Geotechnical Measurments and Explorations

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Lecture No. # 22

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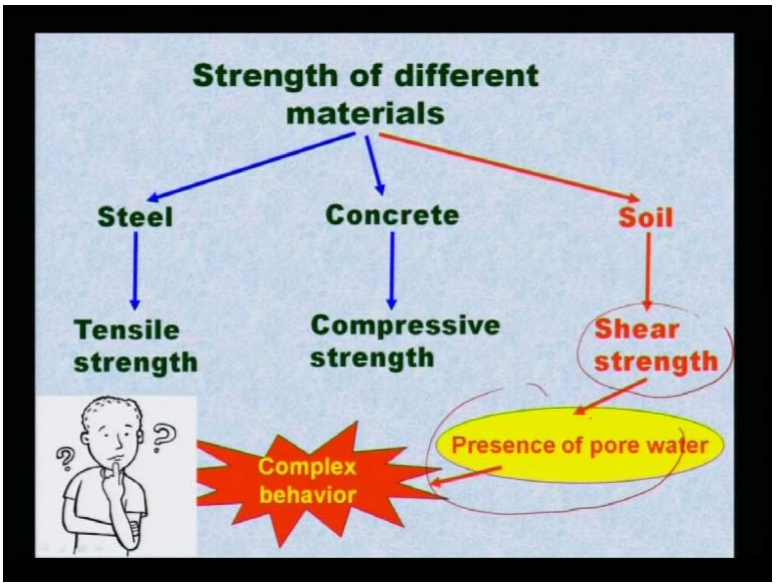

Next part is triaxial shear test, I have already explain, but I want to show in PPT how this shear strength has been measured by means of triaxial test. So, if you look at here strength of different materials - steel concrete, and soil; generally in steel we go for tensile strength, concrete go for compressive strength, but soil shear strength means it is a presence of pore water pressure, and its complex behavior.

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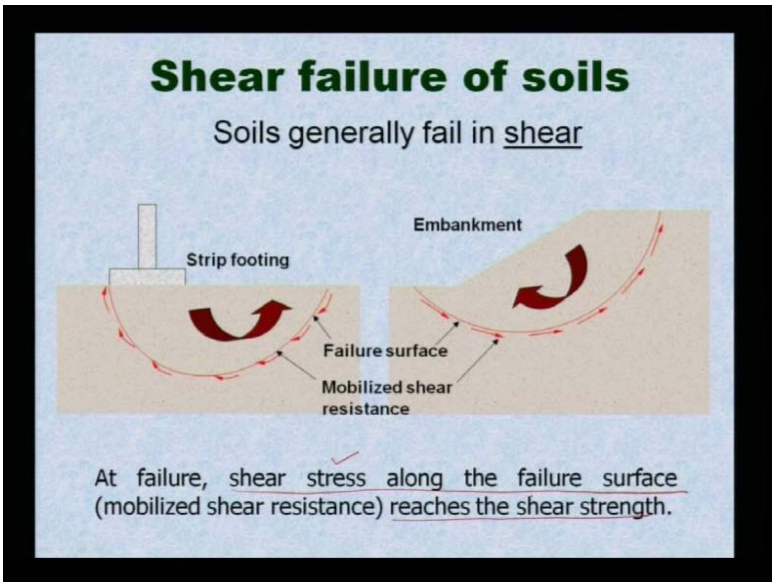

Look at this, if you look at a strip footing how it fails means, soil fails in shear what kind of shear if you look at this strip footing below the strip footing, the failure surface generated and mobilized shear resistance has been marked. Similarly, if you go to embankment, look at the embankment how how this failure surface and mobilized shear resistance it is along this embankment; so this is called soil fail by means of shear. Shear stress along the failure surface reaches the shear strength at failure, one definition is shear stress along the failure surface reaches the shear strength; that means, where we will say that it fails at failure shear strength along the failure surface reaches the shear strength, shear stress along the failure surface reaches the shear strength.

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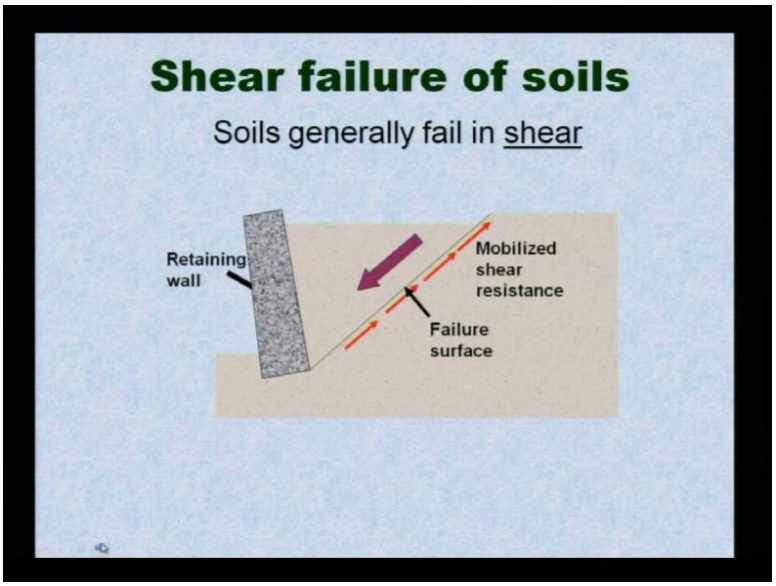

Now, similarly look at the retaining wall, generally what happen this retaining wall? Retaining wall is here, either retaining wall it may fail by means of translation, rotation or both; if you look at here, it has been rotated. Now, once it has been rotated, how this failure surface mobilized? Mobilized shear resistance it has shown.

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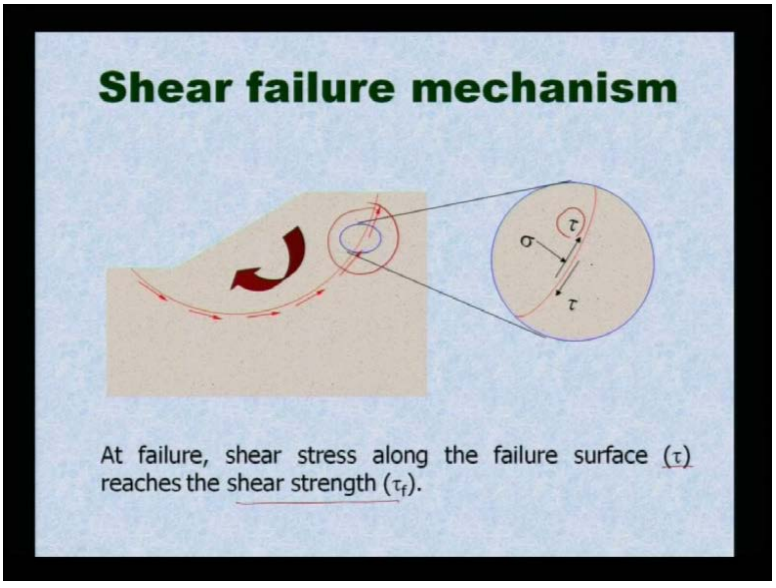

This soil grain, what is shear failure mechanism? The soil grain slide over each other, it has been already explained, but I am just showing it in PPT form, presentation forms, soil grain slide over each other along the failure surface. And it is a soil grain, it is not no

crushing of individual grains; there is no crushing of individual grains, look at this the failure mechanism I have taken from one of this, and it has been shown here. You see, this is your shear stress along the failure surface reaches your shear strength tau f, tau along the failure surface reaches the shear strength.

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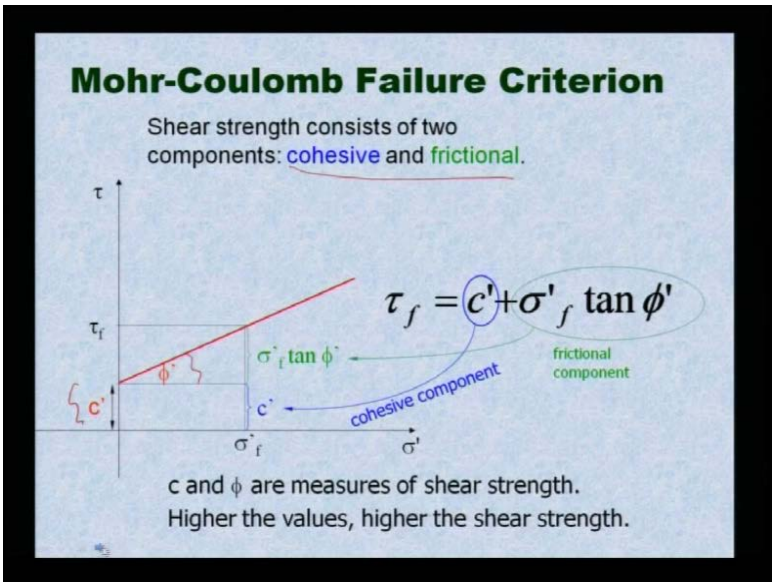

These I have already discussed Mohr-Coulomb failure surface, in terms of total stress, in terms of effective stress. Then shear strength consists of two components, that is your cohesion, and friction, and if you look go for a Mohr circle, the biotical intercept it is called cohesion, and the angle it is called a frictional angle.

