Geotechnical Measurements and Explorations
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Lecture No. # 33

Last lecture, we have finished is direct shear test procedures and techniques.

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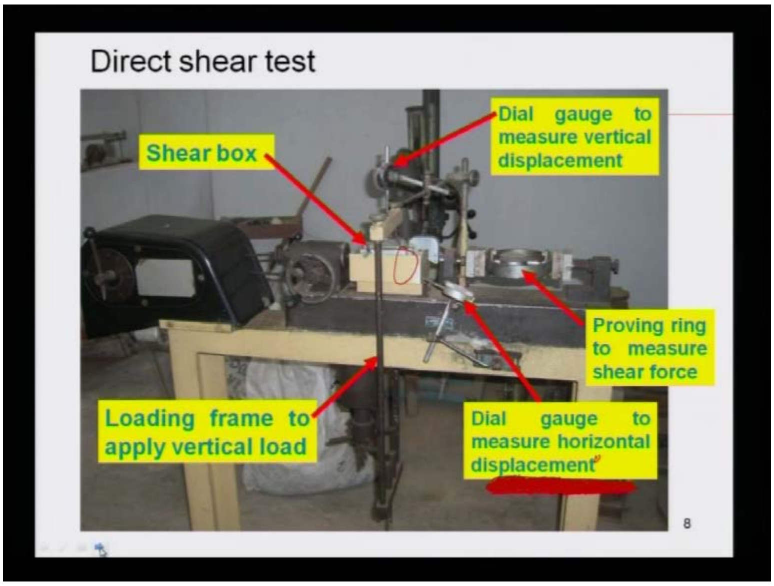

How it has been conducted in the laboratory, just to show this once just slightly repeat of this. This is your shear box, then loading frame to apply vertical load, then dial gauge measure vertical displacement and dial gauge to measure horizontal displacement. And this is your proving ring to measure shear force applied from here.

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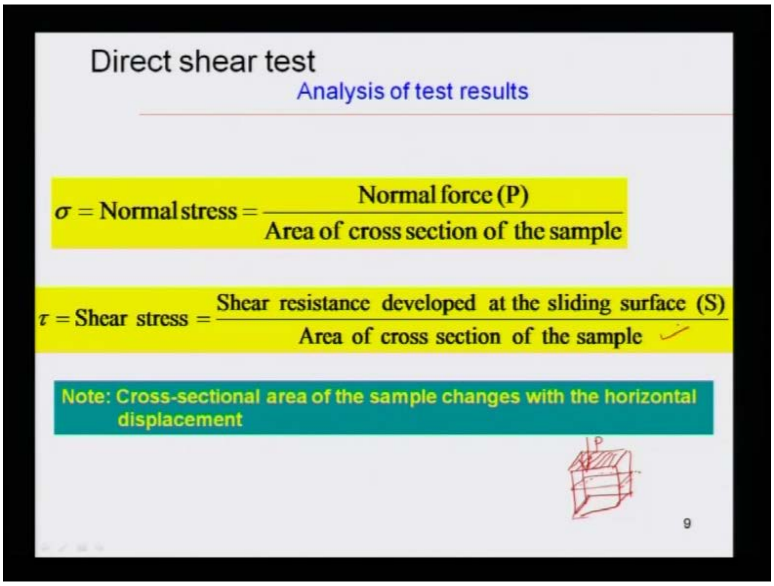

Now, as I said normal stress generally measured normal force by area of cross section, normal stress has been applied by vertically. So, this is the load or normal force p with this area if the direct shear box is like this, this area, this is the area normal force per area that is your normal stress.

However for shear stress as this is a predefined failure plane, so this will be distorted. This area will be every time for every shear it will be distorted, so that means area correction is required for shear stress. So, area of cross section of the sample has to be corrected for each shear load. A shear stress is equal to shear resistance developed at the sliding surface by area of cross section of the sample. So, cross sectional area of sample changes with this horizontal displacement as I said, so that means area of correction is required for your direct shear test in case of in the case of calculating shear stress.

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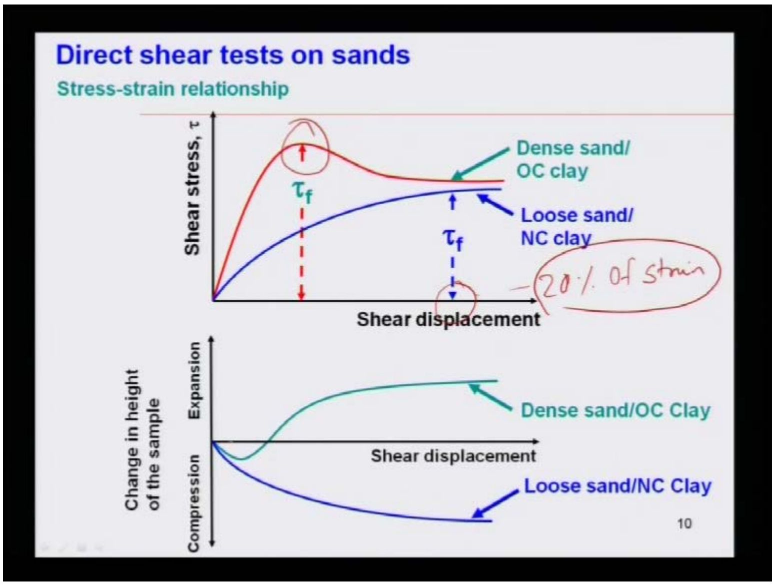

Now, direct shear test on sands stress strain relationship. If I plot shear stress versus shear displacement, how it looks. So, shear stress per shear displacement definitely will get a peak failure or peak shear stress you will get it. This will observe for dense sand or over consolidated clay. Similarly, change in height of the sample. How do you measure change in height of the sample? By means of dial gauge vertically placed, so whether it is a compression or extension change in height you can measure it. With this shear displacement how do you measure? Shear displacement will be measured by this dial gauge which has been placed laterally. So, with this change in height of the sample with this shear displacement, this kind of curve we will get it for dense sand or over consolidated clay.

