Advanced Soil Mechanics
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Lecture - 30
Interpretation Triaxial Test - CD

Welcome all of you in the last lecture we have seen the interpretation of CU test. Now, the last one is consolidated drained CD test. So, we will see the interpretation of CD test in today's lecture.

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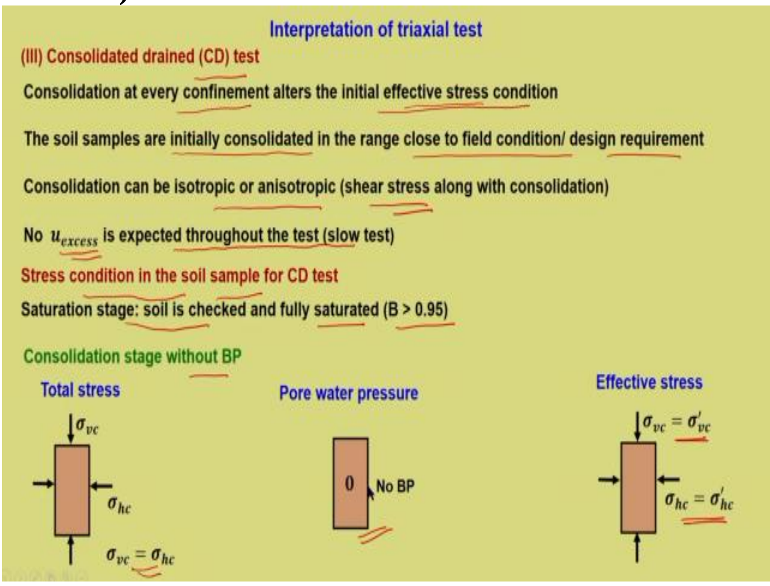

So, it is all about consolidated drained test CD test just like CU test consolidation at every confinement alters the initial effective stress condition at least we have to have 3 samples for obtaining Mohr Coulomb failure envelope and shear strength parameters. So, when we do we will have at least 3 consolidation pressure or 3 confinement σ_{31}, σ_{32}, σ_{33} in increasing order.

So, at every consolidation pressure, the initial state of the soil gets altered, it undergoes more densification and hence, the strength will also be different. So, that is what it means, and why it is happening? It is happening because the initial effective stress conditions are getting altered. Now, we need to keep in mind that the soil samples are initially consolidated in the range close to field condition or design requirement.

So, when we apply σ_3 for any specific field application, so, we have some clue about the anticipated overburden pressure. So, the confinement in the field will be definitely σ'_h which is coefficient of earth pressure multiplied by effective overburden pressure. So, we know the range what is expected in the field. So, in the lab also the confinement or the cell pressure that we choose will be in line with this.

This we have to keep in mind when we are doing to triaxial testing for very specific projects where it is extremely important that shear strength parameters should be close to reality. Now, consolidation can be isotropic or anisotropic. That is what is meant by isotropic consolidation that is what we normally do. Anisotropic means, we can also consolidate at some k_0 value for maintaining more realistic situation because isotropic consolidation as we discussed in the last lecture is not actually realistic we choose it for simplicity.

Now, if you choose to have anisotropic consolidation that can also be done, but we need to remember that during anisotropy, anisotropic consolidation, we are bound to induce some amount of shear stress into the sample. But since the consolidation pressure or confining pressure is not that high, that is not going to create too much of a problem and it is more like a densification. So, it is not going to create much issue but during anisotropic consolidation, we are bound to have shear stress developed within the sample.

No excess pore water pressure is expected throughout the test and that is how CD test becomes a very slow test. When you load a saturated soil sample, there will be immediately an increase in pore water pressure. Now, we have to do the loading in such a manner that during shearing pore water pressure does not develop and this is a very hard task when it comes to low permeable material. It is practically difficult to avoid pour water pressure.

So the loading rate will be excessively slow and that is how it becomes a very slow test. Similar to UU and CU test where we have discussed about the stress condition in the soil sample we will see or we will repeat it for CD test as well. Of course, the first stage is saturation stage it has to be fully saturated which is ensured by the B parameter greater than 0.95 so first let us see the consolidation stage without backpressure we have seen exactly same for CU test.

But it is important for completeness that we repeat this here as well total stress σ_{vc} and σ_{hc} and for isotropy consolidation $\sigma_{vc} = \sigma_{hc}$ pore water pressure equals 0 because there is no back pressure. So, effective stress will be $\sigma_{vc} = \sigma'_{vc}$, $\sigma_{hc} = \sigma'_{hc}$ there is no pore water pressure.

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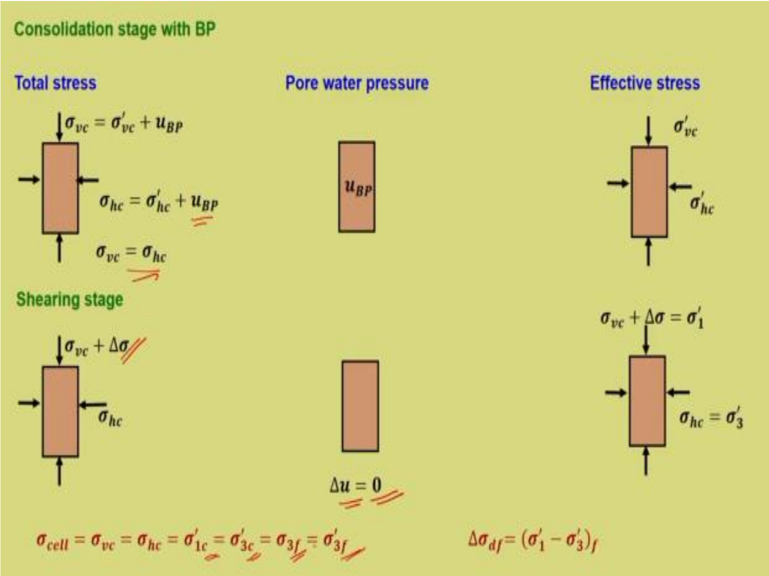

Consolidation stage with backpressure so, $\sigma_{vc} = \sigma'_{vc} + u_{BP}$ similarly, $\sigma_{hc} = \sigma'_{hc} + u_{BP}$ here it is same isotropic consolidation we are raising the pore water pressure also by u_{BP}. So, that there is no alteration in the effective stress condition it remains same as σ'_{vc} and σ'_{hc} as we have in the previous stage. Now, here when you apply back pressure, the back pressure line is kept open for drainage as well and the drainage happens against the back pressure and that is okay.

