen that from the consolidation itself because whenever you are supposed to find out let us say the settlement delta S or let us say the shear strength tau f you are always considering the effective stress parameters rather than the total stress parameters. So, for a normally consolidated clay if basically the sample is undrained then basically the strength is reduced. So, in that case you will see that sample y where basically the strain rate is much less is subjected to higher shear stress than sample x.

You can also think this from this point of fact that in case of sample y the sigma 3 dash is also reduced because and because u see that at the end of the consolidation phase both these samples are at the same stage. So, obviously at the end of the consolidation stage even this sample has a sigma 3 even this sample has sigma 3 dash this sample has sigma 3 dash as the effective confining pressure while immediately when the test, starts then what will happen is that since the since the strain rate in the sample x is much greater than the sample y so what will happen is that an internal pore water pressure will develop.

So, this sigma 3 dash then will reduce to sigma 3 as I have said in the previous question as well that sigma 3 will now be equivalent to sigma 3 dash thus will be equivalent to sigma 3 - u. So, this sigma 3 dash will be equivalent to now sigma 3 and u will be the pore water pressure. Now since this is a normally consolidated clay so obviously the sigma 3 dash at the end of the shearing will be less than the sigma 3 at the end of the consolidation stage.

So, obviously x is subjected to a less confining pressure than y and this leads to the peak stress of sigma 1 dash less for x less than sigma underscore y. So, obviously sigma 1 dash x - sigma 3 dash so obviously the failure or sigma at failure for x will be less than sigma at failure for y. So, the shear stress for x or shear stress basically for the sample x will be less than the shear stress for the y.

Now let us try to draw the Mohr circle and see how this comes out to. So, this is our sigma tau envelope. So, this is the sample sigma 3 at the for the sample x let us say at the end of consolidation. So, obviously this sigma 3 is equal to sigma 3 dash for x at the end of consolidation and similarly for y also it will start from the same point. So, obviously it will start from here y.

Now as you can see that after since it is a since it is a now it has become an undrained test, so obviously the effective stress now will go back. So, this is the sigma 3 dash for x and this difference is given as u or the pore water pressure that is developed during the sample x. So, for y obviously the diameter will be greater than x. So, obviously the shear stress in this case is greater. Now let us move to the next part or the next question.

So, we have known that basically with the increase in strain rate in case of a consolidated drain test, you should decrease the strain rate as far as you can but with the increase in strain rate what will happen is that the strength is going to reduce and you are not going to get a consolidated drained test, rather you are going to through consolidated undrained test, where basically the shear strength may not be the desired shear strength that you actually wish to find out.

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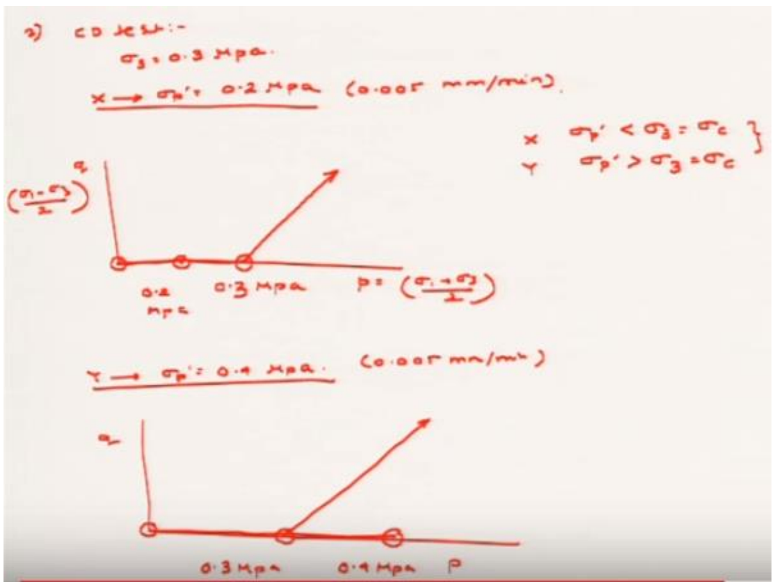