Now, if I plot in the same graph for loose sand and normally consolidated clay there will not be any failure pattern, there will not be any peak you will get if I plot shear stress versus shear displacement. So, definitely the failure pattern will be achieved or failure criteria you have to adopt 20 percent of strain. 20 percent of strain will be adopted as the failure criteria. Similarly, if this change in height of the sample in compression or tension with the shear displacement you will get it, this will come like this, this is for your loose sand or normally consolidated clay.

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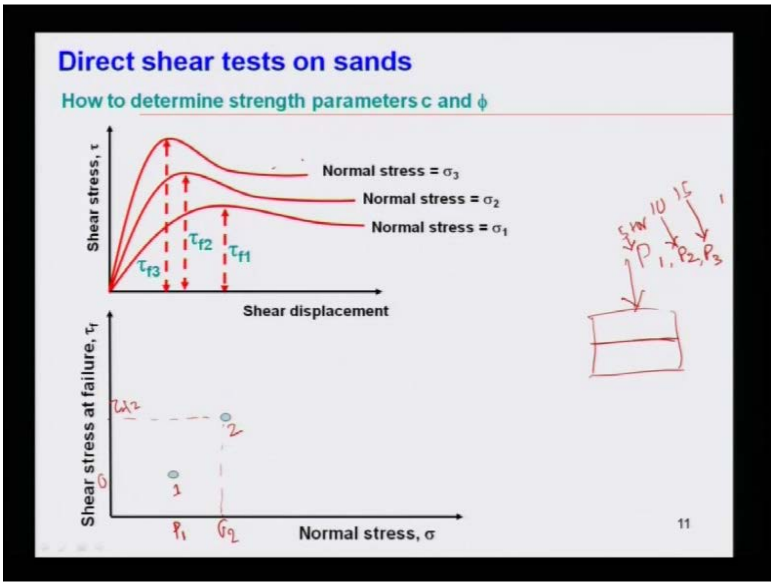

Now, how to determine strength parameter c and phi from direct shear test on sand? First, you measure your shear displacement then find it out shear stress, find it out your vertical displacement or compression or extension, find it out your based on the load, find it out your normal stress. Then plot shear stress versus shear displacement for a particular normal stress, suppose if this is my shear box that means for one load says p 1 you applied from there you will get a normal stress of sigma 1 which is equal to p 1 by a, for this normal stress you will get a shear stress versus displacement with this normal stress you will allow the soil to shear in a predefined failures of plane.

So, for particular normal stress sigma 1 draw your shear stress versus shear displacement and find it out from the peak what is your shear stress failure, you can find it out from peak tau f 1 means for one test for first load of p 1 or normal stress of sigma 1 you will get tau f 1. Now, shear stress at failure tau f and normal stress. Now, after getting this you plot shear stress at failure tau f versus normal stress then mark this point. This point is nothing but, this is your point. This point is related to your shear stress versus shear displacement for a particular value of normal stress of sigma 1, I am getting suppose say you are getting of shear stress suppose say of phi, phi per 2 kilo newton per meter square or k g per centimeter square whatever you will get, you are getting as per this unit then you plot it for a normal stress suppose say p 1 is equal to 1 kilo newton per meter square or phi kilo newton per meter square. This is your p 1 and this is your shear stress. So, this point you are getting. From this you are getting your first point for first test of with corresponding to a normal stress and shear stress at failure you will get your first point. Now, proceed to second test similarly, for a normal stress of sigma 2 say suppose for a load of p 2.

We can find it out sigma normal stress sigma 2. With this normal stress sigma 2 you will find it out your shear stress and shear displacement till failure and plot shear stress and shear displacement, once you plot it shear stress and shear displacement if you are getting a peak that means that is your failure from there you find it out your tau f 2. So, with this tau f 2, with this normal stress sigma 2 plot means identify your point where it is lying this graph in shear stress at failure versus normal stress. This is your second for second set of normal stress with this shear stress and shear displacement you are getting tau f 2 that means with your normal stress sigma 2, this is your tau f 2. Now, with this you proceed for your third set of this normal stress suppose say sigma 3.

Normal stress suppose say load you apply, suppose say p 3. Suppose, initially you applied load of 5 kilo newton, then 10, then 15. So 15 is nothing but, your this will relate to your stress corresponding to 15 kilo newton load and p 2 is your stress corresponding to 10 kilo newton load, p 1 is stress corresponding to 5 kilo newton load. With p 3, normal stress with p 3 you will get respective shear displacement and shear stress then plot the shear stress versus shear displacement from there you will find it out your tau f 3.

