Advanced Soil Mechanics
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Lecture – 22
Shear Strength Cohesive Soil - Stress Strain

Welcome back. So, we have seen we have started shear strength of cohesive soil. Now, in this lecture, we will see the typical stress strain characteristics of cohesive soil and how it influences the shear strength of cohesive soil. Now, we have already seen a kind of stress strain response for loose and dense state of the soil when we discussed granular soils. So, more or less the lectures will be in the similar lines, but the initial condition what we stated as dense and loose, there is a slight difference when it comes to cohesive soil.

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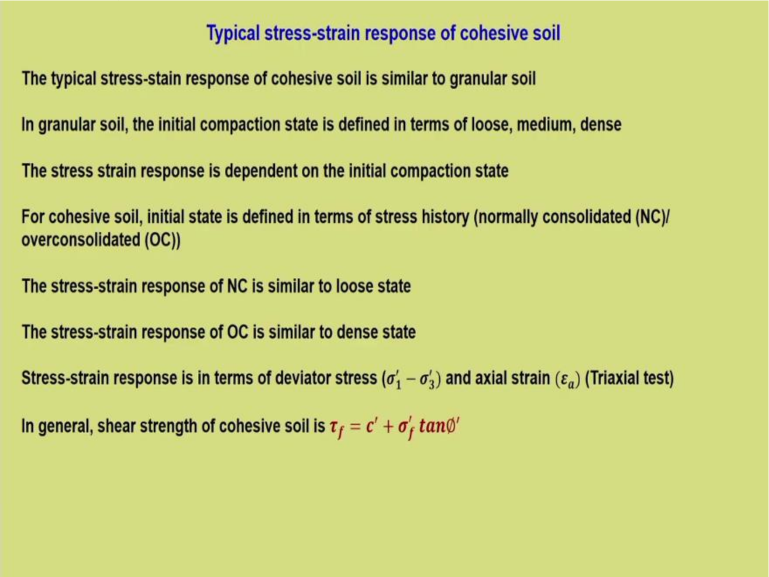

So, we will see what is that difference? The typical stress-strain response of cohesive soil it is similar to granular soil which means to say the end response remains same. In granular soil the initial compaction state is defined in terms of loose medium and dense we have seen that the stress strain response is dependent on the initial compaction state. For cohesive soil, the initial state is defined in terms of stress history normally consolidated or over consolidated.

Now, possibly you will appreciate the point why we discussed about the volume change characteristics of the soil it is basically for this the stress history dictates the kind of stress-strain response of cohesive soil. The stress-strain response of NC is similar to loose state. The stress strain response of OC is similar to dense state. So, stress strain response is in terms of deviator stress and axial strain because we are referring basically to triaxial tests.

In general shear strength of course, if soil is $\tau_f = c' + \sigma_f' \tan\phi'$, this is a general expression. Now, when will c' be there, when it is not there, that is a typical thing which we need to see. Now, let us not go by the judgment that a cohesive soil is always have cohesion, this is not correct. As we move in the lecture, as we progress in this particular module, we will see that it is not so under what circumstance we have cohesion we will see later, but in general we can consider the Coulomb's model $\tau = c' + \sigma' tan\phi'$ and this is for effective stress a long term condition.

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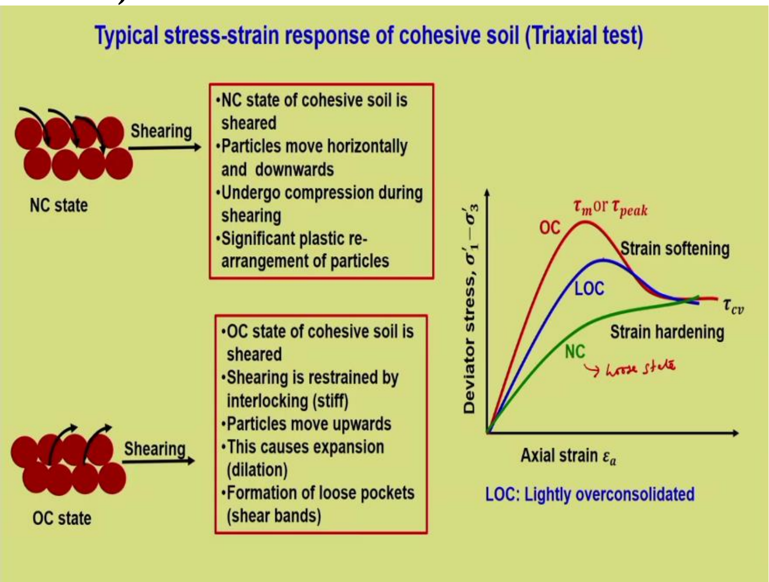