We should not think that since there is back pressure that is going to oppose the drainage coming out of the sample, this is mainly because, u_{BP} is not acting like an excess pore water pressure it is as I told in the previous lecture backpressure is more like a static pore water pressure. So, any pressure over and above will drain will create a hydraulic gradient which helps the flow from sample outwards so, that is not going to be a problem.

So, back pressure is kept open during the shearing stage as well so, u_{BP} remains in the sample. So, next comes the shearing stage so, here the deviatoric stress or the axial stress is applied $\Delta u = 0$ that is not considering backpressure, it is only for the shearing stage or the loading stage there is no development of pore water pressure because that is the condition which is important for this particular test.

Hence, $\sigma_{vc} + \Delta\sigma = \Delta\sigma'_1$ and σ'_3 so, it is the same. So, there is no pore water pressure so, everything remains the same. And here we have $\sigma_{cell} = \sigma_{vc} = \sigma_{hc}$, which is equal to σ'_{1c} that is only for confinement c stands for confinement which is equal to $\sigma'_{3c} = \sigma_{3f} = \sigma'_{3f}$ please note here it is equal why?

Because shearing stage there is no pore water pressure in the CU test this was not equal to σ_{3f} σ'_{3f} why because in the final sharing stage they will be poor to pressure development. So, the final effective confinement pressure will not be same as the initial the pore water pressure will be there and the final deviatoric stress is $\Delta\sigma_{df} = (\sigma'_1 - \sigma'_3)_f$ at failure.

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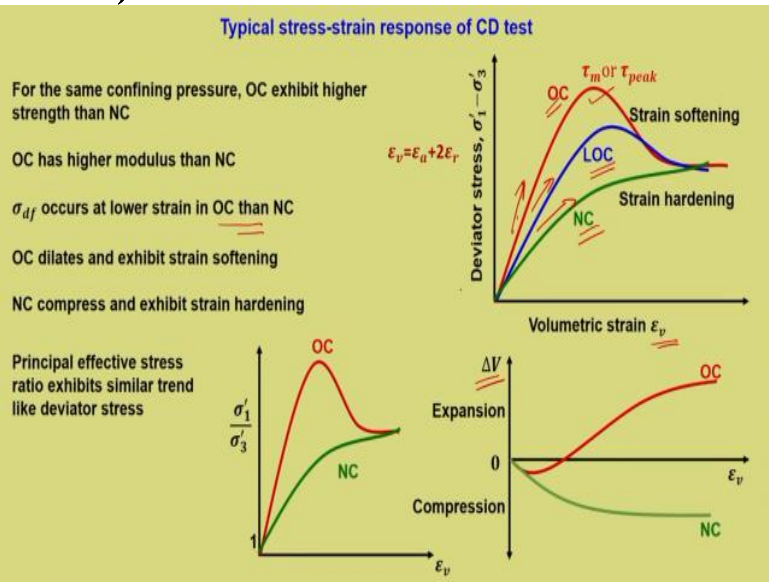

Now typical stress strain response of CD test, it is more or less same as that of what we have seen for CU test there is nothing changed changing and that is true also because all these stress strain responses are more or less general in nature. There are 2 classes as we have seen in the previous lectures. If you consider granular materials, it is loose and dense and when it comes to clay type of soils we have based on stress history, one is normally consolidated the other one is over consolidated.

Now, loose sand and normally consolidated clays have same class in terms of stress strain response, whereas, a dense sand and over consolidated soil falls in the other class which has a specific stress strain response. Now, this is not going to change so, that is why it will look same, you have the over consolidated, normally consolidated and lightly over consolidated please remember the peak of lightly over consolidated is not ensured always.

It depends upon how much over consolidation it has undergone rather it depends upon OCR over consolidation ratio, if the over consolidation ratio is close to 1 it may not exhibit peak, but it is still ligtly over consolidated. So, this I will not explain much, it is all the same and it is plotted with respect to ϵ_v one can always plot it with respect to ϵ_a as well. Now, here, please note here it is ΔV, ΔV is the volumetric change. Now, in the CU test, the only difference is instead of ΔV there it is Δu.

So, for over consolidated sample, there is an initial compression followed by dilation and for NC there is progressive compression. For the same confining pressure, OC exhibits strength higher than NC, let us say these are all conducted at same confining pressure you can see that OC is exhibiting a higher strength OC also has a higher modulus if you see the slope this is progressively reducing so OC has a stiffer material, because it is already subjected to that much pressure in the past.

So it has more stiffness σ_{df} occurs at lower strain in OC than NC. So, these are some very minute important points which we have to understand the peaking of the OC happens at a lower strain the peak happens because of dilation and the stiffness of OC material is more. So, all these minute points are important and we have to keep in mind OC dilates and exhibit strain softening I will not again get into those details, this has been repeated a lot of times.

So, you might be already knowing this NC compress and exhibit strain hardening and the principles stress ratios just similar to what we have done for CU test, it also exhibit the same kind of trend as we have got for deviatoric stress.