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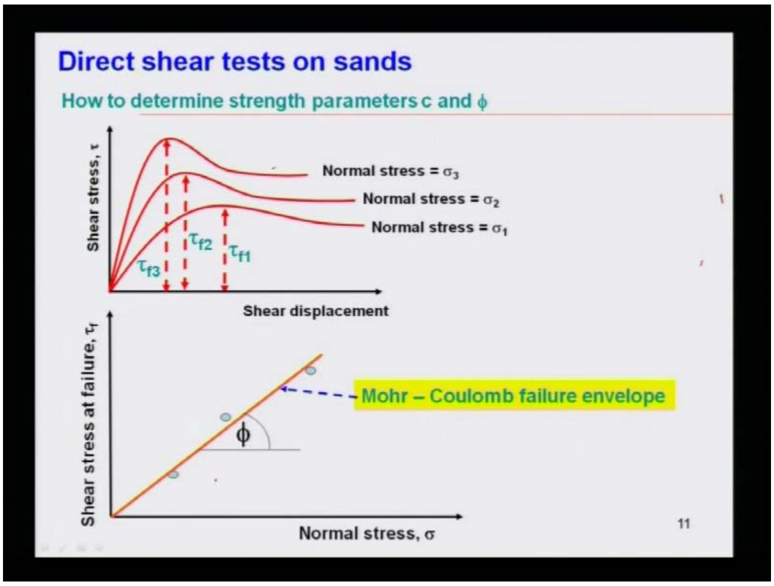

This is your failure, shear stress at failure you will find it out from the peak tau f 3.

With corresponding to sigma 3 and shear stress at failure tau f 3, then identify your third point where it is lying shear stress at failure tau f versus normal stress sigma. This is your third set of point you are identifying with this third set of point. Now, with this you are getting this 3 points in the graph that is shear stress at failure tau f and normal stress sigma for normal stress sigma 1, normal stress sigma 2, for normal stress sigma 3. 3 points you are plotting. Now, next step is draw a smooth line, as far as possible draw a line it will cover all the 3 points. So this is nothing but, your Mohr– Coulomb failure envelop. If it passes through origin then you will get phi, if it is not passes through origin then you will get both c as well as phi.

Now, once again I am repeating. How to find it out your direct shear test, how to determine your strength parameter c and phi, how to determine your c and phi that means for each set of load normal stress find it out shear stress and shear displacement and plot shear stress versus shear displacement and from there find it out your shear stress at failure for normal stress of sigma 1. Similarly, they if we are going to do at least 3 test you have to perform. That means normal stress say sigma 1, sigma 2 and sigma 3 and with these 3 normal stress you will find it out your shear stress at failure. Once you will get shear stress at failure then plot shear stress at failure versus normal stress. So, once you plot shear stress at failure and normal stresses identify this points. This points for first set of test, this is your normal, this is your shear stress at failure. Second set of the test this is your shear stress at failure.

This is your normal stress at failure. Similarly, third test once you get this 3 points then you can draw this by means of best curve draw a smooth line then you will find it out your mohr-coulomb this is nothing but, your mohr-coulomb failure envelope, from their you can find it out phi as well as c.

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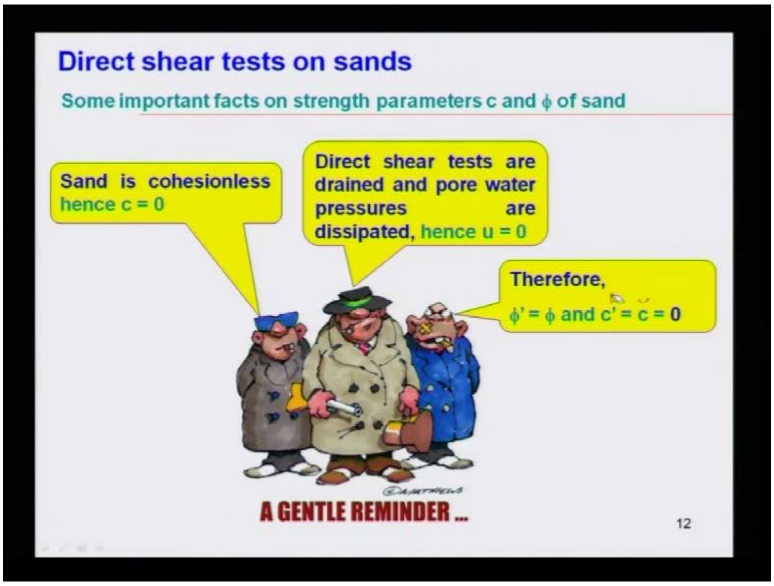

Some important facts on shear strength parameter of c phi of sand, whatever you are getting from direct shear test on sand. Remember sand is a cohesion less soil hence c parameter is to be 0, c is equal to 0. Second case is your direct shear test are drained and pore water pressures are dissipated means as I said earlier direct shear test is almost it gives best result for drained test that means in this case pore water pressure u is equal to 0.

So therefore, phi prime phi effective phi prime is nothing but, is your phi minus pore water pressure. So, this will be as pore water pressure u is equal to 0, u is equal to 0 that means phi prime is equal to phi and c prime is equal to c, in this case as it is cohesion less soil c is equal to 0. That means c prime is equal to c is equal to 0 c prime is your effective c is your total so this is equal to 0.