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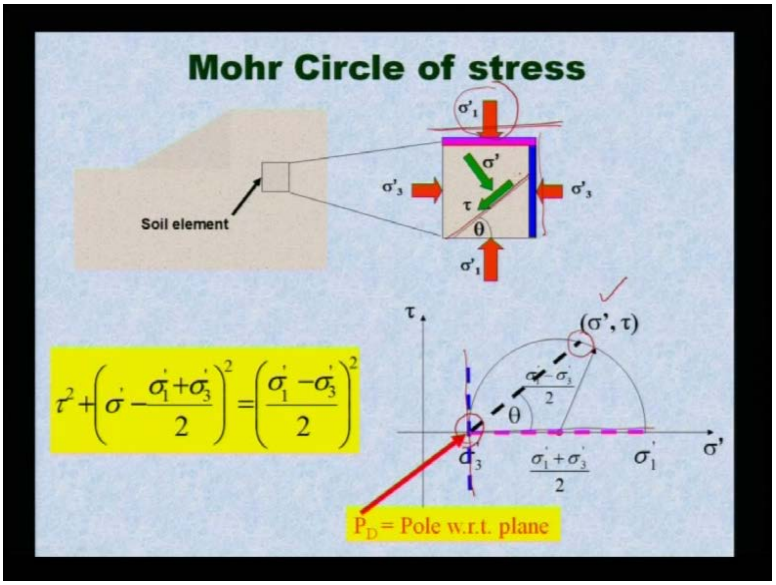

Now, Mohr circle of stresses if you look at the soil element, anywhere else below the ground may be in embankment, if I take a soil element it is acted upon by vertical stress as well as lateral stress. And the failure surface look at here, if there is a failure surface of theta it makes an angle, this is your shear stress, and normal stress along the failure surface. Reserving this tau is equal to sigma 1 minus sigma 3 prime by 2 into sin 2 theta, and sigma prime is sigma 1 plus sigma 3 prime by 2 plus sigma 1 minus sigma 3 prime by 2 cos 2 theta.

If I draw the Mohr circle between this means sigma 1, and tau this this is sigma 1 measure principal means a vertical stress or you can say a lateral stress, and draw the Mohr circle from there you can find it out what is your tau and failure surface. Pole with respect to plain, here one thing is there pole, what is pole? Pole is your intersection of principle plains; sigma one is acted upon this is my major principle stress, it is acted upon this is the direction, then this is the direction where the major principle stress has been acted intersection of principle plains.

Then sigma 3 is acted upon by here, this is your minor principle plain, and this is your minor principle plain in the sigma 3 I draw it, where that intercept it is call pole with respect to this plain. Generally with respect to this plain once you find it out pole with respect to pole you can draw your failure envelope at an angle theta, and this is where you can find it out shear stress, and normal stress at failure plain; this is my failure plain, shear stress and normal stress at failure plain.

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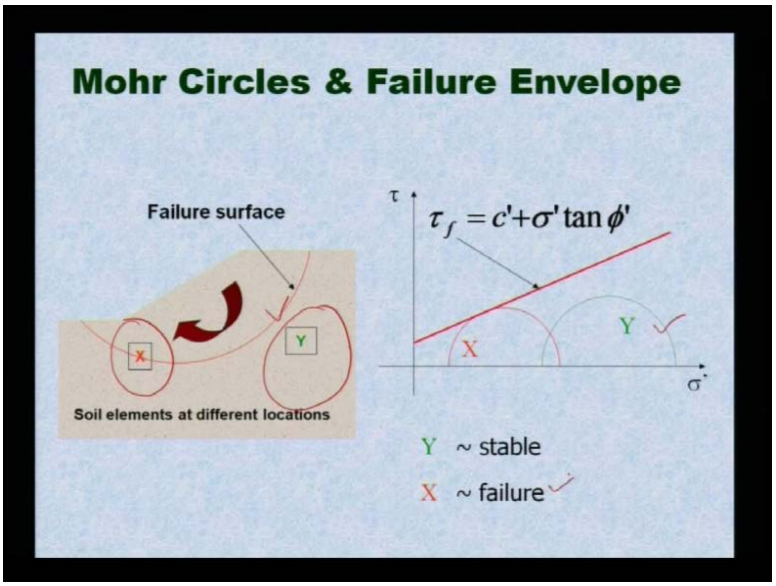

Now, thing is that if I draw a failure surface here, soil element at different location. Now, this is my failure surface, now is this failure surface is stable? Answer is yes, because it has not tau's this failure envelope; tau is equal to c plus sigma tan phi, that is why it is stable. Now, look at here, this at this point it is stable, now whether this point in the failure plain, it will be it will be stable or fail, because it touches your failure envelope that is why it is failed.

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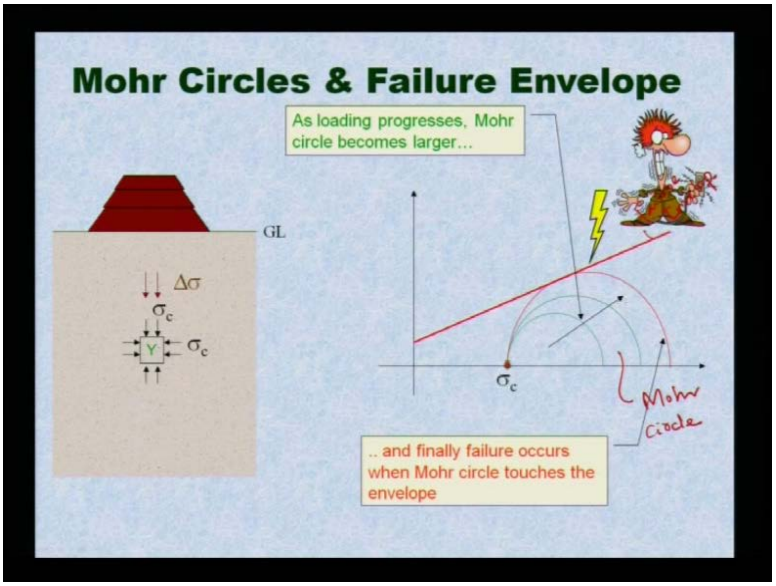

You see this soil element inside this ground, it does not fail, if the Mohr circle is content within the envelope, that means this is my failure envelope; this is the failure envelope, and this is your Mohr circle, that means it contains inside this failure envelope that means it is stable. Finally, I audit - pressure audit, now it has gone and touches, here finally failure occurs.

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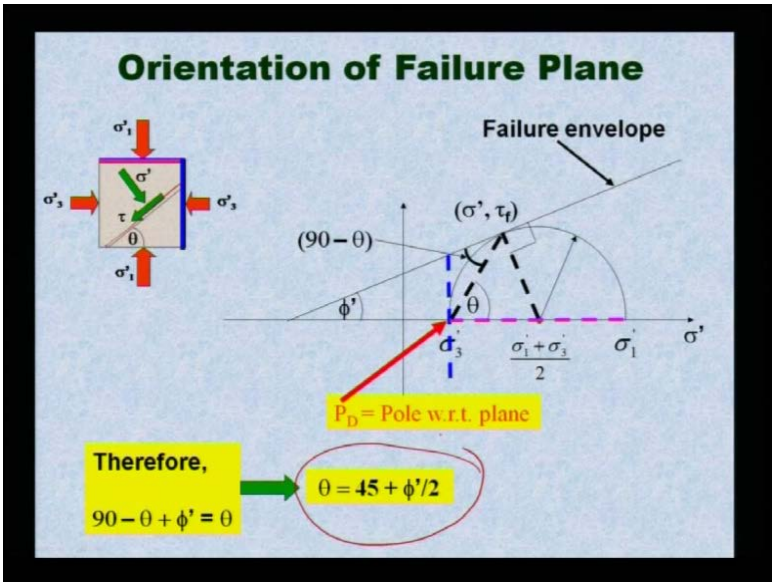

Same thing I have shown it with respect to pole 90 minus theta, so what is that is angle? This angle failure envelope failure envelope at this plain shear plain, this angle will be 45 degree plus phi by 2.