So, typical stress-strain response of cohesive soil: Now, more or less things remain same the y axis, x axis have changed, but the response remains more or less similar. For an NC soil that is NC, state when it is sheared, we can see that it is a loose state, why it is a loose state, because it has not been stressed too much in the past. So, NC, state of cohesive soil is sheared particles move horizontally and downwards because it is in a loose state undergo compression during shearing.

So, it is it is getting packed more how because in the spaces it gets readjusted significant plastic rearrangement of particles happen and that will result in a kind of response which you can see here similar to that of loose state. Now, for OC state, when it is sheared shearing is restrained by interlocking. Why? Because the present stress which we are applying the soil has already experienced in the past.

So, it is stiff enough to respond to that particular stress. So, since the packing is done in a stiff manner, the particles have to move upwards. Now, this causes expansion or dilation, the way it we explained it for dense state of this soil. Formation of loose back pockets when it dilates and that is known as shear bands. So, because of which there is a dilating response and there is a strain softening which happens.

So, this is mainly because of the upward moment of the particle which causes dilation. Now, there is an intermediate state a stress state, which is called lightly over consolidated or LOC. Now, whether an LOC will exhibit a peak behavior or not, it depends upon the amount of over consolidation it has been subjected to. So, it need not always exhibit peak.

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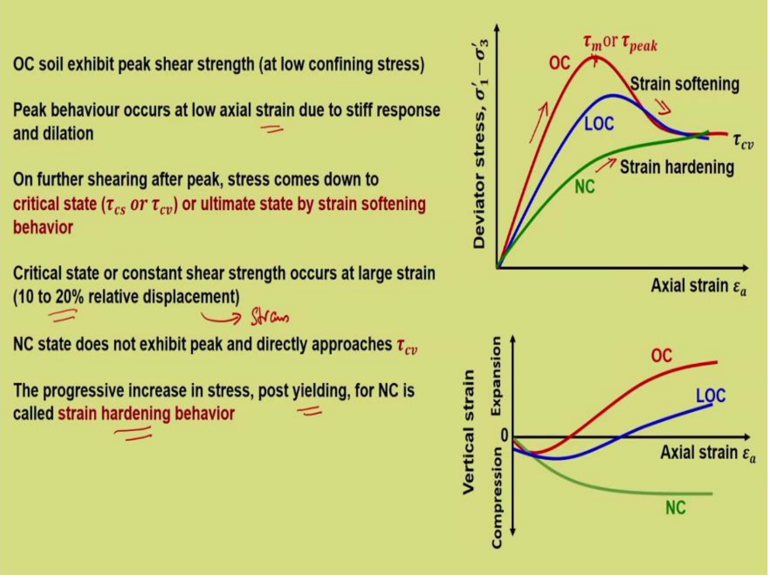

So, OC soil exhibit peak shear strength at low confining stress so, this is what it is at low confining stress when the dilation is possible it will exhibit peak and peak behavior essentially occurs at low actual strain. So, that it can show a stiff response at low axial string because of dilation that is what has been shown by this response on further shearing after peak after reaching peak the stress comes down to critical state the same manner what we have discussed for dense state of granular soil.