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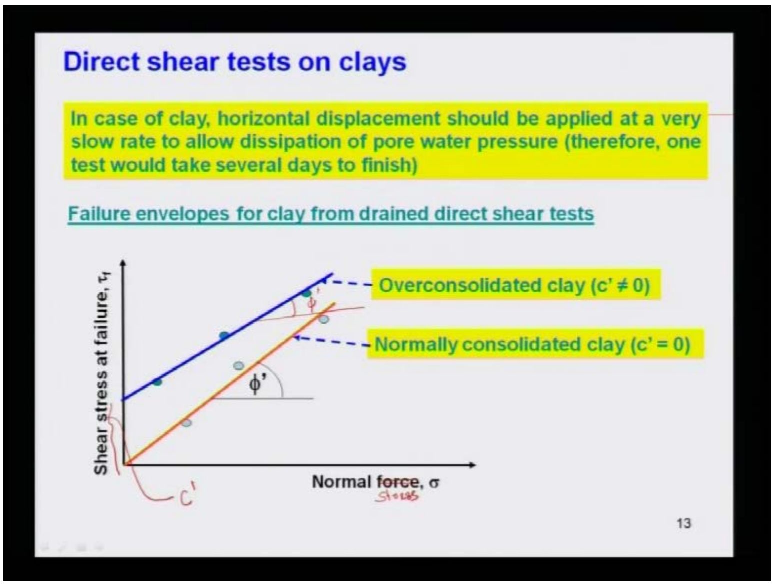

Direct shear test on clay. Now, we have discussed direct shear test on sand. Now, we are going to discuss direct shear test on clays. In case of clay, horizontal displacement should be applied at a very slow rate. If you remember well the displacement laterally horizontal displacement applied to generate your shear stress along the pre defined failure plane.

So, this horizontal displacement in case of clay, it should be very slow rate to allow dissipation of pore water pressure. Therefore, 1 test would take several days to finish. That means it should be so slow so it will allow slowly dissipation of pore water pressure will occur. So, 1 test would take several days to finish. Failure envelopes for clay from drained direct shear test. So, for normally consolidated clay, for normally consolidated clay if I plot shear stress at failure versus normal stress or normal, this is not normal force this is a normal stress. And, for normally consolidated clay if I draw it, it will be c prime is equal to 0, you will only get phi prime. For over consolidated clay it is not possible that c prime is equal to 0, it is not 0.

So, you will get in case of over consolidated clay both c prime as well as phi prime, that means this vertical intercept is your c prime and whatever angle it makes with your horizontal plane this is nothing but, your phi prime. Now, where this is one way of direct shear test you can find it out strength parameter, particularly strength parameter shear strength parameter c and phi and direct shear test is more applicable, more applicable for drain test where this pore water pressure development of pore water pressure may not occur at that condition drain test u is equal to 0. We, have discussed for sand, for sand c is equal to 0, as it is a cohesion less soil. So, phi is equal to phi prime, for clay for normally consolidated clay c prime is equal to 0 and for over consolidated clay you will get c prime as well as phi prime. This is for a particular soil, I have means there are two techniques in the laboratory to find it out, shear strength parameter. One, is from triaxial test other is from direct shear test as I discussed earlier.

Now, besides this shear strength parameter where this

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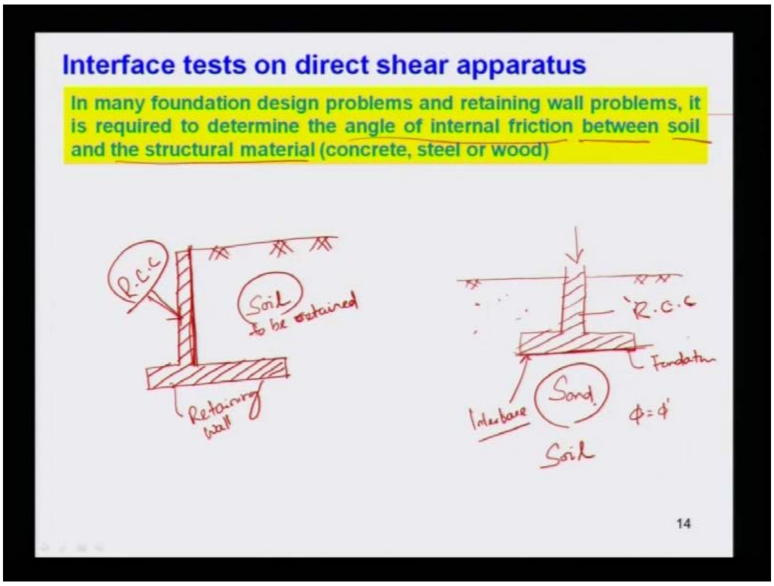

direct shear test is applicable? What is its importance? Now, if I come back to here then interface tests on direct shear test apparatus. What is interface test? If you look at this interface test many foundation design problem, any retaining wall problem it is required to determine the angle of internal friction between soil and structural material. Let us take for example, 1 footing. This is the footing constructed over a cohesion less soil. So, say this is sand. Now, for sand you will get phi or phi prime from direct shear test that is fine. Now, the moment you apply the load next question is hard the surface.