Now let us consider another consolidated drain test, for the same sample x and y. In this case the sigma 3 is 0.3 MPa. Sample x was subjected to a sigma P dash. Now you know from your definition of consolidation that sigma P dash is the preconsolidation pressure. So, sigma P dash is 0.2 MPa and the strain rate is 0.005 mm/min. So, if you remember the stress paths p and q so for the sample x basically it started from here and it moved along this line just because you see that during a preconsolidation during a consolidation phase there is no shear stress. So, obviously it was subjected to along this line because there was no shear stress so q is equivalent to 0.

So, this point is 0.2 MPa and then it was sheared and then it was sheared. A preconsolidation pressure of 0.2 MPa was applied and the consolidation pressure was 0.3 MPa and then it was sheared. This for the sample x. Now for the sample y the sigma P dash or the preconsolidation pressure was 0.4 MPa and the strain rate is 0.005 mm/min. So, in this case what happened was that this is qp. The sample started from this point. It moved along this line to 0.4 MPa then it reverted back to this point 0.3 MPa and then from here it moved along.

So, you see in one of the cases basically what happened the preconsolidation pressure that was subjected or sigma P dash is greater than sigma 3 or sigma c the consolidation pressure. This is in case of sample y while in case of sample x the sigma P dash is less than sigma 3 or sigma c. Now this will point out one important thing that what you should do in case of a triaxial test, and what you should not or basically whether the whether you should subject it to a stress that is greater than the consolidation pressure or not at any condition.

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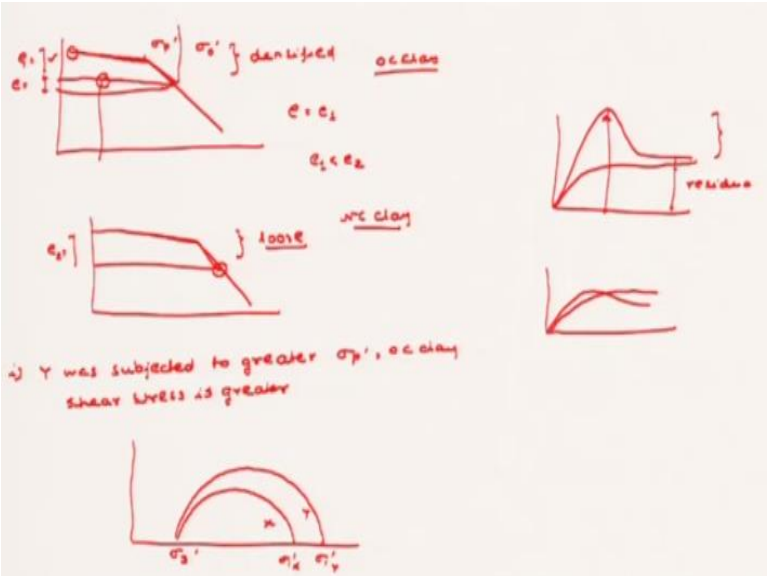

So, if you go back to the original definition of consolidation then you remember that in a consolidation curve if your sigma 0 let us say you start from here and your preconsolidation pressure is sigma P dash and let us say that if in case of preconsolidation pressure you move along this line and then you come back at this point sigma 0 dash and then you and then you can go back here this is preconsolidation pressure.

Then the void ratio in this case is less compared to the case where basically you just move along this line and move at a point that is greater than the preconsolidation pressure e 1 is less than e 2. So, if you cross a preconsolidation pressure and after that or if you go to the preconsolidation pressure and then you revert back to a position that is less than the preconsolidation pressure it is obvious that since the soil has been subjected to a stress history that is greater than the that is greater than the present stress history which is an example of an over-consolidated soil the void ratio in the first case will be much less than the void ratio in the will be less than the void ratio in the second case.