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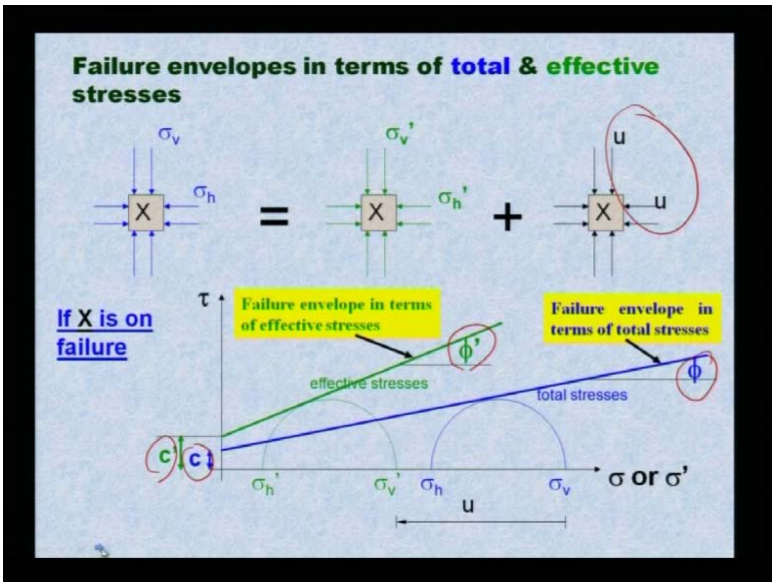

Mohr circle in terms of total stress, and effective stress; if you look at here total stress - in case of total stress sigma h, and sigma b is there. In case of effective stress, the pore water pressure will come into picture, then it will be shifting towards here, towards this left. So, this is your failure envelope in terms of effective stress, this is c prime, phi prime, and this is your phi and c; phi, c is your failure failure parameter means c and phi in terms of total stress, and c prime and phi prime in terms in terms of effective stress. This I have explained also earlier.

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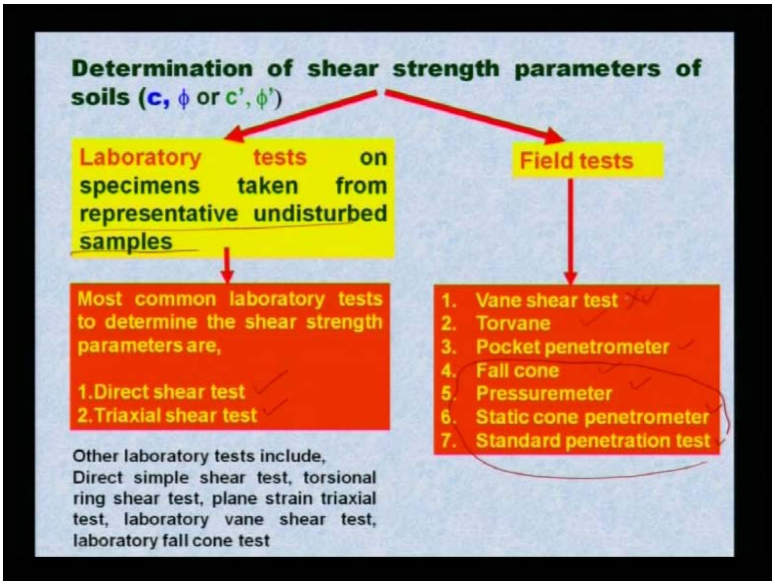

Determination of shear strength parameters in laboratory test on generally on specimen taken from the representative undisturbed sample, I have said earlier most common laboratory test to determine shear strength parameter is your direct test, as well as triaxial shear test. And in field test, shear strength parameter you can measure it by vane shear by means of torvane, pocket penetrometer, fall cone, pressure meter, static cone penetrometer, standard penetration test, we have almost discussed all these accept these vane shear that I will show you later on. So these are the test, if I what are the different test I can do in the laboratory as well as fields, so that the shear strength parameter of soil can be determine.

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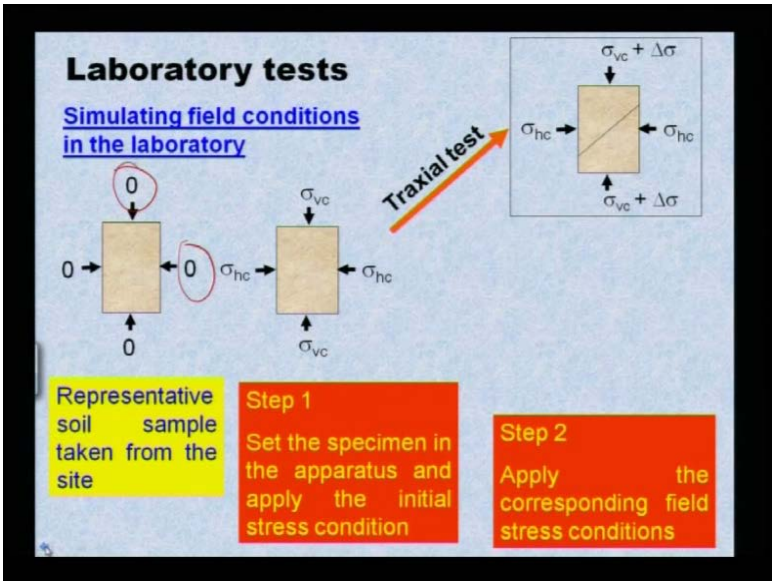

Laboratory test, now simulating field condition in the laboratory, if initially the movement representative soil sample taken from the site, it has no over bottom pressure, it has no lateral pressure.

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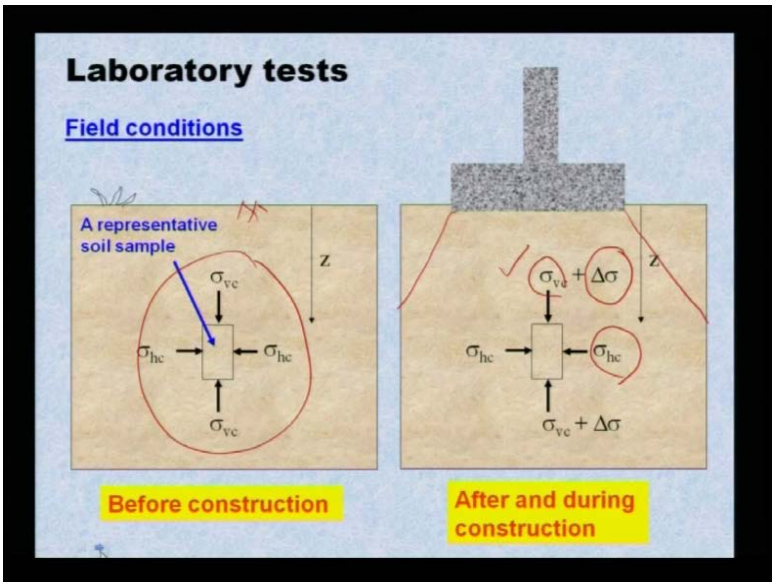

That means it lost if you go back here look at here, as a soil representative below the ground surface; if this is the ground surface below this ground surface this soil element, it has all ground pressure over bottom as well as lateral and confining pressure. So, after construction it is before construction, it is before construction this is at the ground level. One soil is there, this is before construction; after construction increase in stress this is your over bottom, because of your soil; and this is your lateral, and this is your over this is your increase in stress, because of your because of your after construction of footing, this will come increase in stress.

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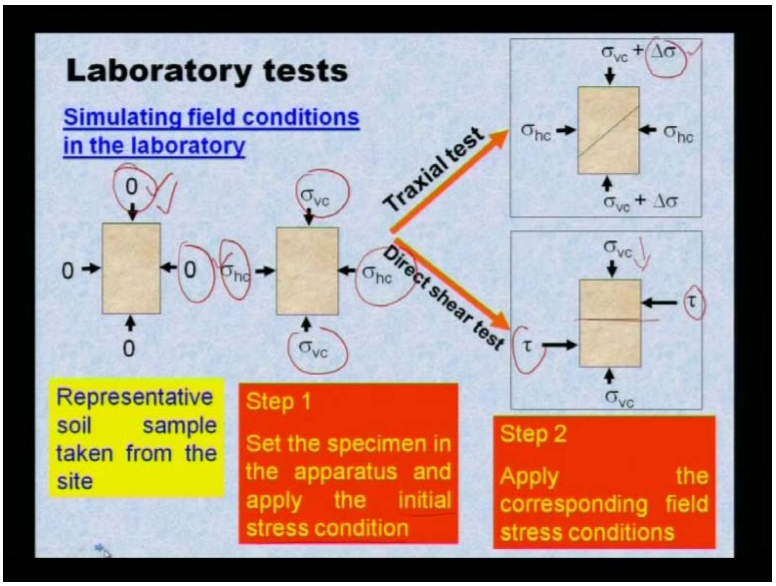

Now, the movement you take the soil sample from the ground it lost its over bottom, as well as confining pressure, so lateral pressure is zero, over bottom pressure is zero. Now, step one - set this specimen in the apparatus, and apply the initial stress condition; that means apply the initial stress condition means, all round confining pressure you have to set after taking out set it in the law, and in the equipment triaxial test put it. And give this specimen with your initial stress conditions, that means all round confining pressure what is there you apply, then apply the corresponding field stress condition look at here, corresponding field stress condition is your increase in stress, because of your footing or increase in stress, because of your applied load outside.