What is the inter granular or frictional angle between sand and foundation? Because this foundation is constructed by r c c, reinforce concrete structure r c c. So, that means what is the inter friction angle between this foundation between this foundation and the soil and the soil at interface. This is called nothing but your interface. This is a case 1. Now, come back to other case. Look at this. This is your retaining wall, retaining wall means it retain soil one side so that road can be constructed from low line area to high line area. So, this is your retaining wall. For design point of view, now if this is my soil to be retained, soil to be retained for design point of view. Now, what is the friction angle between the soil and the wall? Because, these are not 2 materials.

It is soil and this wall. Wall is constructed over reinforced concrete structure r c c that means it is mixture of steel, concrete, sand, cement all. So, these are the 2 different materials. Now, for these 2 different material, what is your friction angle between at the interface within this retaining wall and soil? How do you get it? You will get it from direct shear test apparatus that is why this is the another useful test to find it out, interface test or inter frictional angle between soil or any material or other than the material of soil. In many foundation design problem and retaining wall problems it is required to determine the angle of internal friction, remember angle of internal friction between soil and the structural material. It may be concrete, it may be steel, it may be wood.

So, now how I am going to find it out this inter frictional angle between the structure and the soil. Now, next step is your by means of direct shear test you will find it out inter frictional angle between soil and the structure. Can you imagine how you are going to find it out by means of direct shear test.

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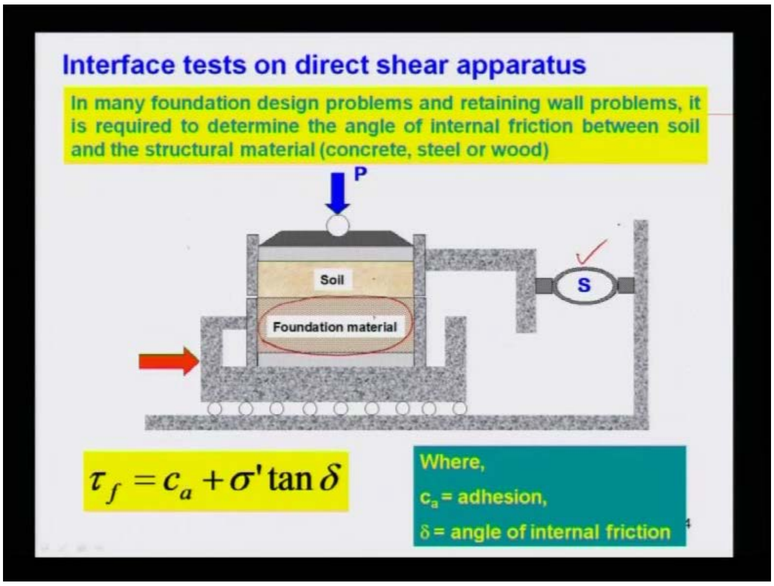

Just think, look at here. This is your complete test set up, in this test set up in the shear box what earlier it has been done. Earlier it has been done, complete shear box is filled by soil. When you allow the shear force, the shear stress will generate between generate along the between the particles of soils.

Now, what happen one part of the one side half of the shear box you take your material. This is your foundation material other than the soil, it may be concrete, it may be steel, it may be wood. You place this completely inside this box half of the box other half you take once you place this, how it is a bifurcated? It is completely you can make it into two parts, if I take the shear box. So, first take the bottom part of the box. Then, what happen you first in the bottom part place your foundation material same size of the foundation material either it is a wooden concrete or may be steel. After placing this top part you place over your bottom part with screw, tight it so that you can place soil inside. Then entire shear box you take it and place it and before doing the test, this screw has to be taken out so that this shearing can be applied. Otherwise, you can do either you put it in the top part, bottom part of the foundation material or what you can do you take this shear box, half of the shear box, fill your soil material, take your soil, soil material.

After placing then take your other half, then take your other half, then screw it. Then here you place your foundation material, either you place it your bottom or top you take it one half is your foundation material, other half is your soil material or soil. Then after placing you go for direct shear test. Then what will happen just think what will happen, this will be shear along with this that means soil will shear along the foundation material that means shear stress generated at the surface then whatever shear strength or shear strength parameter you are going to get phi that or delta that is nothing but, angle of internal friction between soil and foundation material. So, this is most important test, direct shear test it can be used to find it out the inter friction between the soil and the structural material.

Now, look at this tau f is nothing but, c a plus sigma prime tan delta. So, where c a is adhesion. Adhesion between earlier it was adhesion c is your adhesion of the soil. Now, it is adhesion between soil and foundation material. Now, delta is nothing but, from the here earlier you are getting it tan phi, phi is angle of internal friction between the soil.

Now, it is delta. Delta is nothing but, angle of internal friction between the soil and foundation material. This is all about your direct shear test and I have shown you completely the test apparatus. How this test apparatus, dimensions. How you are going to do the test in the laboratory? What is the physics behind it? How the shear stress has been generated along the predefined failure surface and how you are going to measure your shear force by means of proving ring?

How you apply your normal stress by means of vertical load and what is your output? How you are going to get your shear strength parameters from direct shear test for sand as well as clay? Also, I have discuss means I have shown you the interface test on direct shear test apparatus, from their you can find it out internal friction angle between your soil and your material or structural material. How you are going to find it out c a and delta. This is all about your direct shear test.