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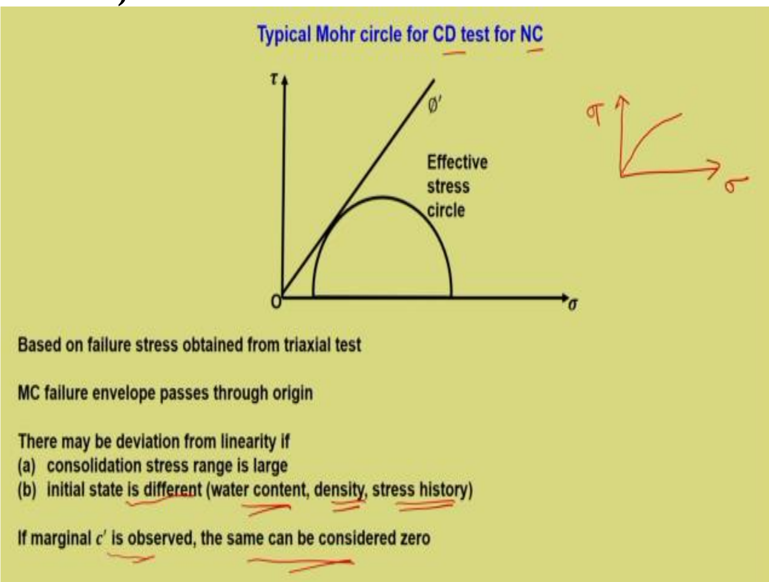

Now, typical Mohr circle for CD test for NC. So, remember it is CD test for NC yes, we have seen and for NC, we need to keep in mind that the failure envelope it passes through origin. So that is very important aspect which we have to keep in mind based on failure stress obtained from triaxial test MC failure envelope passes through origin there may be deviation from linearity, now, this appears to be pretty linear, we can also have kind of deviation from the linearity as well.

Now, this may happen if the consolidation stress range is large, this aspect also we have discussed in our previous lecture, as the normal stress goes on increasing there will be a kind of restriction in the movement when there is restriction in the movement the friction mobilized will be coming less and hence the friction angles start reducing. But, at the same time, since the particles are coming closer to each other, it can exercise more cementitious effect and this may not be a real cementitious effect.

But when the particles comes closer, there is a kind of apparent bonding that gets developed because of which the cohesive intercept appears or it becomes more. So, that is what will happen at a higher range or when we are considering a wide range of confining stress, it can also deviate from linearity if the initial state is different. Now, when we are conducting the shear strength test specific for a material at a particular place, we need to make sure that we have identical samples, now what is meant by identical?

The initial state of these samples should be same and when initial state is same, it means that the initial effective stresses are same. Now, if initial effective stresses are same, it is going to have a comparable strength, but then the strength will be different depending upon the amount of confinement that we give later so that is how it works. So the initial condition of the samples should be similar or identical.

Now, if there is deviation from that, like we have a different water content or different density, or even there is change in stress history, then that is going to create or that is going to give us Mohr circle of unexpected diameter that means, it is not a proportional increase in the diameter rather there will be changes now, this exhibits non linearity so that is what it means. Now, if marginal c' is observed, we know that the soil sample is normally consolidated we conduct the test.

And we find that there is a marginal c' that is coming we can easily ignore it provided we know that the soil sample is NC we can neglect this marginal c' and force the failure envelope through origin. So, this c' or the intercept can be considered 0 so, that is up to our judgement. So, there are cases where you even though we know for NC it passes through origin it may so, happen that it will not pass through origin and the very marginal c' is observed so, neglect that.

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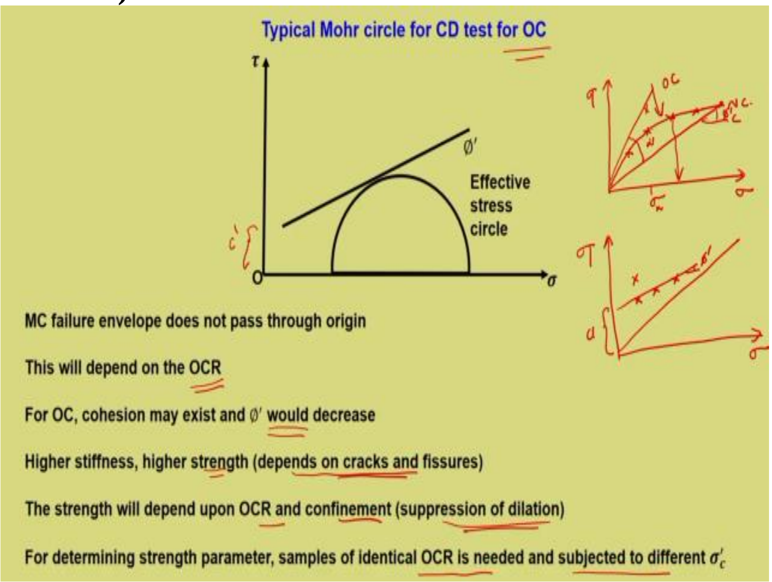

Now, let us come to a typical Mohr circle for CD test for OC is this we have seen in the CU test as well τ versus σ Mohr circle and the failure envelope gives ϕ' and it also give a kind of c' the intercept Mohr Coulomb failure envelope does not pass through origin and how much the intercept is that will depend upon the OCR how much the soil sample is over consolidated if you remember the plot, we have seen this before.

So, this is for NC or critical state friction angle and we have already seen this response and we have drawn like this. So, this comes for OC now, these points where it will fall this will depend upon the OCR of the sample. So, if the OCR is high over consolidation ratio is high that means that it is heavily over consolidated if it is heavily over consolidated the dilation angle will be more than what is dilation angle this is the angle over and above the critical state angle.

