Soil Dynamics
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Lecture 22
Determination of Dynamic Properties of Soils (laboratory Tests-Part 2)

Hello everyone, today we will continue our discussion on determination of dynamic properties of soils. In last class, we have studied how to determine that dynamic properties namely dynamic shear modulus and dynamic elastic modulus, using resonant column test, which is a low strain laboratory test, we have also studied how to find out the damping ratio in resonant column test.

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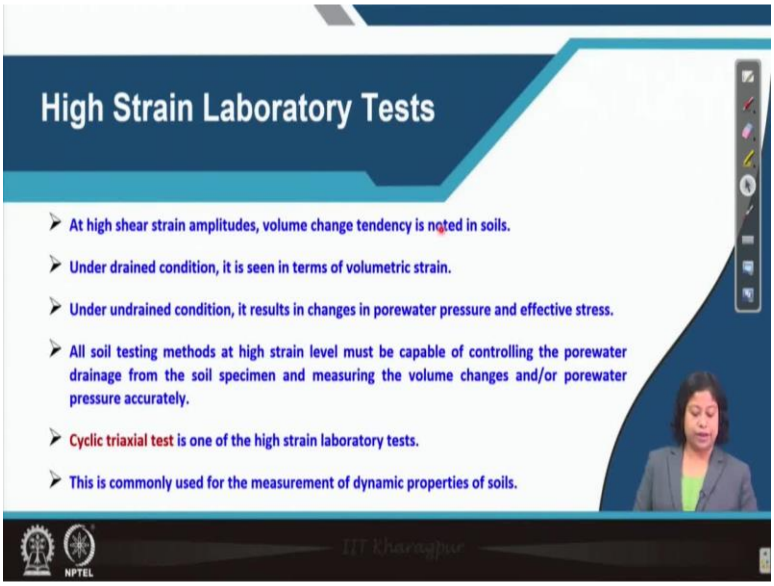

Today, we will discuss the high strain method, high strain laboratory test. There are different laboratory tests which are coming under high strain laboratory tests for an example, cyclic triaxial test, then cyclic torsional shear test etc. So, in our syllabus of this course, there are two laboratory tests one is cyclic triaxial test and the other one is cyclic torsional shear test which we will discuss.

So, what is high strain laboratory test? What is the specialty? At high shear strain amplitude volume change tendency is noted in soil that is a special feature of high shear strain laboratory test. Under drained condition that means, when we are allowing pore water pressure to dissipate that time it is seen in terms of volumetric strain.

But, under undrained condition that means, we are stopping that pore water pressure or pore water itself, we are stopping pore water pressure to dissipate from the system that time what is happen? It results in changes in pore water pressure and effective stress if pore water pressure increases effective stress will decrease if pore water pressure decreases, then effective stress will increase.

So, all soil testing methods at high strain level must be capable of controlling the pore water drainage from the soil specimen and also the capable of measuring the volume changes and or pore water pressure accurately. So, it should do two things it will be capable of measuring the volume change or it should measure the pore water pressure. Cyclic triaxial test is one of the high strain laboratory tests which I have already told you. This is commonly used for the determination of dynamic properties of soil.

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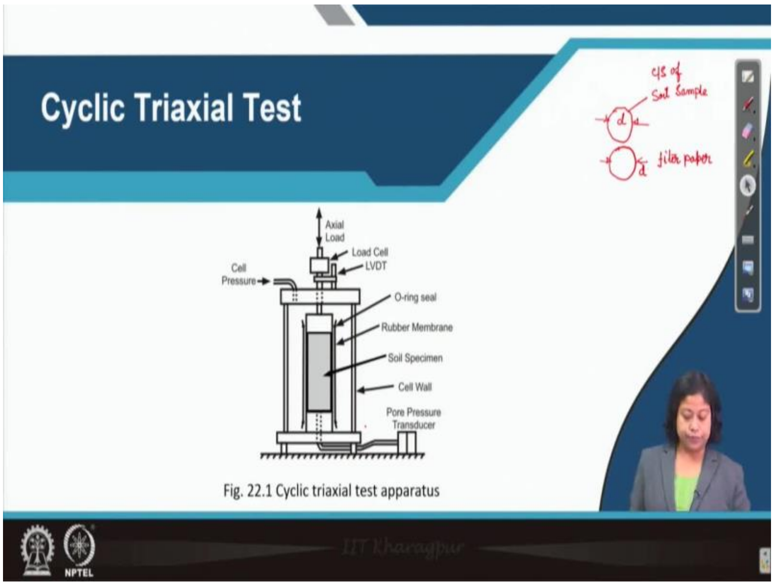

Here you can see a schematic diagram of one triaxial test apparatus. So, this is our triaxial cell, the entire thing is resting on the pedestal. Now, you can see the pedestal on which bottom load platen is placed on the bottom load platen one porous stone is placed and above the porous stone. There should be one filter paper and the cross which is the filter paper should be cut in circular size. So, I can show here just so, if this is the cross sectional area of our sample generally in case of cyclic triaxial it is generally not less than 50 or 51 millimeter as per the ASTM specification.