Next page of laboratory test this is most important parameter, of course permeability determined in the in situ means

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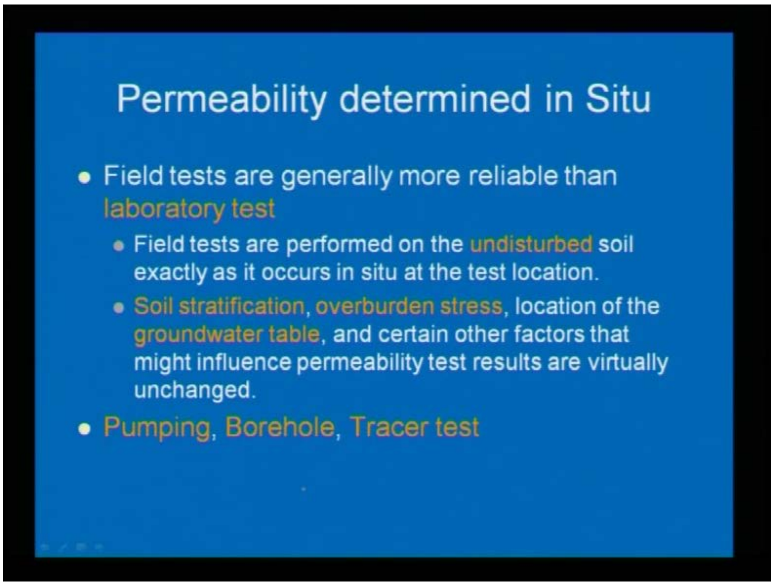

how do you find it out coefficient of permeability field as well as laboratory?

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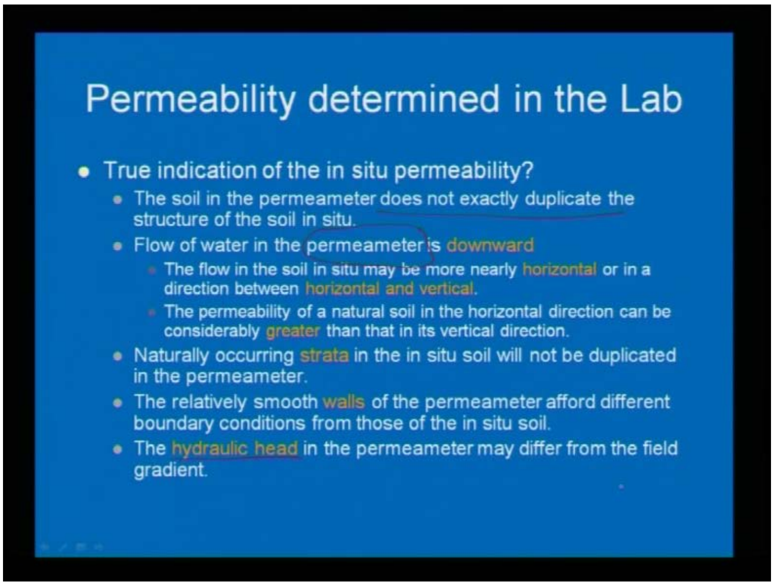

So, first we will start permeability determined in the lab. So, what do we mean by this permeability its basically true indication of in situ means it is a water flow, the soil in the permeameter does not exactly duplicate the structure of soil in in situ. If somebody will ask what do you mean by permeability that means as far as the geotechnical engineering is concerned I will say flow of water in soil, flow of a water in soil is the meaning means that that is the meaning how much water passed through a soil that term says the permeability.

So, flow of water in permeameter is downward. The flow in the soil in in situ look at the differentiation in the permeability in the lab, how far it is differ from your in situ permeability. Generally in the lab we will do it by permeameter test either constant head permeameter or variable head permeameter. I will discuss, I will show you this how this lab test has been done in the laboratory. So, by means of permeameter apparatus this soil does not exactly duplicate this structure of soil in in situ. This is first one you can say that this is your draw back or may be these are your limitations. It does not exactly duplicate the structure of soil in in situ. Flow of water in a permeameter.

Generally, in the laboratory by means of permeameter. Generally this is the test in the laboratory we say permeameter test or permeability test flow of water in permeameter is down ward that means whatever we do in the laboratory test generally it is downward however flow in the soil in in situ may be more nearly horizontal, it may possible in the field, it may be horizontal, it may be in the direction between horizontal or vertical if in the field, if this is my field it may possible flow is flowing like this so that that means this is horizontal, it may possible flow is flowing like this that means it may be vertical, it may possible that flow is flowing in a inclined direction it may be vertical as well as horizontal.

The permeability of a natural soil in horizontal direction may be or can be greater than in its vertical direction. It has been proven in soil mechanics so in natural soil as in horizontal direction the permeability is greater as compared to permeability in vertical direction. Naturally occurring strata in the in the in situ soil will not be duplicated in permeameter. Whatever in in situ the soil is there we cannot make it exactly same in the laboratory. This is the only indicative of how much your permeability in the laboratory test it gives an indicative of in situ permeability. The relative smooth wall of the permeameter of a different boundary condition from those in in situ, if you look at in the lab I will show you the lab test equipment next class.

So, if you look at in the lab by means of permeameter you are doing, you are allowing water flow from vertically from one end to other end. The boundary condition we have fixed, this is a pre defined boundary conditions you can say or it is well defined means earlierly it is defined these predefined boundary conditions. So, which is not true which is not the boundary condition is not same as in case of field in situ, boundary condition is wide range biometric condition we will get it. The hydraulic head this is more important, the hydraulic head in the permeameter may differ from the field gradient. Hydraulic head is fixed in permeameter in laboratory test. So, which is not true in the field it may be different in case of laboratory test also.