So, in this case this sample is much more densified than this sample. So, obviously if a sample is denisfied then obviously the sample for a the Mohr circle for a densified sample will have a higher shear stress compared to the Mohr circle for a loose sample. That is what generally happens. So, in this case also the sample y was subjected to greater sigma P dash. You can easily see from here from this figure that you are going back means this is this should be the what the void ratio should be so e is the difference in the void ratio that is created due to the between the initial and the final part due to the reverting back to the stress less than the preconsolidation pressure.

So, obviously this is an example of OCR or over- consolidated soil over-consolidated clay while this is an example of NC normally consolidated clay. Since it is an OC clay so obviously thus it will be subjected to a greater sigma P because you all know that for an OC clay the graph is somewhat like this but for an NC clay the graph is somewhat like this. So, at residual state they meet at the same point but actually at the ultimate state it is obvious that a normally consolidated OC clay will have a greater strength than NC clay.

So, y was subjected to a greater sigma P dash so it behaves as an OC clay so obviously the shear strength or shear stress is greater. So, let us draw the Mohr circle in this case. It is sigma 3 dash let us say and this is sigma 1 dash or let us say y and this sigma 1 dash for x. Now here in the case the standard is very less so obviously whether you go for an x or whether you go for a y in both the cases the effective stress is equivalent to the total stress.

Now remember that all these cases are regarding only one soil sample only if basically the 2 soil samples are entirely different from one another in that case obviously the dense sand and the loose the dense the dense or the loose may not behave in the same way. That means they both have the same P but since in this case both the soils just only one difference is there that one of them is over-consolidated while the other one is normally consolidated. That is why the peak in case of an over-consolidated clay is greater compared to that of a normally consolidated clay. You can also think it from the point of the preconsolidation point of view as I have showed from the simple consolidated graph.

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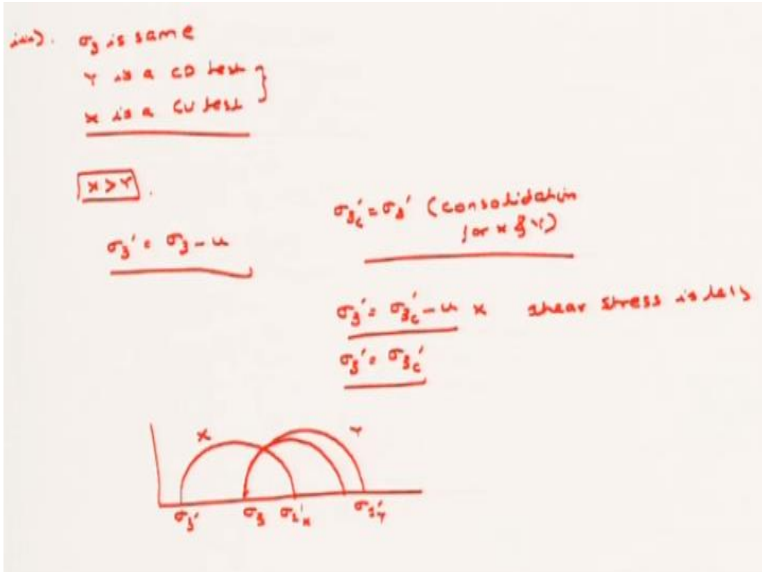

Moving to the third problem it is said that the sigma 3 is same while sample y is a CD test, sample x is a CU test, Now if you can remember this correctly then this is same as compared to the first problem because in the first problem also we said that since the strain rate in case of sample x was higher so actually it was a CU test, rather than a CD test. So, in this case also the stress x stress or basically shear strength of x will be greater than that of the y.

But remember that this is not always the case. In certain cases, it may so happen that the in case of a consolidated undrained test, the strength is low compared to that of the consolidated drained test. So, in this case you should keep you should not think this as a general recommendation that always in case of a consolidated undrained test, the strength is less than that of a consolidated drained test.