So, if this is the diameter D of the soil sample then the shape and size of the filter paper will be circular and the diameter also be D or slightly higher than D. So, if this is soil sample I can write cross section of soil sample then this is filter paper. So, at the top of the porous stone, one filter paper is placed, then that cylindrical soil sample will be placed above the filter paper and at the top of the cylindrical soil sample, we will place the second filter paper above which again we will place another porous stone to facilitate the drainage.

Then this top load platen will be placed which is attached here you can see which is attached to our rod and the diameter of this rod is approximately one sixth of the diameter of this soil sample. And that rod is connected to the load cell and load axial load will be applied through that rod to the sample or through the, I can say through the top load platen.

Now, you can see here one LVDT is placed which measure the axial deformation of the soil sample pore pressure transducer which is connected to the triaxial cell should be capable to measure the pore pressure under undried condition.

Now, the rubber membrane will be used to confine the cylindrical soil sample and also it will cover the load platen top and bottom load platen and the porous stones. O rings will be used to make to tight the membrane to the platen and porous stones. So, the arrangement is almost same as the arrangement we see in our static triaxial test. Here you can see the another pressure line through which cell pressure is applied to in to this soil sample

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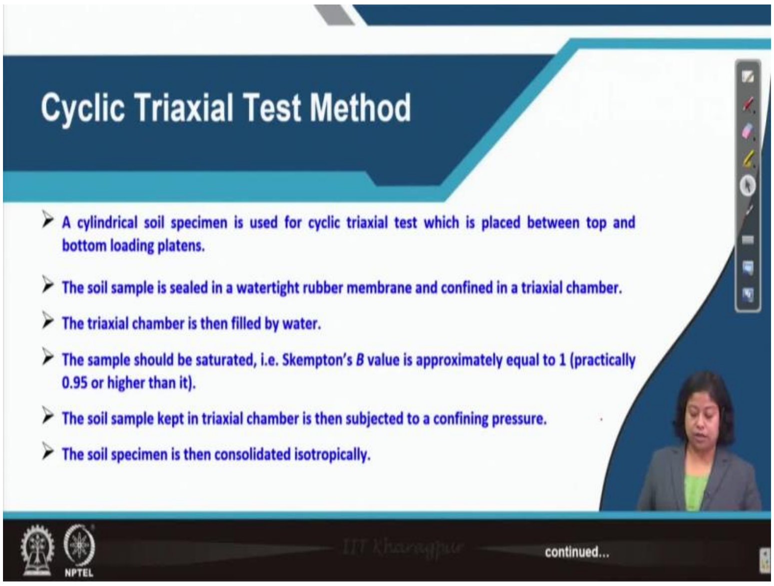