Now, next come back to your this is all about the what are the draw back if I do the permeability test in the laboratory, how far it is reflecting truly to the field condition.

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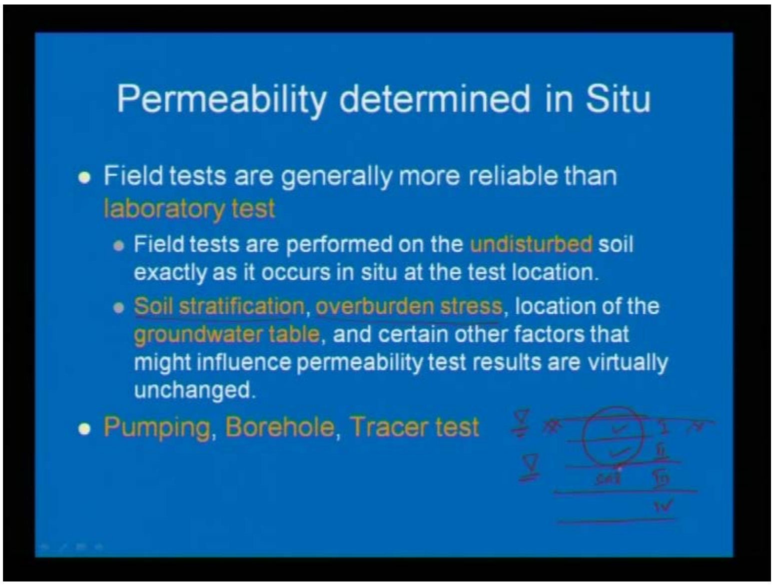

Now, next is your permeability in in situ. Generally in field tests are more reliable than your laboratory test. You can say it is always, so whatever test you do in the field these are more reliable because without disturbing soil sample in soil sample as it is in that you are doing that test, so whatever do test in the field or you can say that field test are generally more reliable than laboratory test. Field test are performed on the undisturbed soil. It is particularly undisturbed soil, this soil is not getting any disturbance. Soil stratification, over burden stress, location of ground water table and certain other parameters or other factors that might influence your permeability test that will be unchanged in case of field test. In case of field test soil stratification, soil stratification means how the soils are soils are in the field generally deposited layer by layer.

So, layer 1, layer 2, layer 3, layer 4. This is a layer by layer that means layer 1, layer 2, layer 3, layer 4. So, this is called stratification. This stratification in the field it is most important parameter. So, while doing the laboratory you may not make this stratification as it is in the field. Then over burden stress, suppose you are taking a you want to measure the permeability of soil of the third layer, the moment you measure the permeability of the soil of the third layer that means above the third layer, layer 2, layer 1. They are there, that means the over burden pressure comes into picture. This over burden pressure you cannot create or simulate exactly to the field condition in the laboratory, then location of ground water table, it may possible that water table may be at the ground surface or water table may be at the 2 meter, 3 meter below or at certain depth below the ground surface. How do you simulate this location of water table in laboratory?

So, also there are other parameters which influence particularly your permeability. These parameters will be unchanged in the field means I am just comparing why field tests are better than your laboratory test, we will discuss one by one laboratory test as well as field test. These are the parameters you can say I cannot simulate soil stratification as exactly as in field, over burden is lost the moment you are doing. Same over burden cannot be simulated, ground water table it may fluctuate, how to simulate the ground water table in the field condition in the lab. So, that means these are the major parameters which are affecting your permeability, then what are the tests they are in the laboratory and what are the test in your field.

As I said in the laboratory there are two tests methods, it is called constant head permeability. Laboratory if I write it laboratory, one is your constant head permeability test, constant head permeability test. Other is your variable head permeability test.

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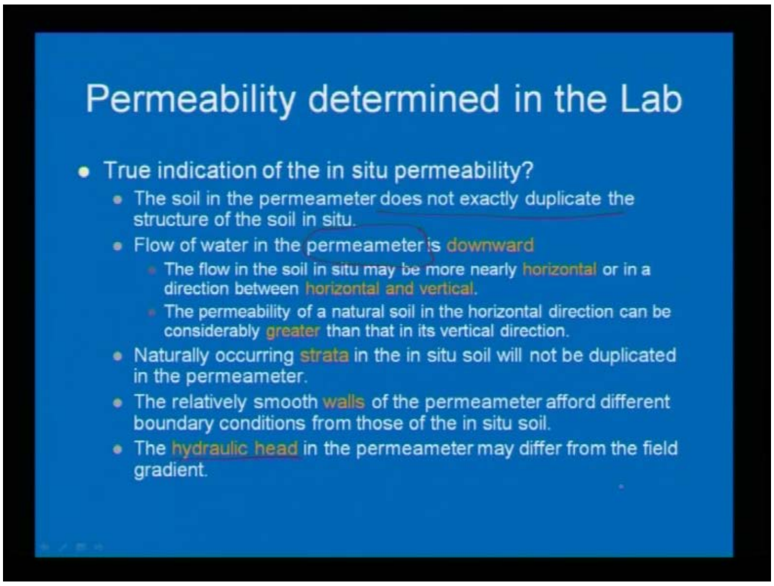

The test equipment by which the test has been conducted this is called permeameter, as I said earlier this is called permeameters. The test equipment where we are going to do this in the lab permeability test this is called permeameter.