The effective stress is always less than that of a consolidated drained test. It may sometimes happen that it may be greater but it depends it all depends on how you prepare the sample or what whether the same samples are considered or not or whether there will be what will be packing void ratio what conditions you are subjecting it to. So, depending on all these cases these things are happening.

So, in this case also x is a CU test, obviously in this case the effective stress for x will be less because the sigma 3 or the consolidation pressure for both x and y at the end of the consolidation was same so sigma 3 dash is equivalent to sigma 3 dash at the end of consolidation for x and y but then what happened was that in one of the cases it was an undrained test, while in the other case it was a drained test, so sigma 3 dash in one of the cases reduced from the sigma 3 c at the end of consolidation while in the other case it was the same.

So, since at x it was subjected to a lower confining pressure it was subjected to a lower confining pressure so obviously the shear stress in this case is less and as you can remember that the graph is somewhat like this and so this is for x while this is for y this is sigma 3 dash this is sigma 3 sigma 1 this is sigma 1 dash for x sigma 1 dash for y. So, obviously x is subjected to a lower shear stress compared to that of y.

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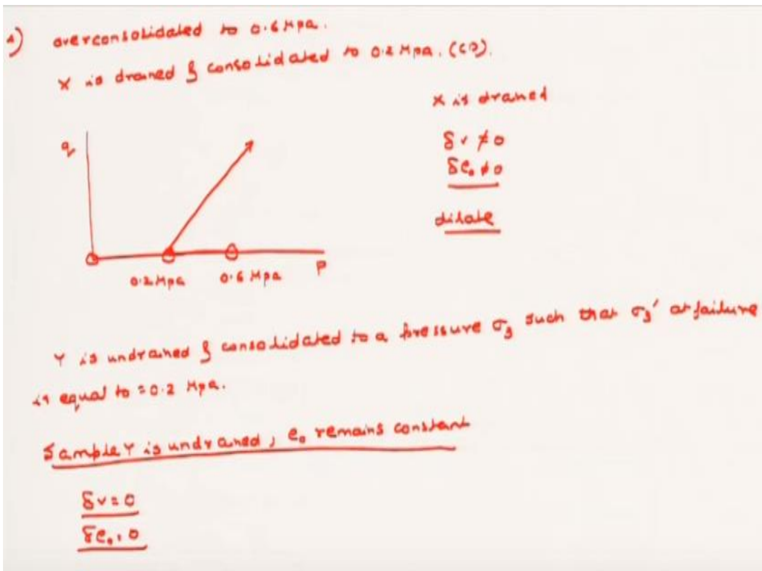


Now for the fourth problem it is said that both samples are over-consolidated to 0.6 MPa. Now sample x is drained and consolidated to 0.2 MPa. Now drained and consolidated means it is a consolidated drained test, so 0 0 then it moved back to 0.6 MPa. This is p this is q and then it reverted back to 0.2 MPa. So, this is an example of an OC soil and then it moved along this line 3:1. That is how it happened in case of x.

For y, basically it is said that it is undrained and consolidated to a pressure sigma 3 such that sigma 3 dash at failure is equal to 0.2 MPa. Now in this case y is undrained and consolidated. So, since y is undrained and since y is undrained and consolidated now we have to first plot that the limit sheared conditions as I have said in the residual state the conditions are the same. So, in this case also this conditions are the same.

Now sample y is undrained and the void ratio e 0 remains constant because since it is undrained so as you know from your definitions of an undrained test, that the delta v is equivalent to 0 this is delta v is equivalent to 0 so obviously the void ratio is also almost delta e 0 is also equal to 0 because the void ratio in case of a soil represents the volume change. So, sample since sample x is drained means since in this case x is drained so obviously in this case the volume change is the only factor.

So, delta v is not equal to 0 so delta e 0 is not equal to 0. So, if you consider it to be a over-consolidated soil then in case with the (()) (42:26) of draining or basically if you consider it even to be a normally consolidated with the (()) (42:29) of draining what will happen? The void ratio will either increase or decrease depending on whether the sample is dilating or basically compression during the shear. Now the clay is over-consolidated so obviously you know that the sample will dilate.