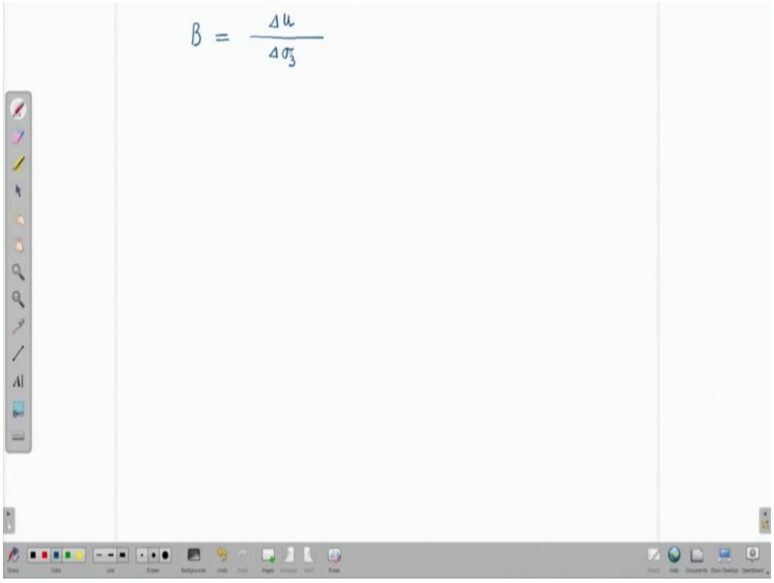

Come to cyclic triaxial test method. As I already said a cylindrical soil specimen is used for cycling triaxial test which is placed between top and bottom loading platens, the size of the cylindrical specimen is specified in ASTM. So, there it is said that the minimum diameter of the cylindrical specimen should be as close as 51 millimeter. Sometimes we take it also 50 millimeter and the height to diameter ratio should be 2 is to 1 or more than that, but the, during the loading, we need to ensure that the sample should not buckle.

Then another important thing is that the soil which we use for testing that grain size of that maximum grain size of the soil should not be more than one sixth of the diameter of the cylindrical specimen. So, let us take 50 millimeter diameter of the cylindrical specimen. So, in that cylindrical soil sample we can take soil have been maximum grain size 50 divided by 6 in millimeter.

Then the soil sample is sealed in a water tight rubber membrane and confined in a triaxial chamber as I have shown in the previous figure, the triaxial chamber then will be filled by water the sample should be saturated. Now, how do we understand that the sample is saturated, there is a mechanism to check the saturation level of the sample.

We need to find out the Skempton's B value which is also called as Skempton's pore pressure parameter. So, that we need to check and if our sample is saturated, then these B values should be as close as 0.95 or maybe slightly more than that, ideally it should be 1. So, how to find out the Skempton's pore pressure parameter B?

So, B which is Skempton's pore pressure parameter can be determined by using this equation delta u divided by delta sigma 3 where delta u is the change in pore water pressure and delta sigma 3 is changing confining pressure. So, the next step here is the soil sample kept in triaxial chamber is then subjected to confining pressure that means after ensuring full saturation. Next step is to apply the confining pressure to the system.

Next step is consolidation. So, the soil specimen is then consolidated isotropically. So, what is isotropically consolidation? That question may come in your mind.

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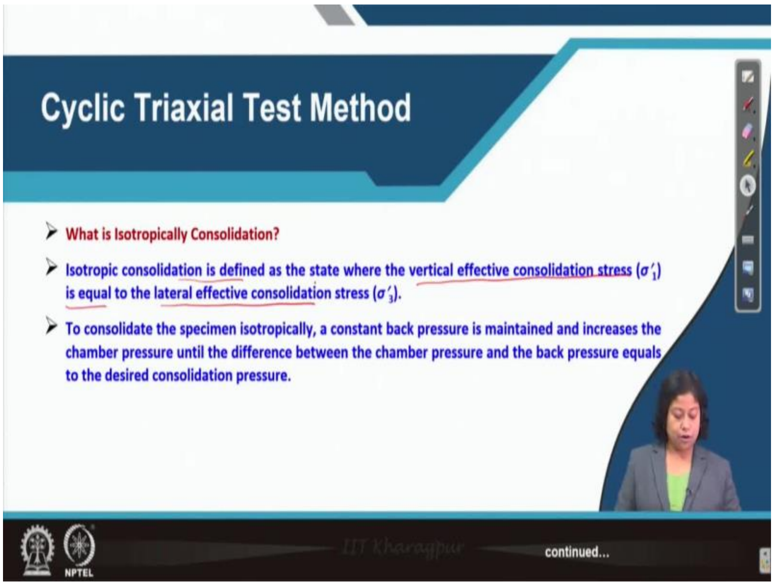

Let us see what is the definition of isotropically consolidation? Isotropically consolidation is defined as the state where the vertical effective consolidation stress which is sigma 1 dash equal to the lateral effective consolidation stress that is sigma 3 dash that means when the all-round pressure remains same from the top and from the site of the soil sample that time we can say the soil is consolidated isotropically.

So I am just repeating the definition once again, isotropically consolidation state represents the vertical effective consolidation stress is equal to the lateral effective consolidation stress. Now, to consolidate the specimen isotropically, a constant back pressure is maintained in the system and increases the chamber pressure until the difference between the chamber pressure and the back pressure equals to the desired consolidation pressure.