So, this you have to set it, in direct shear test, in triaxial test what will happen? First you take it, then set all round confining pressure, then set your field condition simulate in direct shear test initially there is no confinement. So, only vertical pressure you apply, then with respect to that shear test you measure in a plain of horizontal plain.

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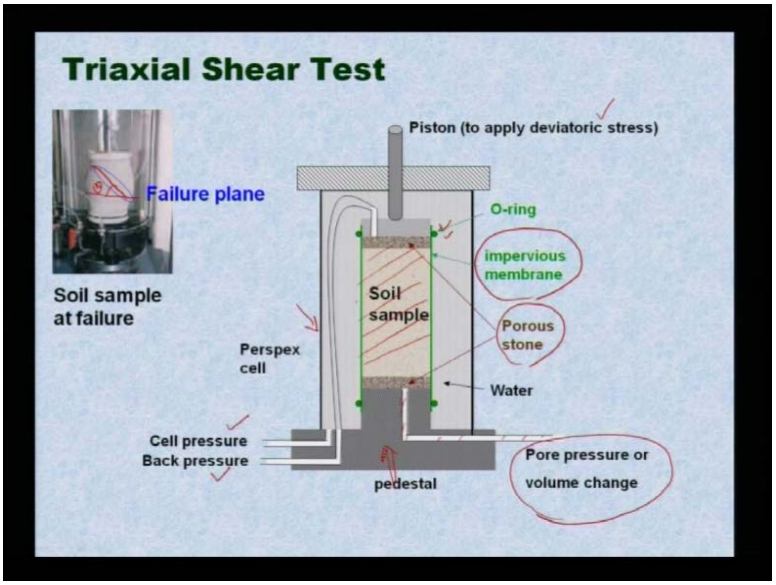

Then, just showing this how this triaxial test it looks like. Though I have discussed earlier, and basic principles I have discussed. This is a complete triaxial cell, we say triaxial cell. If you look at this, the triaxial cell generally in between this cell, the soil sample at this point the soil sample is to be provided above the pedestal, this is your above the pedestal soil sample will be provided. Then once soil sample will be provided, then both the soil sample, both the ends of soil sample porous stones will be provided.

So that only water can go, and soil will be remain in its positions, then there are valves; it can control cell pressure, you can apply to the soil around the confining pressure, as well as you can apply back pressure. And this is your perspex cell, and there are two o rings - one is o ring here you can provide, and a membrane - impervious membrane, where it would not allow water from soil to pass through this. And there is also, another arrangement here, it can measure how much pore pressure generate or because volume change change in volume you can measure it. Then there is a piston here, at the top there is piston to apply the deviatoric stress, here is there the piston you can apply the deviatoric stress, this is just a description a schematic diagram.

Now, how looks if I go to the triaxial machine how it fails, if you look at here, the failure has been mark it is failed at an angle theta with this, this failure is clearly observed.

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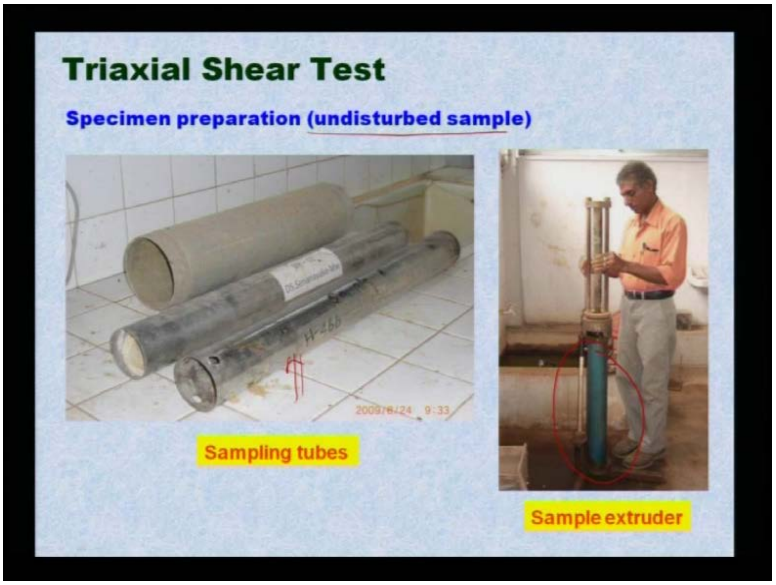

Now, next step is before you are a preparing sample in triaxial equipment or triaxial cell, first collect the specimen; that means, specimen preparation. So, collect the specimen that is mean undisturbed samples collected from the field by means of sampling tube, these are the this is the this is a type of sampling tube from where you can push inside the ground, that I have shown last class from there once you collect your undisturbed sample, then you have to prepare your specimen of your required diameter or this triaxial test. This machine is called sample extruder that means here you put your sample above this, then bottom you push it, so that sample only sample will come out.

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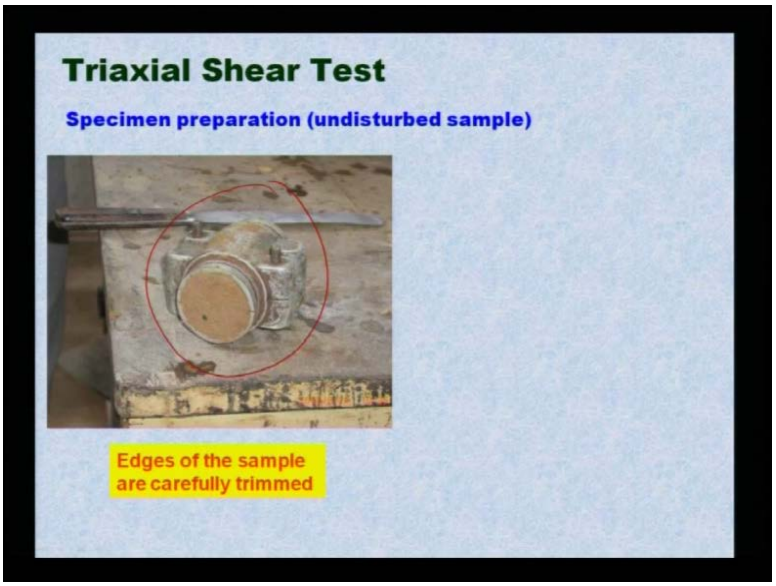

Then once sample will come out a mold of requisite diameter, suppose say sample size of 36 by 72, this you put it inside the sample. So, that edge of the sample carefully trimmed, outside the edge carefully trimmed.

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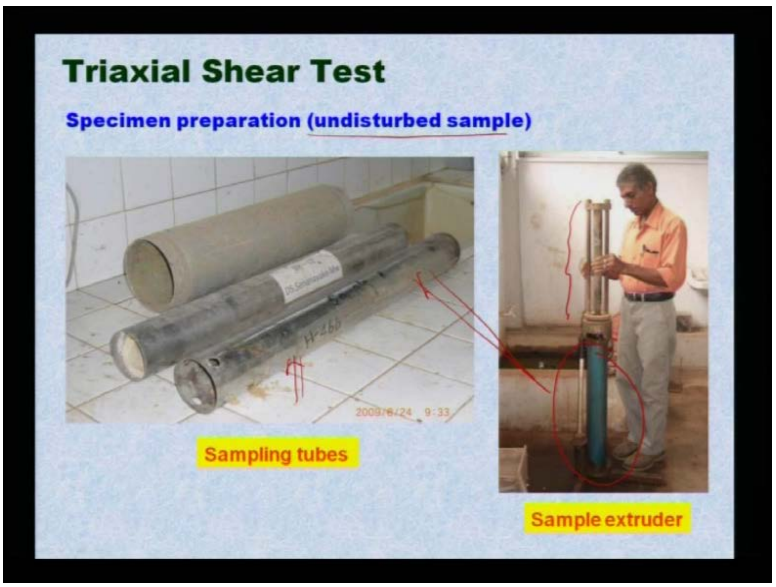

If you look at here, from here this sample will come out from bottom, if these are the cell, sampling tube if I push it; so it will come out inside this only sample will come out.