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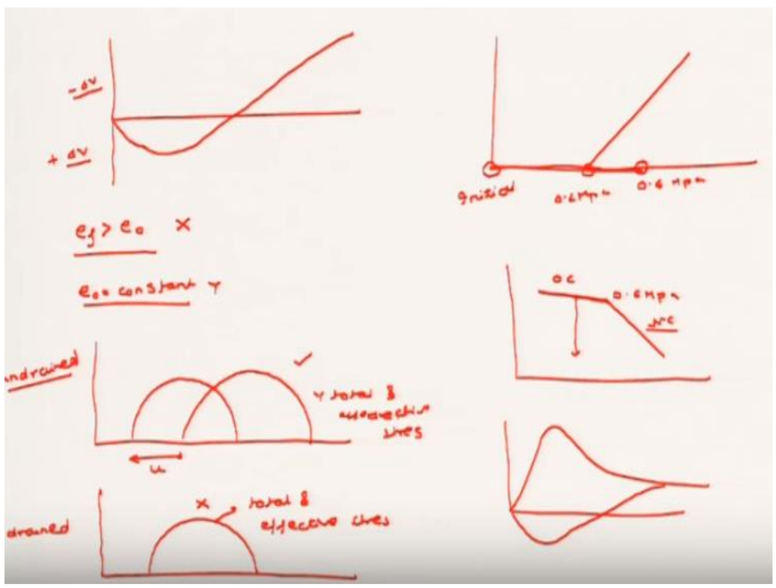


That means the volume change in this case if this represents the compression because we always take compression as positive in case of soil while we take tension as negative in case of soil so delta v will be in compression and then after it will increase. This is what happens in over-consolidated soil because I showed you just from the stress path diagram that this is the initial condition.

Then it moved along to 0.6 MPa because it was pre-consolidated and then it moved back to 0.2 MPa. So, as you know from the consolidation curve this is 0.6 MPa this is the OC line while this is the normally consolidated line. So, obviously it moved along this line and then it reverted back to 0.2 MPa. So, obviously it is in the over-consolidated range and since it is the over-consolidated drain you always know that an over-consolidated clay will behave like this in case of a stress while basically the corresponding volume change will be equivalent to dilation.

So, since its corresponding volume change will be equivalent to dilation so obviously the volume is increasing. So, the volume at failure will be greater than the volume at consolidation. While for the other sample you know that e 0 is constant. So, since for the sample since for since for one of the sample or since for the x sample you see that the volume is the volume is increasing since for the x sample the volume is or basically the void ratio is increasing while for the other sample the void ratio is constant.

So, considering from the concept of void ratio if you remember since the sigma 3 is almost the since the sigma 3 is almost the same undrained and consolidated and drained and consolidated for x the Mohr circle will again be less than the Mohr circle at y. So, just like the similar conditions this is at x this is at y so y this is the total and effective stress for y so this gap is let us say u and for x it will be here so this is the total and effective stress because x is drained this x so because x is drained so the total and effective stress will be same while y is undrained so obviously the total effective stress will be different.

Now this is for the case of y this is for the case of x. So, in case of x the volume change is more or basically the void ratio is more so obviously it is obvious that basically the shear strength in that case or shear strength in case of x will be less than that of y because you already know that in corresponding to the volume change it means it is a loose sample or basically behaving as a loose sample. While in case of y since the volume change was constant throughout so basically in this case you can say that it is almost a it is almost the same behaviour as it was experienced before so obviously the shear stress in this case is going to be more rather than that of x.