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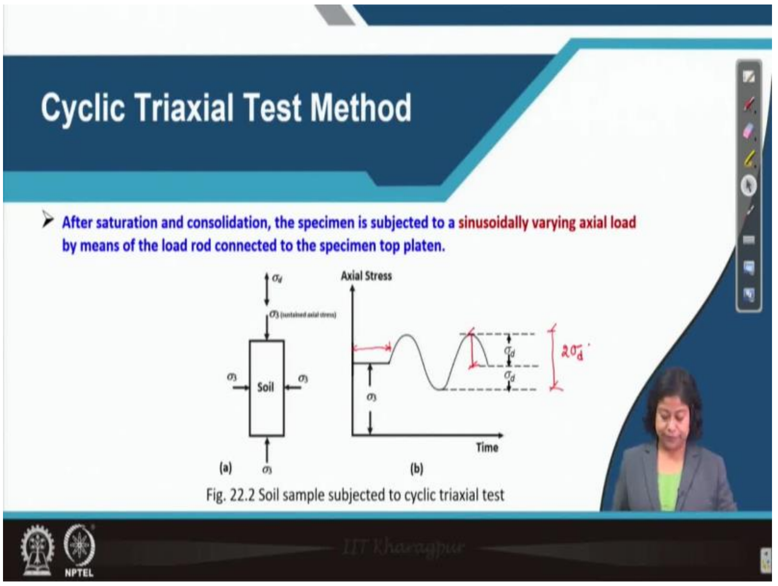

And of course, before starting this exercise we need to ensure B value is close to 1 or close to 0.95. Now, after saturation and consolidation the next step is to apply sin vertical load that means the sample is subjected to a sinusoidally varying axial load. Here you can see already before the stage sample is subjected to all round pressure which is sigma 3 then so, in this diagram up to this it is. What is going on here? We are consolidating sample at sigma 3.

After that we are applying axial load and you can say it is sinusoidal axial load. So, now, how much is the total axial load sigma 3 plus sigma d times in this case it is sin curve. So, sigma 3 plus sigma d sin sigma D sin omega t where sigma d is the single amplitude of the load. So, single amplitude means this one and if we are talking double amplitude that means, this one so, in this case double amplitude is 2 sigma d.

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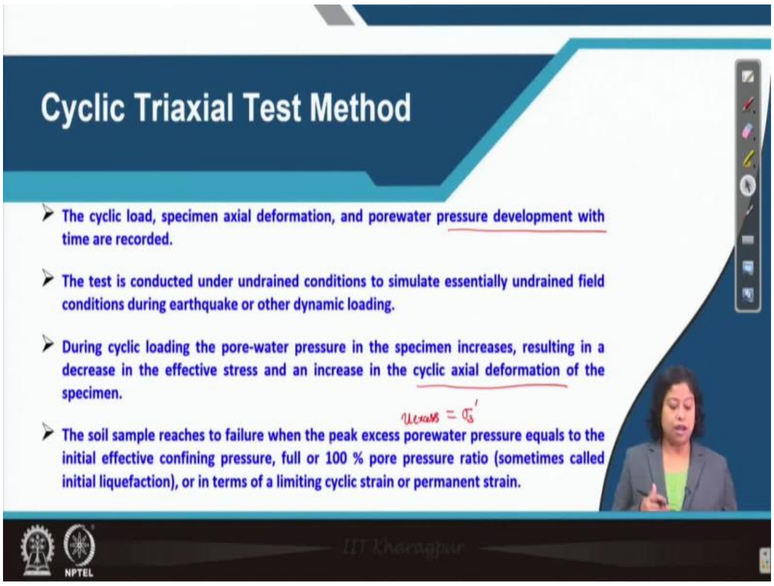

Now, the cyclic load specimen axial deformation and pore water pressure which is developed in the soil with time should be recorded. The test is conducted under undrained condition to simulate essentially undrained field conditions during earthquake or other dynamic loading. So, basically the second state of this cyclic triaxial test the system will remain undrained that means, drainage valve will remain close.

So, pore pressure will be developed in the soil and that should be recorded the development of the pore pressure with time will be recorded. Other than that, we will record the axial deformation and the amount of the cyclic load which is applied to the soil sample that means the vertical load.

Next, in next step. So, during cyclic loading the pore water pressure in the specimen increases and it causes a decrease in the effective stress and an increase in the cyclic axial deformation of the soil specimen. The soil sample reaches to failure when either of these 3 criteria will be reached.

So, what are these 3 when the peak excess pore water pressure equals to the initial effective confining pressure that means, if I will say peak excess pore water pressure is u excess then that should be equal to the initial effective confining pressure that means sigma 3 dash. Or I can actually I should not put here sigma initial effective confining pressure.

Second condition says full or 100 percent pore pressure ratio, sometimes it is called as initial liquefaction and the third condition says in terms of a limiting cyclic strain or permanent strain. So, there is some definition of limiting cyclic strain or permanent strain for some cases.