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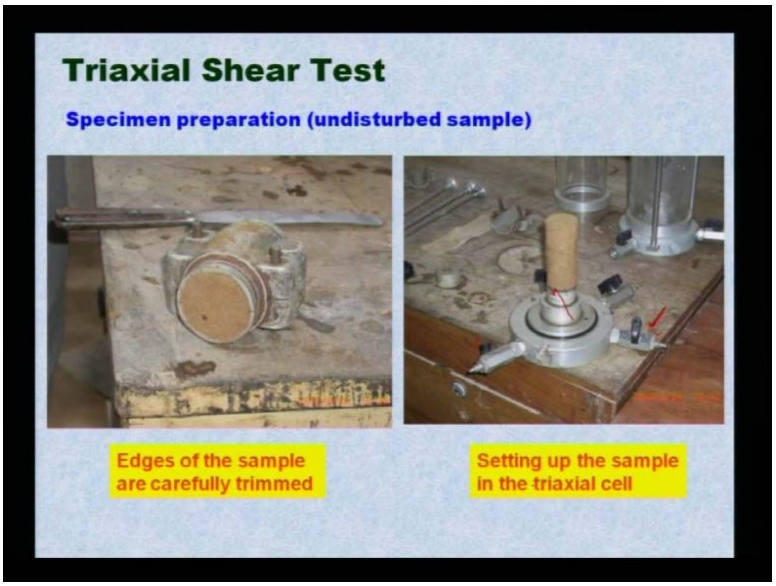

The movement sample will come out outside edge, this is my diameter, this is the diameter of the sample required, and this is the length of the sample. This is required for the test, other part you can carefully trim. So, that it remains plain, look at this? How it looks this is your complete sample. Now, after trimming of both the edges, you can open this; this is a splitted one, splitted mold, we can split it, so that only sample will come out. Once sample will come out, this is your triaxial cell or pedestal pedestal. Then, these are all your valves for confining pressure, applying pressure, apply measuring pore water pressure, then above these pedestal this is the porous stone. As I said, this is your porous stone, it put at the base then above this porous stone, and put the soil sample setting of sample in the triaxial cell.

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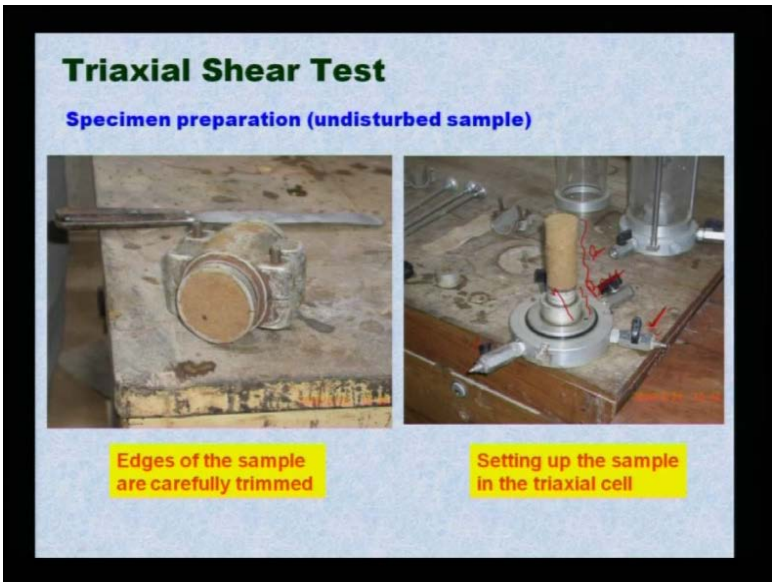

Now, look at this, o ring because before this once you put the sample in the base above the this is my base, above base first put the porous stone; above porous stone put the sample, then once you put it sample, above the sample again you put your porous stone.

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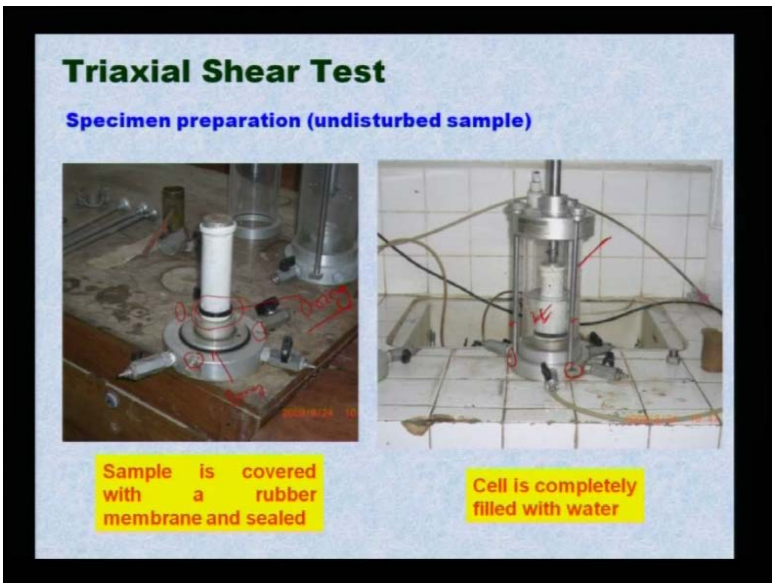

After putting this porous stone, apply this for this pedestal the arrangement, then apply the membrane; this is the membrane where it would not allow water from the soil will come out. So, then provide the o ring, what is the function of o ring? This is o ring, this o ring it will tight this membrane with the soil, and porous stone in position, it will intact in

position. Then, similarly you can provide o ring also at the top, sample is covered with rubber membrane and sealed.

If both the ends it will sealed it has been shown only one end. Look at here, the movement it has been sealed, that means you provide o ring at the bottom as well as the top. Then, once it is there at the base of the pedestal, you provide the sample, then cell this is my cell, this is the cell you put in position if you look at this this cell. These are the three parts, opposite to each other diametrically, this is the arrangement where it fix so that what happen? This cell can fix in tight in position, then the cell once fix, this cell here again one more o ring it is there, so that it would not allow any leakage from the cell to outside. So, it has been fixed in tight, once it has been fixed in tightly, so after that you apply or allow field with this up means cell is completely filled with water. Why water has been applied? You can apply also kerosene, you can apply also any fluid, so that it can give self pressure. Other fluid generally not applied, because they may chemical react, air is much more preferred. then water generally in everywhere else it is applied; so it will be DAL water, you can fill it, so that you can achieve your confining pressure of whatever you apply the confining pressure you can achieve it.

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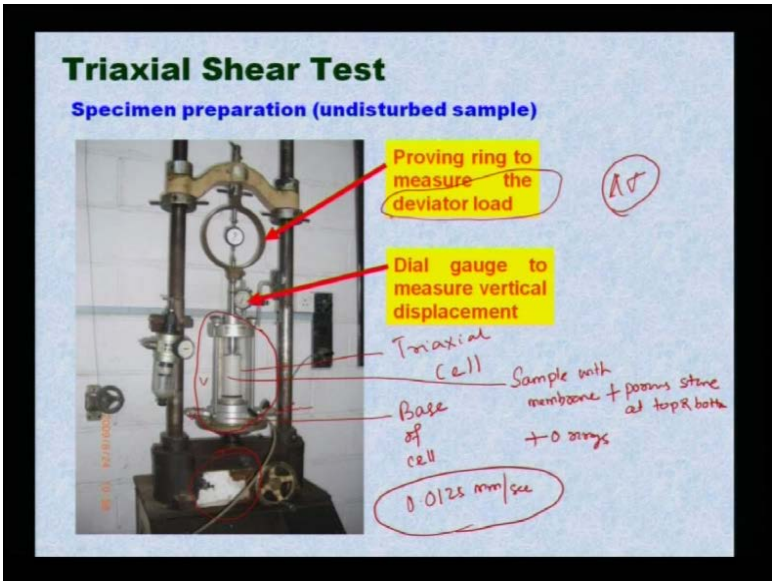

Now, look at in this case this is the complete triaxial cell, this triaxial cell if you look at here, this is the pedestal or base of the cell - base of cell. Now, this is your triaxial cell, and inside this is your sample sample with membrane plus porous stone at top and

bottom plus your o rings, then inside the sample inside the inside the cell water is applied to applied water is filled to apply your confining pressure. Then, if you look at here, this is called proving ring - proving ring has been provided to measure the deviatoric deviatoric load which has been applied, that means this load once you applied load by area, it will give deviatoric stress which is nothing but your delta sigma.