Now, this is the critical state angle ϕ'_c. So, if the over consolidation is more, let us say this is the σ_n. Now, corresponding to this, if the over consolidation is more than what happens the point shifts upwards. So, this dilation angle increases. So, OCR also determines the kind of c that we are going to get for OC, cohesion may exist and ϕ' would decrease as compared to NC the ϕ' is going to decrease.

Because it is the particles are pretty close to each other and hence the mobilization of friction is limited by its movement but since it is close by it develops a kind of cementitious characteristics, I will not say it is real cementation but a bonding is developed. So, that results in a higher c' then NC and lower ϕ', now, low ϕ' for OC does not mean that this strength will be lesser than NC it will be still more but as you can see here, this is the OC part from here to here.

You can see for every point the strength of OC is greater than NC, higher stiffness, higher strength for OC, but the strength will depend upon the amount of cracks and fissures, when it is over consolidated it is also likely to have more cracks and fissures depending upon the kind of tensile stress that gets developed within the sample. Now, this will enable to have lesser strength.

So, when we say higher strength, it is not necessarily always higher strength, the presence of cracks and fissures also determine what kind of strength it will have the strength will depend upon OCR and the confinement. Now, another aspect we discussed earlier is the kind of confinement that we give. Now, when the confinement is more it suppresses the dilation so, that also becomes very important.

So, that is why it depends upon OCR as well as the kind of confinement and confinement determines the kind of dilation because confinement can suppress dilation for determining strength parameter samples of identical OCR is needed and subjected to different σ'_c. So, sometimes when we explain based on this figure, there will be a sort of confusion on how the OC parameters can be determined. Now, this remains true and but in this particular figure, there are 2 things that is happening here.

For example, this particular point can be as a result of a particular OCR and which corresponds to this particular confining stress or the normal stress. So, if I redraw this now, let us say that there is an OCR corresponding to which a given confinement based on which I get a point here. Now, for the same confinement, I have a different OCR, then or a higher OCR then the point will go up because it exhibits more dilation.

So, that is what is going to happen so, one aspect is OCR. Now, if you want to determine the strength of a given soil sample, it is ideal to have identical OCR. So, 3 samples of same OCR so, then what is changing is the confinement now, for let us say this is a particular OCR now, the same OCR at a higher confinement will give another point. So, this is what we draw and we get c' and ϕ', so that is what it happens. So, when you read this particular graph and this particular graph, we need to understand clearly how the shear strength parameters are established for an OC sample.

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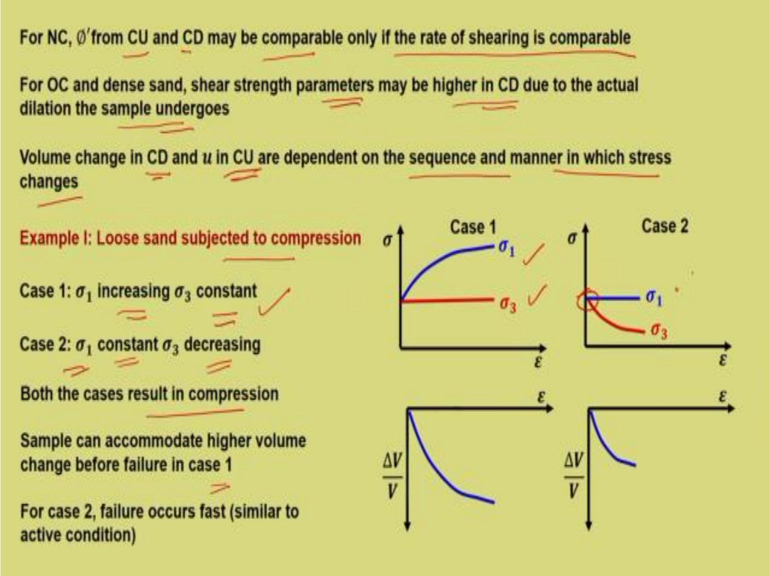

For NC, ϕ' from CU and CD may be comparable only if the rate of shearing is comparable, this is very important. Now, why are we doing CU and CD we have already seen that CD is a slow test and for most of the time for clay kind of soils we adopt CU for obtaining what the effective stress parameters. Now, this effective stress parameters have to simulate or resemble the long term condition that exists in the field which is in fact same as CD.

Now, a comparison of CU parameter the parameter which we obtained from CU, and the parameter which we obtained from CD, if this, need to be comparable, then it is essential that the rate of shearing also has to be comparable. Again this is not going to get fulfilled all the time. Now, if the rate of shearing is going to be that slow CU test also will become slow. So, we need to basically understand there will be some deviation from reality, that is the whole purpose of telling here.

For OC and dense sand shear strength parameters may be higher in CD. Due to the actual dilation the sample undergoes, what this means is that in the CD test, there is actual dilation which is happening not that tendency to dilate and the particles have to do the work against the loading the dilation is a phenomenon which is against the loading against the compression. So, more work is done in this particular case.

And hence, that resembles in higher strength parameters in the case of CD. Volume change in CD and u in CU it is also dependent on the sequence and manner in which the stress changes. What it means is that when the shearing happens the volume change that happens because CD is always associated with volume change and u is there in CU these changes is basically dependent upon the kind of the manner or the sequence in which the stress also changes.

So, this also determines what kind of response we are going to get so, that we will understand with the help of some examples. So, first example is loose sand subjected to compression. Now, we can induce this compression in 2 different ways. The first way is case 1 that is σ_1 increasing σ_3 constant this is the typical conventional triaxial testing, which you can see it here.