So, it reaches ultimate state or by strain softening behavior. So, this is a strain softening behavior and critical state essentially occurs at 10 to 20% instead of here it is not relative displacement it is also strain. So, normally consolidated state does not exhibit peak and directly approaches τ_{cv} or the critical shear strength the progressive increase in stress post yielding. So, somewhere it yields so, it goes and meets the τ_{cv} by strain hardening behavior. So, this is a strain hardening behavior.

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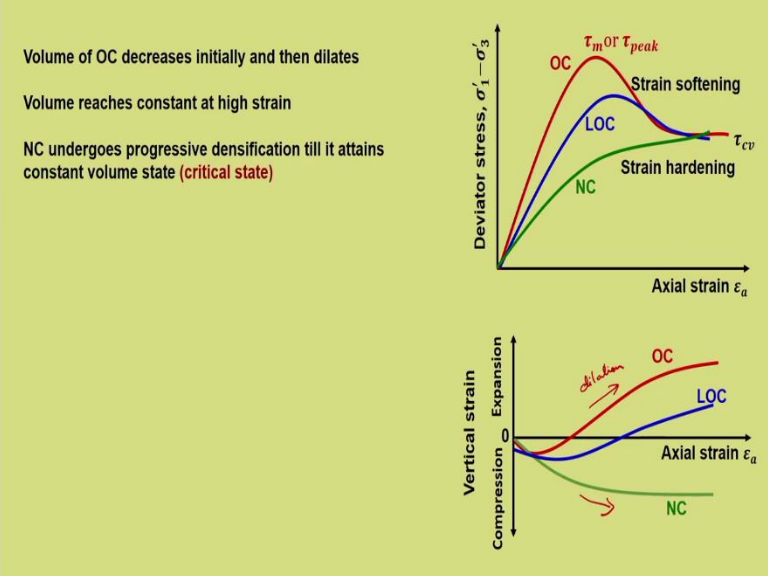

Now, we have discussed about the typical stress strain response, now, we will see what happens to a drained volumetric change response. So, volume of OC that is over consolidated decreases and then it dilates, so, this dilation happens. So, increase in strain increase in the vertical strain happens. So, volume reaches constant at high strain at high strain condition, what happens is the concept of critical void ratio comes into picture. So, the volume essentially becomes same. Normally consolidated undergoes progressive densification as you can see here, till it attains constant volume state, which is the critical state.

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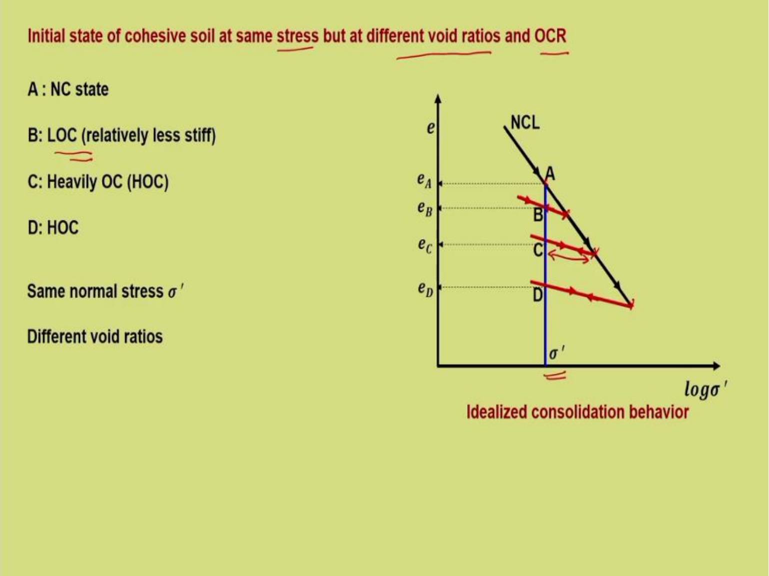

Now, to know the initial state of cohesive soil, it seems does now I am going to introduce another scenario where the cohesive soil is at the same stress, but a different void ratios and OCR. So, if you see an NCL behavior and there is unloading, let us say at 3 different points and on this unloading, like let us say, let us drop a vertical line, so, here, σ' is same, but the void ratios are different e_A, e_B, e_C and e. If you see it is over consolidation ratio, that is also different for this point B, it is not that over consolidated.