Now, dial gauge to measure vertical displacement, this is the dial gauge it has been apply, it has been placed here. So that, once sample has been sample you compress, that means load has been applied to the sample at the top. How much displacement in vertically you can measure by means of dial gauge, then there are three valves; one, two back side as well three, where you can apply your self-pressure, confining pressure as well as you can one one you can here, you can apply change in volume or pore water pressure. Here there are some arrangements, here there are some arrangement, you can set the strain rate you can set the strain rate. Says if I can set 0.0125 mm for second, that means with these strain rate it will apply to allow this proving ring or this arrangement to go inside it will go 0.0125 mm per second, every second you will apply a strain of 0.0125 mm.

You can set high, low or medium, so depending upon that it will go you can measure your means a deviatoric stress, you can measure, and strain you can measure it by means of dial gauges, and other arrangement there is there you can measure your also by means of change in volume pore water pressure it will give.

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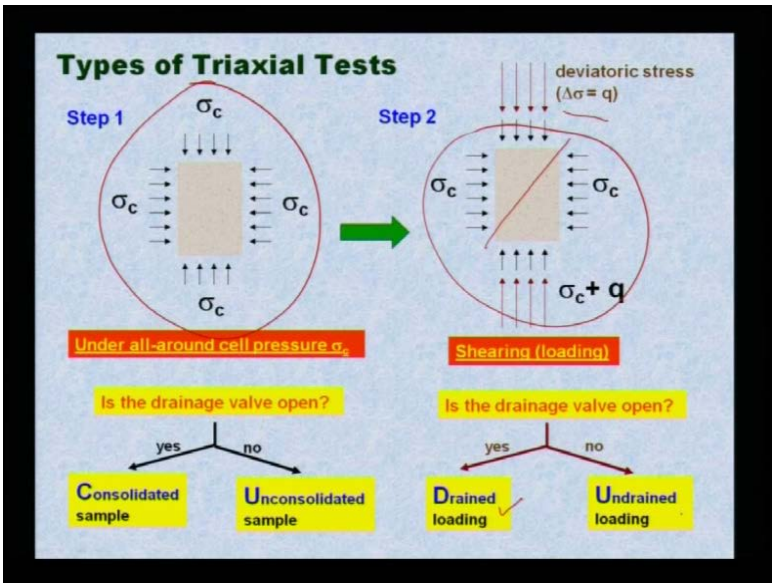

It is also I have said types of triaxial test. Step one, if he this this all round confining pressure has been applied sigma c sigma c sigma c, is that drainage valve open - if this drainage valve is open, if you look at here somewhere else, somewhere else here, this will act as a drainage valve, you can open it I can show you one more also figure yes, this is more clear. One of the valve if I open, so it will act as a drainage valve that means whatever water squeeze inside out from the soil mass, this will come out from the drainage valve. That means, if the drainage valve is open, that means sample will consolidate; if it is not open, sample will be unconsolidated. That I have also said earlier also, just I am showing it in diagram form.

Then, step two, step one is apply your confining pressure, apply confining pressure if drainage valve is open, then sample will be consolidated. If drainage valve is not open, then it is unconsolidated sample.

Now, second step along with this all round confining pressure apply deviatoric stress delta sigma, then the shearing will start by means of your piston at the top it will apply the load deviatoric load, then the shearing loading will be shearing will start along this plane. Now, in this case if again drainage valve is open, then if yes, then it is called drained loading, if no this is called undrained loading.

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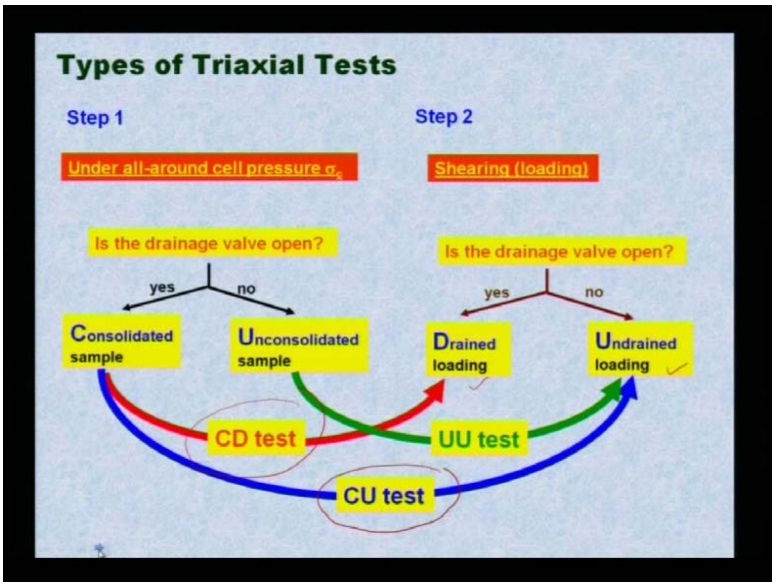

In triaxial test there are two steps: Step one, step two under all round self pressure sigma c I have shown last slide, if the drainage valve is open it is called consolidated sample, if

it is not open, it is called unconsolidated sample. Then, step two shearing or loading, if drainage valve is open in case in during that shearing, then it is called drain loading; if it is not open, it is called undrained loading.

Look at this, step one if the sample is consolidated; that means, if drainage valve is open during all round self pressure application, in that case this is called consolidated sample. Also during shearing if drainage valve is open, then this is called drain loading, if both this conditions have there, this test is called consolidated drain test, CD test. If drainage valve is open, that means consolidation is there, but during shearing time drainage valve is not open, so that is called consolidated undrained test. If both the conditions, if both the condition there is non drainage valve this called unconsolidated undrained test.

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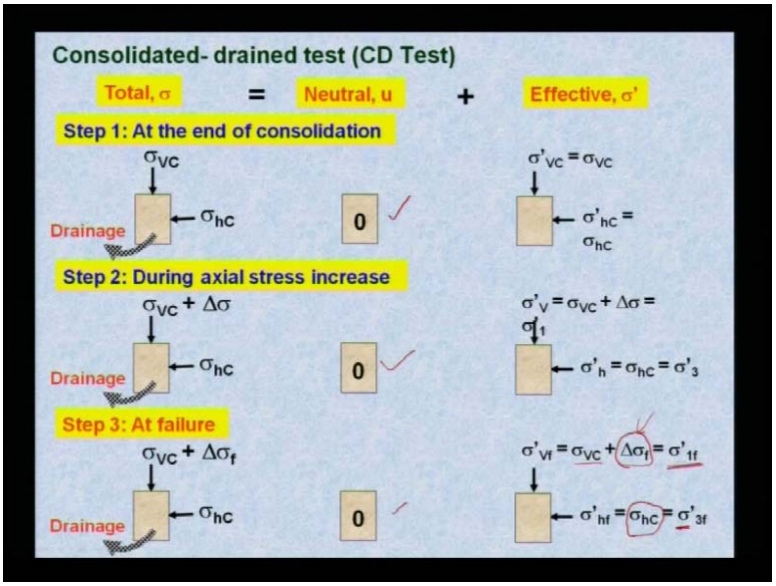

Consolidated drain test, that means consolidated drain test, this is your step one at the end of consolidation. So, that means neutral pore water pressure it will be zero, then during axial stress increase again it is zero at failure, again it will be zero. So, sigma vertical pressure will be sigma v c plus delta sigma f, that is your deviatoric stress, this is your sigma prime one at failure. And sigma horizontal, it will be nothing but sigma h s that is your sigma three prime f.

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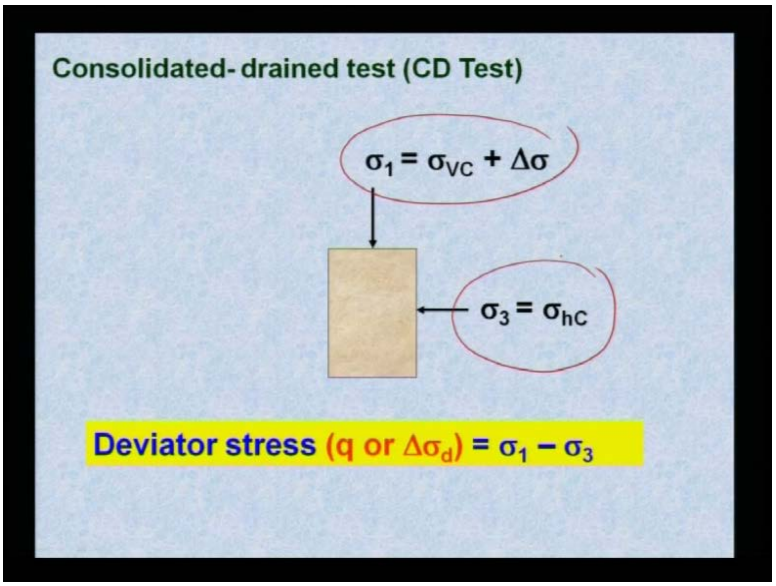

Consolidated drain test CD test, sigma one is sigma v c plus delta sigma, sigma 3 is sigma s c sigma; s c is your lateral pressure, sigma one is your vertical pressure.