So, here the constant σ_3, whereas, σ_1 goes on increasing, case 2 is σ_1 constant and σ_3 decreasing as you can see here σ_1 is kept constant and σ_3 is released. So, what is happening if you have a cylinder which is acted upon by σ_1 and σ_3, where it may be equal in the beginning that is what this particular point is the actual stress is kept constant and the σ_3 is released.

So, when it is released, the tendency of the sample is to compress so, both action case 1 and case 2 results in compression. So, both the cases results in compression now what is the kind of volume change response that we obtain it is shown here sample can accommodate higher volume change before failure in the case of case 1 for this particular case, the failure happens a bit later the strain at which the failure happens will be delayed as compared to case 2 where release of σ_3 results in quick failure.

So, a higher volume change can be accommodated for case 1 as compared to case 2. Now, please remember case 2 is more like a release and this is almost similar to an active condition that is existing in the field. So, when there is a release the soil tend to expand or it goes away from each other. So, it is a kind of same response that we simulate using case 2. So, we can see that how the manner in which or the sequence in which the stress changes in these 2 cases will result in a different kind of response.

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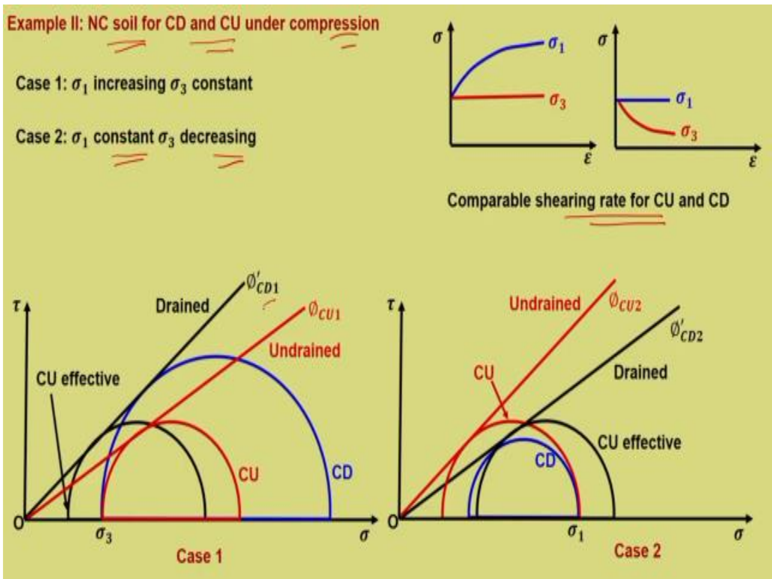

Now, we will see another example, example 2 the earlier one was for granular soil sand, and here we will take an example of NC soil for CD and CU under compression again, case is same increasing σ_1 σ_3 constant, case 2 is σ_1 constant σ_3 decreasing, so, it is the same type of response. Now, only important aspect that we need to keep in mind is in the case of comparison, both CU and CD the shearing rate has to be same. Now, what will be the implication of this on the overall test results so, for case 1 let us draw the case of CU first.

So, CU Mohr circle envelope ϕ_{CU1} that is undrained case corresponding effective stress circle is CU effective which is given by this now, this is a drained response this we have already seen while discussing CU. Now, for the same sample we have conducted CD test, so, CD test is this you can see that the strength is higher for the same σ_3. Now, this will give us the drained envelope and the failure angle that is ϕ'_{CD1} so, this is about case 1. Now, case 2 is σ is constant and σ_3 decreasing.

So, let us see how we can draw that is tau versus sigma. So, for case 2 first let us see CU and we get the CU and this is the undrained failure and I will not say failure envelope undrained trend or linear trend which is given by ϕ_{CU2} the corresponding effective stress circle now, here you have to understand in this case it has moved in the leftward direction because there was positive pore water pressure.

Now, in this particular case, σ_3 is getting released and hence, pore water pressure tends to reduce and it tends to become negative, because it is a release that is happening for the soil sample and that is the reason why it is shifting rightwards. And here σ_1 is constant so, the consolidated drained test envelope also should start from here. So that is what you can see that the diameter of the CD is quite less.

Now that means is that the strength corresponding to CD is pretty less than the undrained case for a constant σ_1 case, why this is so we will explain in shortly. So the drained envelope or the failure envelope ϕ'_{CD2} Mohr Coulomb failure envelope can be plotted like this that will give us ϕ'_{CD2}. So we have ϕ_{CU1} for case 1 ϕ_{CU2} for case 2 ϕ'_{CD1} for case 1, ϕ'_{CD2} for case 2 now, let us discuss this.

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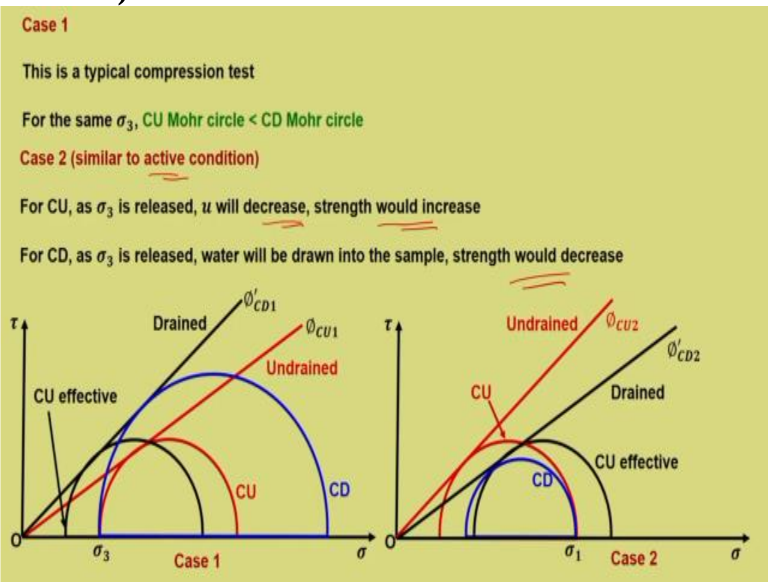

So, case 1, this is a typical compression test all of us know only this particular test. Now, for the same σ_3, CU Mohr circle is less than CD Mohr circle, this is quite expected case 2. Now, case 2 is similar to active condition, we have already told this, this is case 2 for CU, as σ_3 is released, u will decrease hence strength would increase. So, that is why it is shifting towards right for CD.