We can call it as likely over consolidate, it is a relatively less stiff than other over consolidation. See, for this much it got unloaded. So, it is a heavily over consolidated sample. D is more heavily over consolidated then point C, here it is same normal stress, but different void ratios. Now, because of this, even though the is at the same stress condition, the stress strain response will be totally different for all these 4 points a anyway it is normally consolidated, but for B, C and D it will be totally different.

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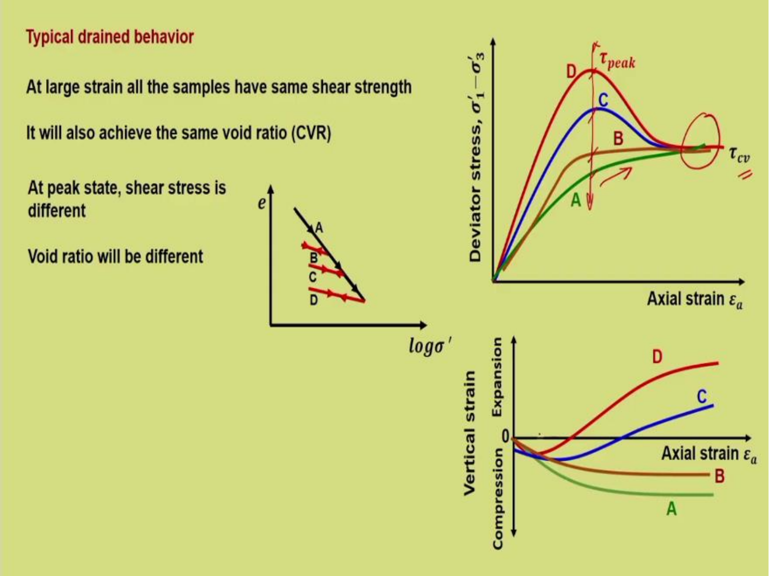

How it is different? It has been marked here. Now B A is a normally consolidated plot. So we know it strain hardens and reaches tau CB. B is likely over consolidated as I told in the beginning, it may or may not exhibit peak depending upon its over consolidation ratio, let us say B is not that over consolidated. So, it is also more or less similar to A but slightly different from that. So it undergoes densification only there is no dilation.

But for C there is a kind of dilation that happens and D that dilation is more which is heavily over consolidated in the same manner. So, there at large strain, all the samples have same shear strength. So, this is what it means, now, even though the conditions are different, where is the actual difference that is coming that is along this peak response at peak response the shear stresses are different.

But all of them comes out to be the same value later that is at τ_{cv}, it will also achieve the same void ratio at tau cv, that is a concept of critical void ratio at a critical stage, it ultimately reaches a critical void ratio, but towards the peak response, the void ratio will be different at this particular point, if you see the void ratio, then it will be different for all these 4, but in the end, when it reaches that critical state, the void ratio also becomes comparable.

At peak state shear stress is different, I have already discussed that void ratio will be different. So, in the volume in the volumetric response also, we can see that A and B undergoes progressive densification and C and D exhibits initial compression and further dilation.

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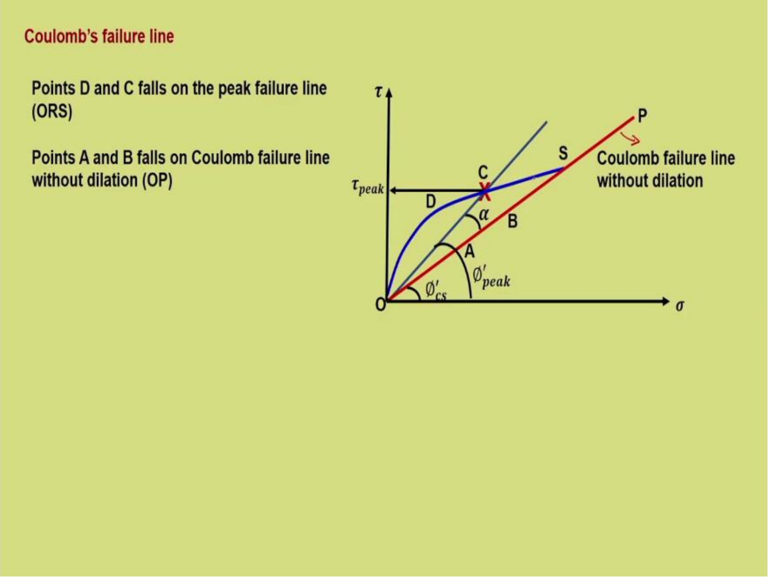