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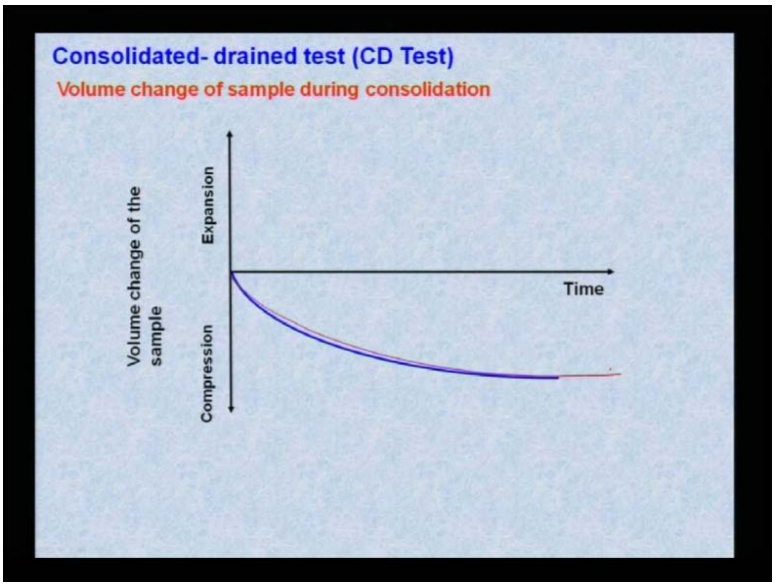

In CD test, consolidated drain test volume change sample during consolidation you can measure. So, this is your expansion, this is your compression, volume change of sample with time during consolidation you can measure, you can find it also coefficient of consolidation all all other consolidation parameters.

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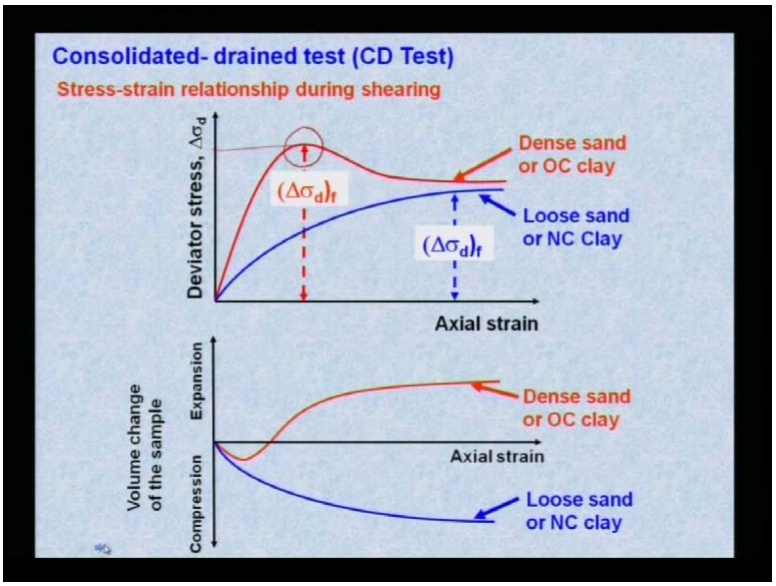

Now, you plot deviator stress versus axial strain in CD test, so as I say peak at peak it will increase linearly, it will go attend the peak, then it will decrease. So, at peak that is your failure, these corresponding to your deviator stress, that is your delta sigma d f; volume change of sample versus axial strain. Similarly, this is for dense sand or over consolidated clay, this is for loose sand or normally consolidated clay.

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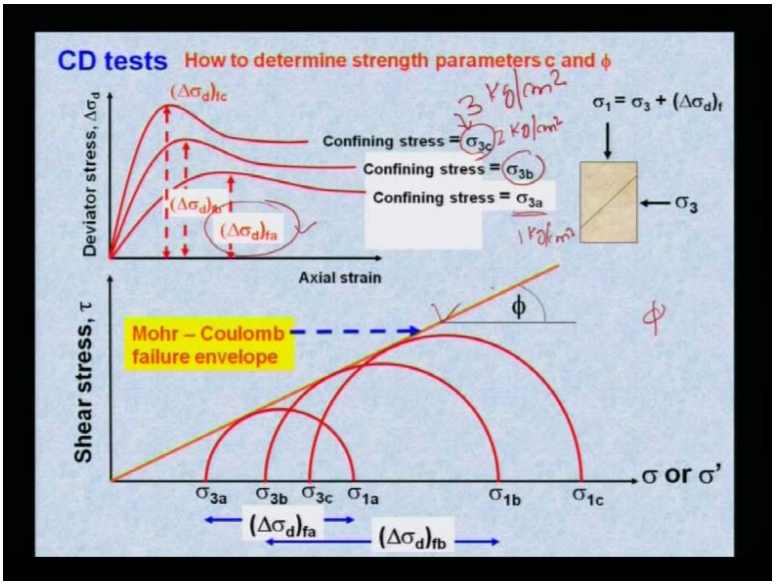

How to determine strength parameter c and phi, this your you get it this is fail - delta sigma d fail confining pressure of sigma delta sigma 3, this is your deviatoric stress

versus axial strain. Then, plot the Mohr circle with one confining pressure, as I said one confining pressure say one kg per cm square, you plot deviatoric stress versus axial strain how much it fails you find it out delta sigma d failure one with this you plot sigma 1, and sigma 3 a one Mohr circle.

Then with second confining stress say two kg per cm square, you plot deviator stress versus axial strain, again find it out the failure deviator stress. Then, plot your second Mohr circle for confining pressure of two kg per cm square. Similarly, do third test suppose this is say three kg per cm square, with this you plot third Mohr circle, then after plotting this three Mohr circle draw a common tangent. You see draw a tangent, it should touch your failure Mohr circle, so this is called Mohr-Coulomb failure envelope, and with this Mohr-Coloumb failure envelope envelope this is phi, and this is your failure angle phi, you can get your phi parameter from this Mohr--Coloumb failure angle, failure envelope.

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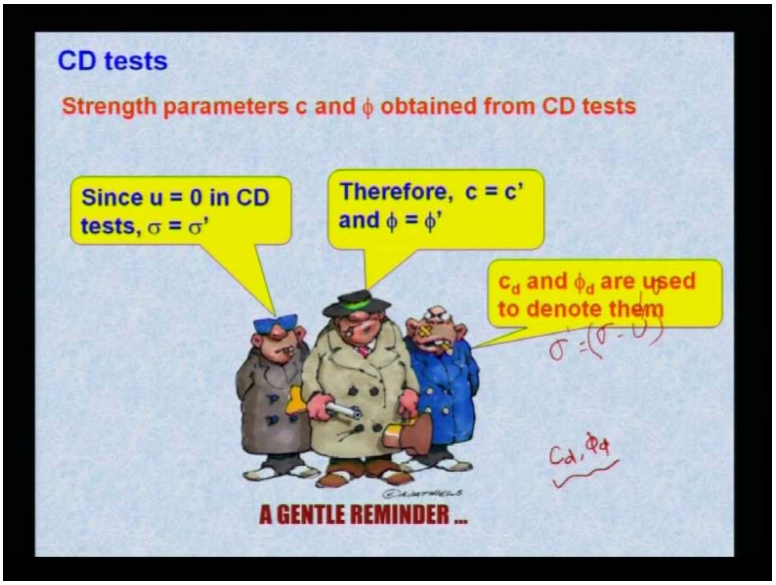

CD test strength parameter c and phi obtained from CD test, since pore water pressure u is equal to 0 in CD test - that means sigma is equal to sigma prime. Sigma prime is your effective stress which is nothing but is your sigma minus u as drainage valve is open in consolidated drain test.

So, in that case u is equal to 0 - that means sigma is equal to sigma prime. Therefore, c is equal to c prime, and phi is equal to phi prime; remember in CD test, c is equal to c

prime, phi is equal to phi prime, sigma is equal to sigma prime, because this drainage valve is open in both the cases during consolidation, as well as shearing. So, generally it has been written CD, and phi d, if I write this strength parameter in terms of CD, and phi d; that means, this strength parameter obtained from consolidated drain test. It says, it obtained from consolidated drain test.