Now what is happening to CD as σ_3 is released, what is happening is because of this release, it has a tendency to draw water inside there is a kind of negative suction kind of thing developed because of this release. Now this draws water in the case of drained enveloped or drained testing, when water gets in, we know that the strength is going to be small or it is going to fall. So that is what is happening and hence the strength would decrease and hence a smaller Mohr circle corresponding to the same σ_1. So, CD Mohr circle is less than CU Mohr circle.

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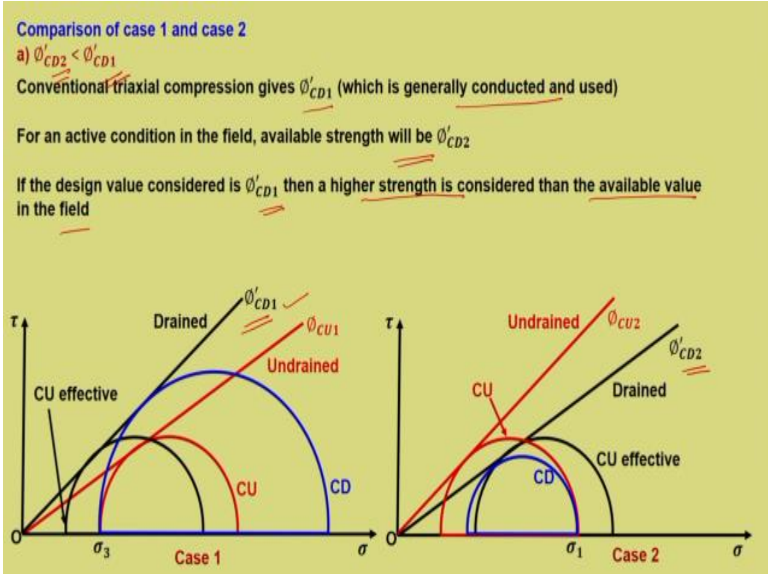

Now, comparison of case 1 and case 2 the same envelope, which we are showing case 1. So we have case 1 and case 2 so it is the same figure that we have drawn. Now we will try to compare some important aspects of these 2 figures. The first comparison is ϕ'_{CD2} less than ϕ'_{CD1} that is ϕ'_{CD2} the drained characteristics is less than that what we have from the normal compression tests that we do in the lab.

So, this is a kind of release test whereas this is a compressive test that is having both are compressive tests, but this is the general triaxial testing that we do now, note that this particular point, what is the implication of this, we already know that case 2 resembles closely the active condition. Now think of an active condition that exists in the field and we want to know what is the shear strength parameter corresponding to that a sample is brought to the lab this particular aspect is not clear to us.

And hence we do a normal compression test the one which is σ_3 constant and σ_1 increasing, we end up with ϕ'_{CD1} this particular value or this particular value, but the actual condition of the field is close to active condition and hence the available strength of that particular soil will be ϕ'_{CD2}. So, what we are doing is we are supplying a higher value of ϕ'_{CD1} compared to ϕ'_{CD2}.

So, conventional triaxial compression gives ϕ'_{CD1} which is generally conducted and used. Now for an active condition in the field, the available strength will be ϕ'_{CD2}. So, if the design value considered is ϕ'_{CD1} then a higher strength is considered then what is available in the field what is available is ϕ'_{CD2}. So, these are some important aspects which we need to keep in mind now is this going to result in some type of failure may not be because we always give adequate factor of safety to account for all such uncertainties.

So whether failure occur or not, is not the question, what is important is we need to perform a triaxial testing, which is very close to the field situation. So that is the whole purpose of this particular discussion. Now, at the same time, we also need to keep in mind triaxial simple compression triaxial testing, it looks very simple, but it is really complicated. To get a very good result from triaxial testing, there is a lot of pain involved and only those who continuously work on triaxial testing will be able to produce a good set of results.

Otherwise, there will be a lot of over sightedness which is possible in this very simple test. Because we have lot of controls in the case of triaxial testing, because of which it makes it much complex than what it appears to be. So there are a lot of things like this and what actually is happening in the field and for all those conditions we simply perform a triaxial compression, because that is what is conventionally possible.

All other kinds of tests needs some specific and skilled manpower for performing this and this is where the shear strength parameters that we obtained from the lab it deviates from the actual results and for the same reason, geotechnical engineering or the strength based problems, it becomes highly uncertain and it gives ample justification for considering these on a probabilistic scale to account for these uncertainties just to add to why and what is the implication of these kind of over sightedness or uncertainties.