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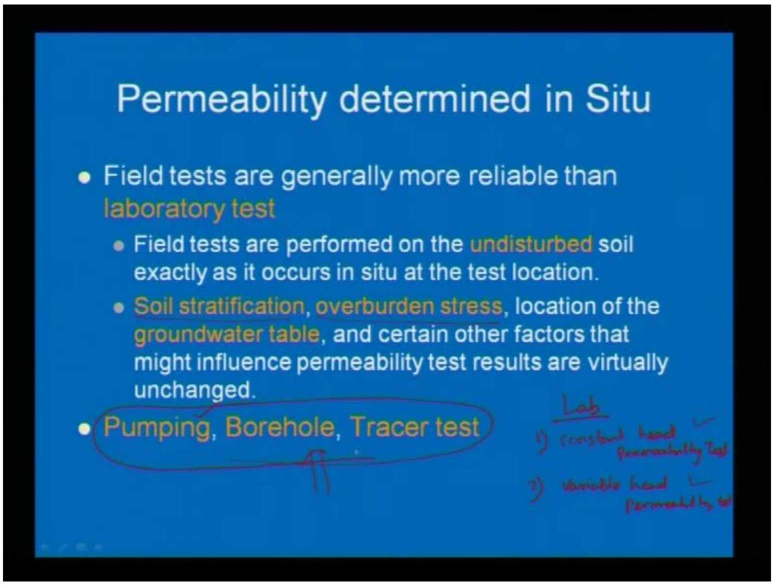

Now, these are the two tests generally we do in the laboratory. What are the test we generally do in the field? The test we generally do in the field, pumping test that means you take pump, certain amount of water leave it and allow water to flow through inside the borehole then measure how much time it takes to flow certain amount of water this is called pumping.

We will discuss this, we will also discuss the laboratory constant and permeability, variable head permeability also, then borehole. In the field you can make a borehole allow water to flow inside the borehole then measure how much water flow inside the borehole with a recorded time, so discharge for time is nothing but, your velocity from their you can find it out your permeability. Then tracer test, you can allow tracer you can find it out what is your permeability in the laboratory in the field. So, these are the complete these are the 3 field tests, generally we do to measure your permeability test in the field. And these are the 2 test, one is your constant head permeability test other is your variable head permeability test in the laboratory.

We will discuss one by one.

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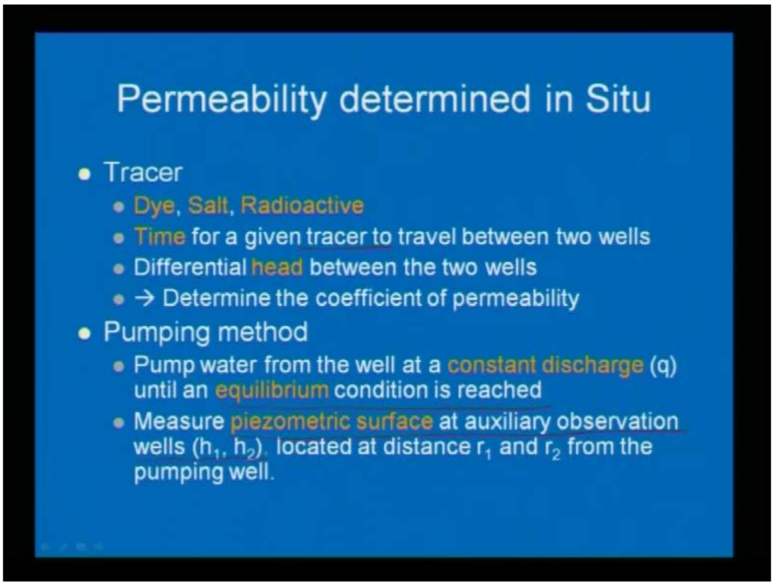

So, tracers it is a dye, salt or radioactive time for a given tracer to travel, you allow like a dye, allow the dye inside water, so time for a given tracer to travel between the two wells. So, two wells you take it in the field you make a two wells and allow dyes inside the water. So, time to travel time for travel from one well to other well, the dye this time you have to measure and differential head between the two wells also you measure, then you find it out your permeability. Tracers means, you allow something it will flow along with the water. So, it will flow one point to other point how much time it takes by means of tracer you can get it because water flow then it is very difficult to trace it out how much water but, tracers you can easily find it out dyes or may be radioactive, may be salt how much tracer it is going from one well to other well this is called method of tracer. Then pumping method, pump water from the well at a constant discharge means you cannot pump it arbitrarily definitely you pump water from the well at a constant discharge until an equilibrium condition is reached that means constant discharge you pump from well.

So, that equilibrium condition achieved and measure the piezometric surface at the auxiliary observation wells, nearby some auxiliary observation wells should be there from piezometer measure the piezometric surface located at distance r 1 and r 2 so this is by this you will find it out pumping method. Another, is your borehole then by making this, I have not written there by making your bore hole how much discharge of water you can collect over the period of time in that way also you can find it out permeability test in the field. This is all about means what are the test generally we are going to do in the laboratory? What are the test in situ we are going to laboratory and what is the advantage? What are the lacuna in the, what is the draw back in the laboratory and what are the advantage if you are going to do in situ? Next class I will explain one by one laboratory test as well as field test. Thank you.