So, Coulomb's failure line; how these ABCD translates to columns failure line, this is the critical straight line fi dash cs and depending upon the amount of dilation, there will be a kind of peak angle which gets added is a dilation angle which gets added to fi dash critical state and that results in fi dash peak. So, we can see that C and D falls on the big failure line. So, it also depends on the kind of confinement it has.

So, we really do not know where actually C and D will fall, but C and D will exhibit peak behavior with dilation angle whereas, points A and B it falls on the critical straight line why there is no dilation. So, this stress remains same and similar to density which we discussed before. There will be a kind of dilation separation at a higher normal stress or higher confining stress.

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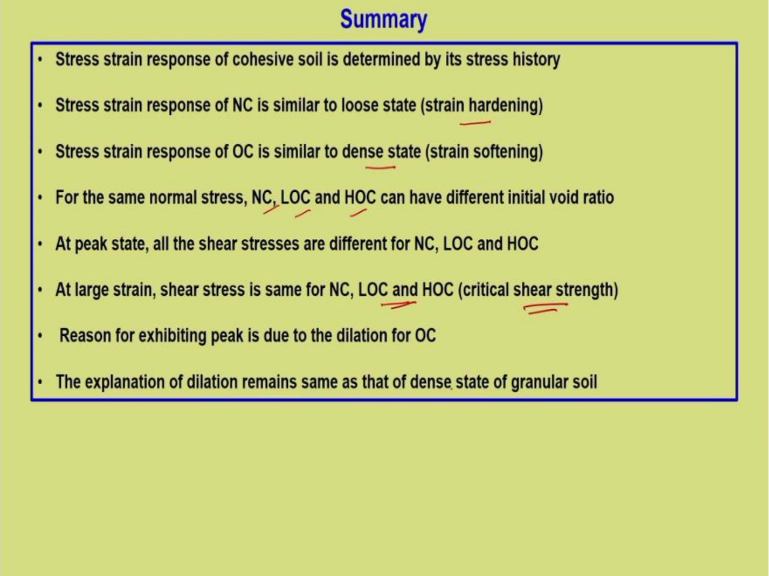

So, that is all about the shear stress response of the cohesive soil during shear strength test. So, let us summarize the important points. The stress strain response of cohesive soil is determined by its stress history. Now, that is a very important point which we need to stress. When we discuss about granular soil we talk in terms of loose and dense when we talk in terms of cohesive soil we understand this in terms of stress history, rather NC or OC.

Stress strain response of NC is similar to loose state which is strain hardening. Stress rate response of OC is similar to dense state which has strain softening. For the same normal stress, NC, LOC and HOC can have different initial void ratio. At peak state, all the shear stresses are different for NC, LOC and HOC. But at large strain shear stress the same for these conditions and that is referred to as critical shear strength.

Reason for exhibiting peak is due to the dilation in the case of OC. The explanation of dilation remains same as that of dense state of granular soil. So that is all about shear strength of cohesive soil. We have just begun. Now we will discuss some of the factors in detail. For example, in the next lecture, we will continue with the discussion on importance of pore water pressure and it is prediction what we call it as poor order pressure parameters and then we will continue with the interpretation of triaxial test results.

So we need a background for those interpretations and that is what we have achieved till now. So, that is all for this lecture. Thank you.