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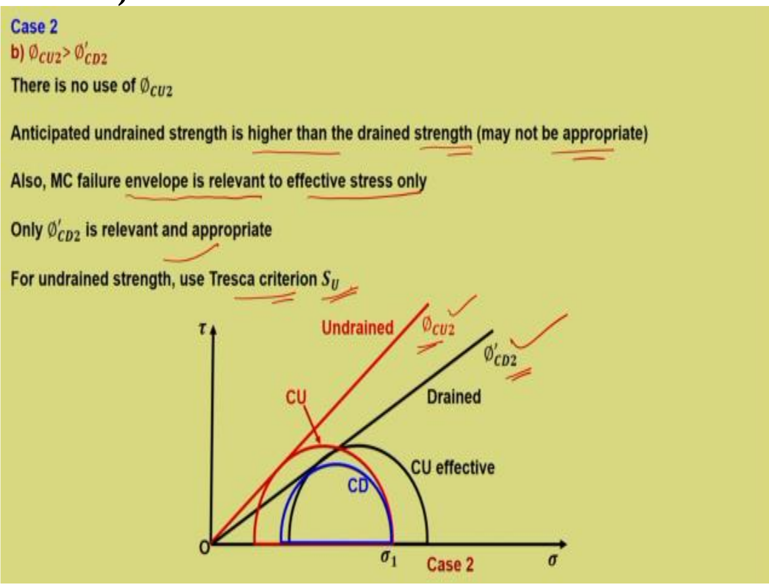

Now, case 2 let us make a comparison in this particular case, we can see that this particular angle is greater than ϕ'_{CD2}. Now, there is not much use of this angle first of all it gives a higher design value. And when we design a particular structure, we always need to be careful in the sense we using a realistic value. Now, always people tend to be on conservative side if one is not confident about a particular situation.

So, here ϕ_{CU2} is greater than ϕ'_{CD2}. So anticipated undrained strength is higher than the drained strength and this consideration may not be appropriate the first reason is Mohr Coulomb failure envelope is relevant to only effective stress so, only this holds. So, ϕ'_{CD2} is relevant and appropriate and for any undrained condition we have seen and we have repeated ample number of times, it is better that we go ahead with Tresca criteria and the undrained shear strength S_u.

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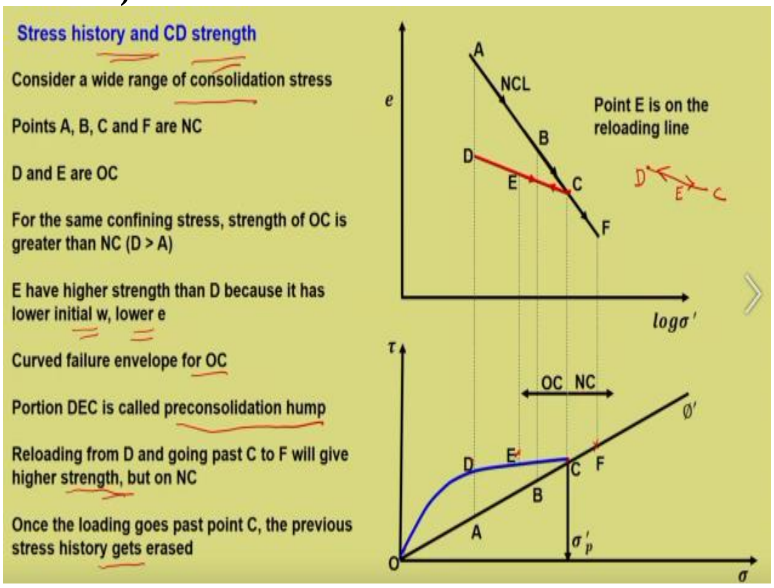

Now stress history and CD strength consider a wide range of consolidation stress. Let us show it in the form of the consolidation curve E versus log σ'_d, this we have already discussed before. Now, point E is on the reloading line which means that from this particular point C it is unloaded to D and then it is reloaded to C now E is on the reloading path that means this is C to D.

So, first C to D happens and then from D it comes back to C and E is on that unloading curve points A, B, C and F are normally consolidated D, E are over consolidated it is very relevant and we have seen this in previous lecture. So, now, let us translate these results to τ versus σ. So, what we are trying to do is we are trying to understand how stress history impacts this CD strength we already know this, but again there it is important that we understand this particular point.

So, here first let us mark the pre consolidation pressure. So, this separates NC and OC behavior so less and more. So, more will be NC for the same confining stress strength of OC is greater than NC that means we are considering point D and A. So, now D and A it is the same stress condition now, but then D has a higher strength than A so, that is one important observation E have higher strength than D now E is a point the soil has gone to D and then it is coming back to E. So, what is happening is it is getting densified from D to E.

So, E have higher strength than D because it has lower initial w and lower e because when this sample comes from D to E it is E is reducing. So, for E has a sample with lower e and hence the strength of E will be more and here the state of OCR is also different for both D and E. Now this becomes the curve failure envelope which we have already seen previously see curved failure envelope for OC we have already seen this portion DEC is called pre consolidation hub.

So, this particular curve DEC, so C will come here reloading from D that is from D and going past C that is from here it is reloaded to C and then when it is loaded further, it moves along F so now F is the normally consolidated point and it will have higher strength, but the point will be so, we are dealing with B and then C. So, from D to C it reaches here because C is the pre consolidation pressure on further loading, it goes up to F.

So, now F is the normally consolidated line, but, this particular F has already been subjected to this over consolidation in the past once the loading goes past C, now, once it goes past C it erases all its previous memory. So, what has been done in CD link that particular thing is lost now. Now, once it reaches see it again comes back to a normally consolidated state. So, that is once the loading goes past C the previous stress history gets erased. So, now, it is left for a new pre consolidation pressure maybe at F so, this becomes a new pre consolidation pressure if it is unloaded from F.