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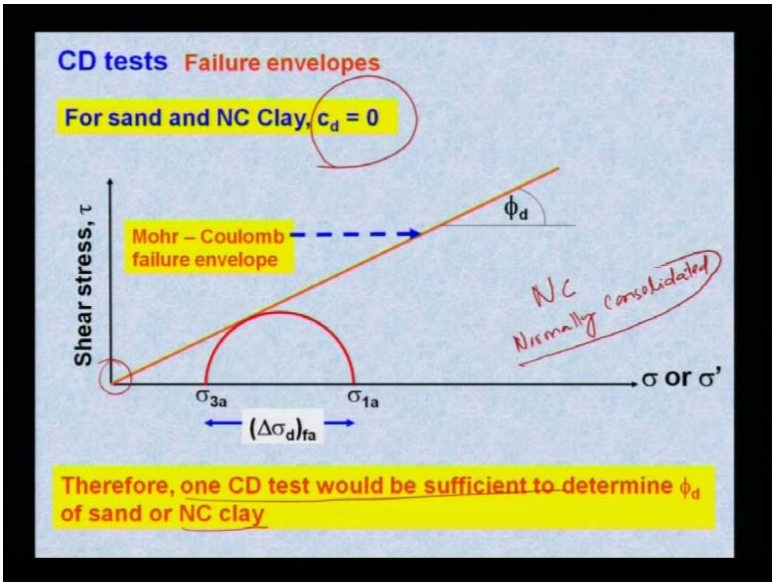

How the failure envelope looks CD test for sand, and normally consolidated clay look at here, it starts from origine with phi d Mohr-Coloumb failure envelope. One's CD test would be sufficient to determine phi d for sand, and sand or normally consolidated clay, because here it will start because u is equal to zero, and c is equal to 0, c d is equal to 0 for sand and normally consolidated clay.

So, it will start it will start from origin, once it will start from origin that means one CD test is sufficient for you to find it out phi d in sand or normally consolidated clay, NC for normally consolidated - NC stands for normally consolidated.

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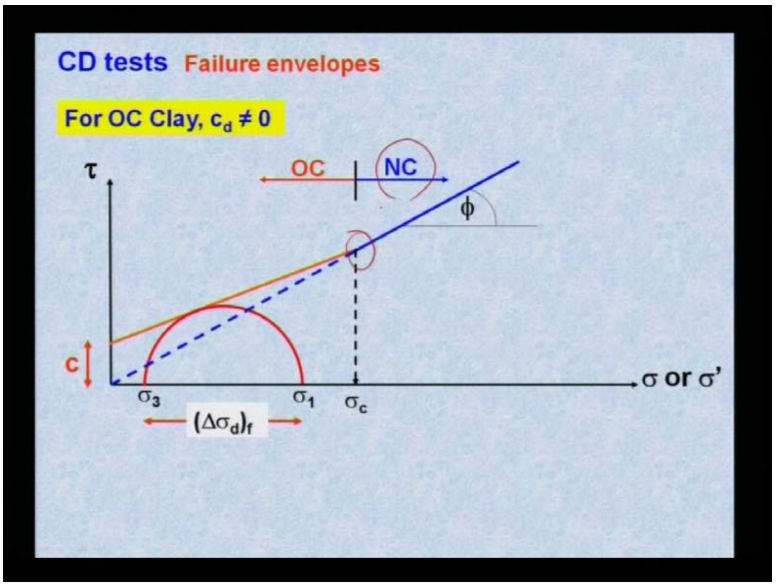

For over consolidated clay, this also I have discussed also earlier, where CD is not equal to zero, you will get a clear breakage between breakage of failure envelope between over consolidation as well as normal consolidation.

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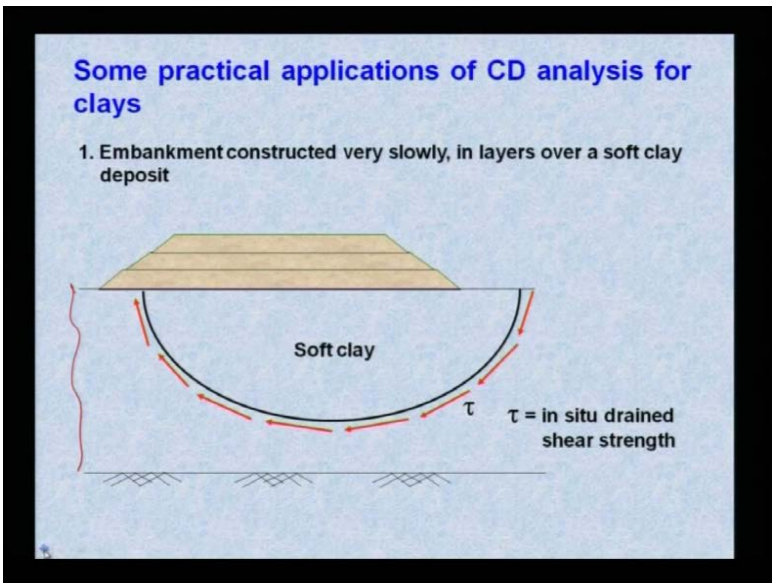

Where this CD test has been applied some practical application of c d analysis for clay embankment constructed very slowly in layers over a soft clay deposit. Remember embankment constructed very slowly, it takes time by stages in layers over a soft clay deposit. This is the soft clay deposit, it is the earlier there this embankment has been

constructed very slowly, that means in stages in that case consolidated drained test analysis will fit.

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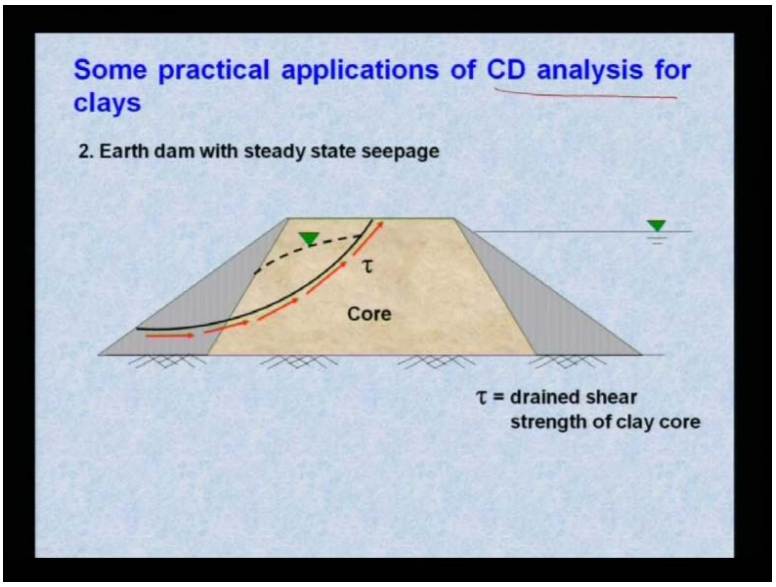

Then, next is your earth dam with steady states seepage, in case of earth dam with steady state seepage also CD analysis required.

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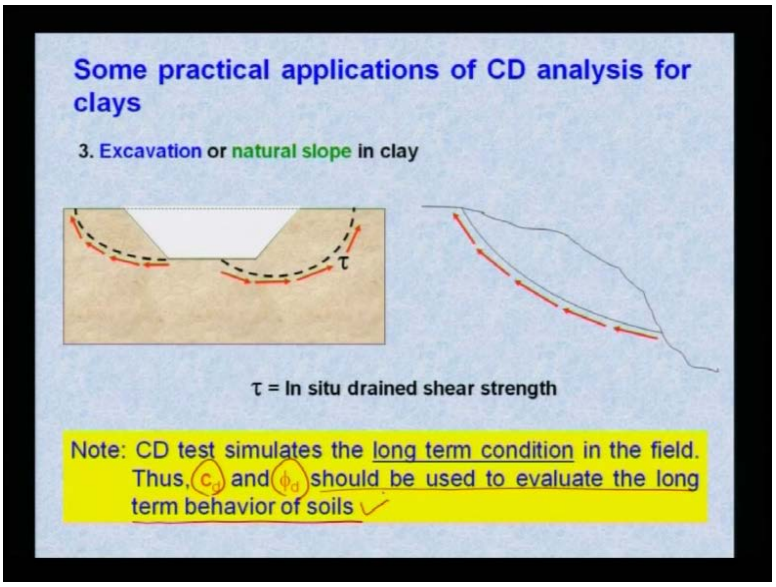

Third example in this case is your excavation or natural slopes in clay, this is your excavation. C D's test simulates the long term conditions, it is not short term condition, it simulates the long term condition in the field thus c d, and phi d should be used to

evaluate long term behavior of soil. Remember should be used to evaluate long term behavior of soil.