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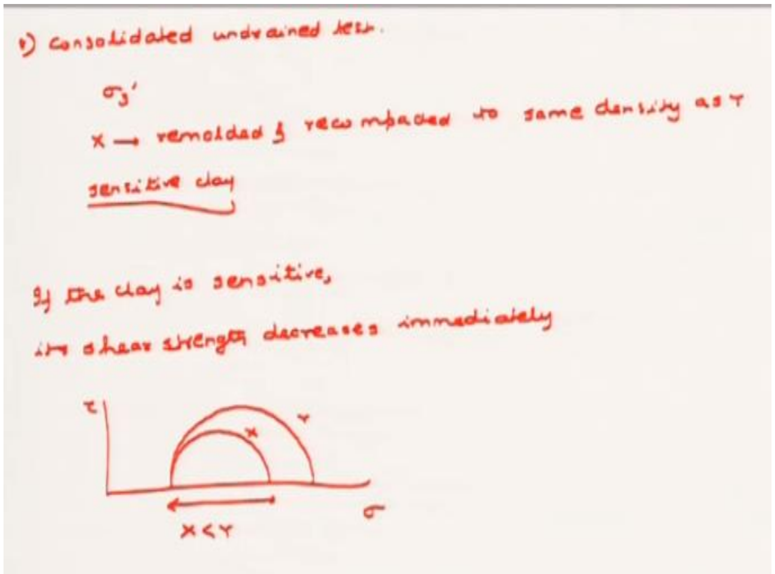


Now let us move to the last question which says that a consolidated undrained test, is conducted and the consolidation stress was sigma 3 dash. In case of x it was remolded and recompacted to same density as y. While in case of y it was not remolded, and compacted and there is one important thing to mention that the clay here is mentioned is sensitive clay. Now as you all know that when basically in case of if you consider a sensitive clay then when you remold it then it completely loses its shear strength.

Since it completely loses its shear strength so obviously the shear strength will almost decrease, almost decrease to 0 because you have seen with regards where basically you will see that the clay after remolding if it is a sensitive clay it will be remolding the shear it will flow like a liquid. So, if the clay is sensitive its shear strength decreases immediately.

So, obviously in this case without thinking in without thinking much you can say that the shear strength of x is less than y because in this case it is a consolidated undrained test, so I am not drawing the effective stress envelopes but you can see easily that whether since it is compacted to the same density so it does not matter that what is the effective stress envelope right now. So, x has a much less strength than that of y because of its remolding nature.

So, in this problem we have discussed that about how with the help of stress paths or how by applying basic concepts of the soil mechanics you can actually think that what should be the shear strength and whether the when you are comparing 2 samples whether the shear strength in case of a consolidated undrained test, or basically in case of a consolidated drained test, should be greater or less like I have said that previously that with the increase in strain rate like the simple inferences that we came across was that with the increase in strain rate what will happen is that especially in case of a consolidated drained test, with the increase in strain rate what will happen is that it will behave more like an undrained manner.

So, in this case if you behave if the sample behaves more like an undrained manner in this case the strength is going to decrease or increase depending on whether the clay is normally consolidated or over-consolidated. Similarly, if the sample is subjected to a preconsolidation pressure greater then obviously the sample will behave in an over-consolidated manner and obviously if it is a drained test, then its void ratio is going to increase so in this case the strength is going to reduce.

So, depending on all these cases you can actually you can actually find out that whether depending on the same sample for the same sample in different stress conditions how physically you can interpret the behaviour of the sample and the strength of the samples. Now we will move to the third problem. Now this third problem basically is a little bit on is a little bit concept of has a little bit concept of mechanics rather than considering all this Mohr-Coulomb failure conditions. So, in this case we will find out that how generally with the help of a triaxial test, you can find out the **cohesion in case** of a triaxial test, and then you can link it with the consolidation test, Poisson's ratio.