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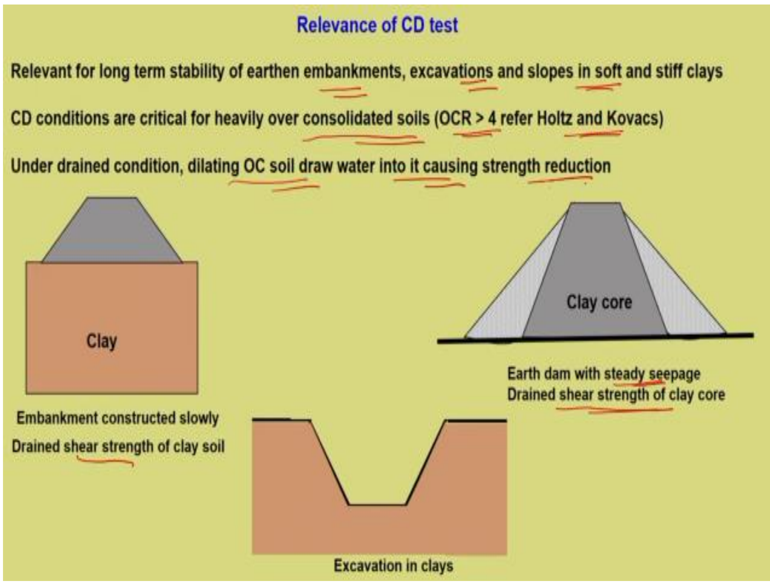

Now, what are the relevance of CD test the way we have discussed for CU test more or less it remains same. In fact, those conditions that we discussed in CU test, is more appropriate for CD test in terms of its long term behavior so relevant for long term stability of earthen embankments, excavations and slopes in soft and stiff clays. So, this is an embankment constructed slowly were drained shear strength of clay will prevail.

Now, that is very important when there is a saturated clay and the construction is happening very slowly then the drainage also would happen along with there will not be much of pore water pressure development and hence, this will simulate closely the CD condition or it can be excavation in clays or it can be an earthen dam with steady seepage. So, the clay core will exhibit a CD behavior. So, the drain shear strength is persisting for clay core.

So, CD conditions are critical for heavily over consolidated soil for OCR greater than 4. And these details are clearly given in Holtz and Kovacs book. It is a very fundamental book where all these details which I am discussing is clearly written. So, CD conditions are critical why for OC condition it is critical, we are considering a CD test drainage is permitted. Now, it is a heavily over consolidated sample during shearing what is the tendency?

The tendency of OC sample is to dilate. Now, as it tends to dilate, it will suck water into it, when it suck water into it water creates strength to reduce so it induces lowering of strength. So, a drained condition in OC is going to be more detrimental because of this particular reason. And this happens mostly in CD test drained tests where water can easily move in or move out.

So, undrained condition, dilating OC draw water into it causing strength reduction so, that is what I just explained.

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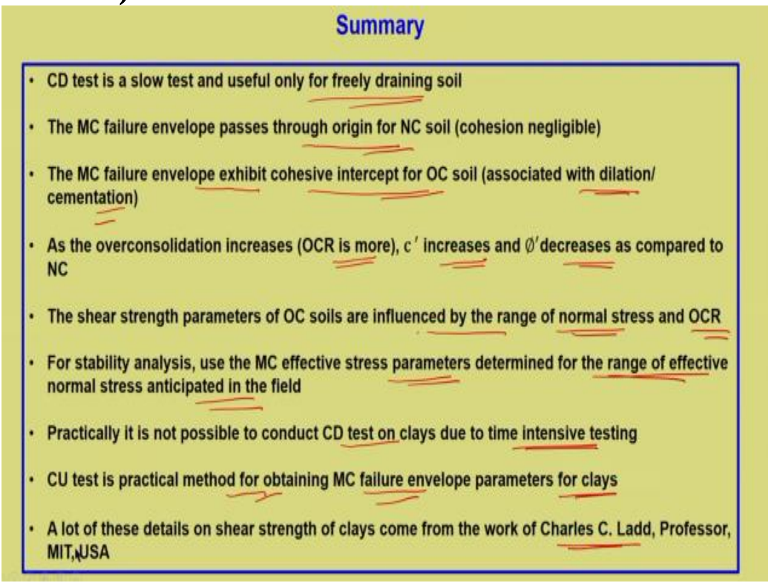

So, let us now just try to summarize this lecture. CD test is a slow test and useful only for freely draining soil. So, we have to keep in mind that even though we have understood CD test, it is practically not useful for clays the MC failure envelope passes through origin for NC soil, we have repeated this several number of times and this should be there in your mind. The MC failure envelope exhibit cohesive intercept for OC soil, mostly associated with dilation or cementation if any.

As the consolidation over consolidation increases, that means OCR is more c' increases and ϕ' decreases as compared to NC the shear strength parameters of OC soils are influenced by both normal stress and OCR. This also you need to understand very carefully like OCR also induces changes in shear strength parameters, and the kind of confinement that we give controls the dilation.

And hence the shear strength parameters, for stability analysis, we have to use Mohr Coulomb effective strength parameters determined for the range of effective stress affecting normal stress anticipated in the field. So, when we are planning the test, we have to make sure that the confinement that we give closely simulates the overburden and the lateral stress condition that is existing in the field.

Practically it is not possible to conduct CD test on clays because it is a time intensive analysis or testing. CU test is a practical method for obtaining Mohr Coulomb failure envelope parameters for clays provided the rate of shearing is not very high. Now, I just summarize this, a lot of these details on shear strength of clays come from the work of Charles C. Ladd, Professor in MIT, USA.

So, you can see that in 1970s, there are quite a number of reports and publications from Ladd and many of these details that have come into the textbook related to consolidated undrained UU test; it is basically coming from his contribution. So I just want to acknowledge this particular aspect also in this lecture. So that is all related to interpretation of triaxial testing so we are concluded this here.

And in the next lecture, we will summarize and we will see certain aspects, which we have not covered in any of these previous lectures, some very minor important points relevant to shear strength and transactional testing. We will have it in the next lecture. And with that, module 2 will be completed that is all for now. Thank you.