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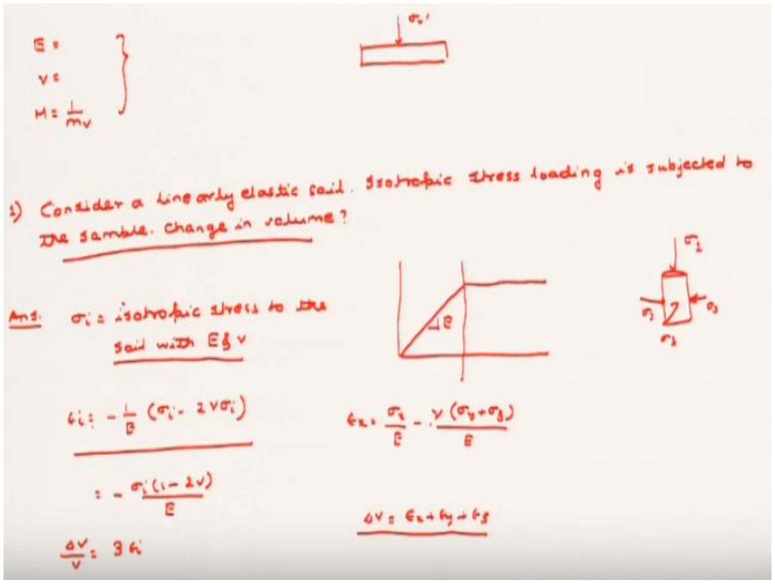


Now this is often considered in the field that basically we have to find out let us say certain parameter like e or the Young's modulus of elasticity especially or nu let us say or basically you have to find out the oedometric modulus or m which is basically the inverse of 1 by m v or the coefficient of volume compressibility. Now this cases it is not always possible or it is you cannot always perform the same test, or the different types of test, in the laboratory because of certain problems.

So, in this case how or what test, you should ideally perform and how you can easily find out that what is the conditions that are to be applied and conditions to be applied and the finding out the finding out this Young's modulus and then Poisson's ratio and oedometric modulus rightly from the test. So, there are certain assumptions however regarding this like suppose in case when you are finding out e then one of the major assumption is that you have to consider the soil or the stress-strain curve always within the linear elastic zone.

Then similar in case of Poisson's ratio also you have to consider this condition and for oedometric modulus similarly you have to consider that always the test, is one dimensional because in case you know in case of consolidation the confinement is applied from both sides. So, the test, only is one dimensional or the stress only is applied in one direction that is why it is termed as Terzaghi's one dimensional theory of consolidation.

So, depending on that you have to find out all this oedometric moduluses, the Young's modulus, and the Poisson's ratio. So, in this case first let us consider a linearly elastic soil and then it is asked that the sample is subjected to isotropic stress loading. Now writing now right now you know all that an isotropic stress loading is the same stress loading that is applied during the (()) (51:47) of consolidation.

That means all that means in all directions the confinement is the same or the pressure applied is the same. So, in this case isotropic stress loading is subjected to the sample and you are asked to find out the change in volume. Now remember that this is a linearly elastic condition. Linearly elastic condition means everything is within this range. That means whatever the stress is applied that is directly proportional to strain and the ratio of stress by strain is equivalent to the Young's modulus of elasticity.

So, if that is the case then for the time being let us consider that sigma i is the isotropic stress to the soil with E now you know E is the Young's modulus of elasticity or basically this part and Poisson's ratio as nu. Now from the basic mechanics definition we know that the strain can be written as - 1 by e into sigma i - 2 nu into sigma i.

Now 2 nu into sigma i means this is totally related to the triaxial stress conditions because you know actually it is written as epsilon x if you consider that is written as sigma x by E - nu into sigma y + sigma z by E. Now obviously we also know that in case of a triaxial this is sigma 1 this two sigma 3 sigma, 3 sigma so obviously sigma y is equivalent to sigma z and sigma x is the only factor that basically is the sigma 1.

So, that is what I have written sigma i - 2 into nu into sigma i by E. Now from here you can easily derive the definition as sigma i into 1 - 2 nu by E. So, then from here you can also find out the volume change delta V by v as 3 times of epsilon i because you know that the volume change is actually equivalent to the strain in 3 directions. Now a little discussion of all this we will all consider in the next lecture which will be the last lecture for the tutorial section. So, thank you.