So, if that reaches, then we will assume that failure occurs if excess peak excess pore water pressure becomes equal to the initial effective confining pressure then also we will assume failure occurs. If 100 percent pore pressure ratio which is also called as initial liquefaction occurs, then also we will consider failure is arrived or soil sample is reached to the failure.

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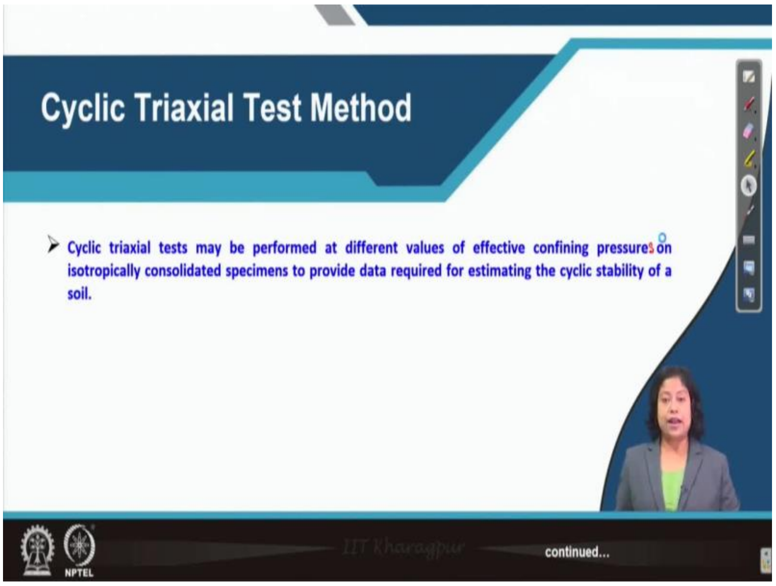

Now, the cyclic triaxial test may be performed at different values of confining pressure in plural I can write confining pressures on isotropically consolidated specimens to provide data required for the estimation of cyclic stability of soil. Basically, the dynamic properties which are in this case dynamic Young's modulus etc.

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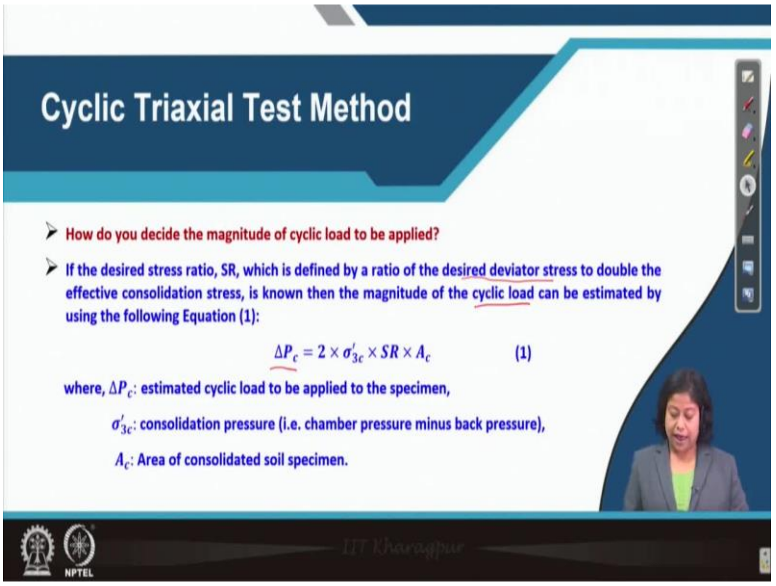

Now, there is an important question here, how do we decide the magnitude of the cyclic load that is required to apply to the soil sample? We will define first the stress ratio, desired stress ratio which is defined by a ratio of the desired deviator stress that means sigma d to double the effective consolidation stress this is called the stress ratio is, if it is known for us, then the magnitude of the cyclic load can be determined by using this equation.

You can see delta P c is the magnitude of the cyclic load which is equal to 2 times of sigma dash 3 c which is your effective consolidation stress times stress ratio which is known for us times A c, what is A c? A c is the area of consolidated soil sample.

Please remember here initially we have taken some soil sample having some particular cross sectional area, but, after consolidation there is a possibility that the area of the specimen that is consolidated specimen may change and that is the reason, when we are calculating the magnitude of cyclic load that means delta P c that time we will consider the area of the consolidated soil specimen, not the starting area of the soil specimen. So, with this we can calculate the cyclic load.

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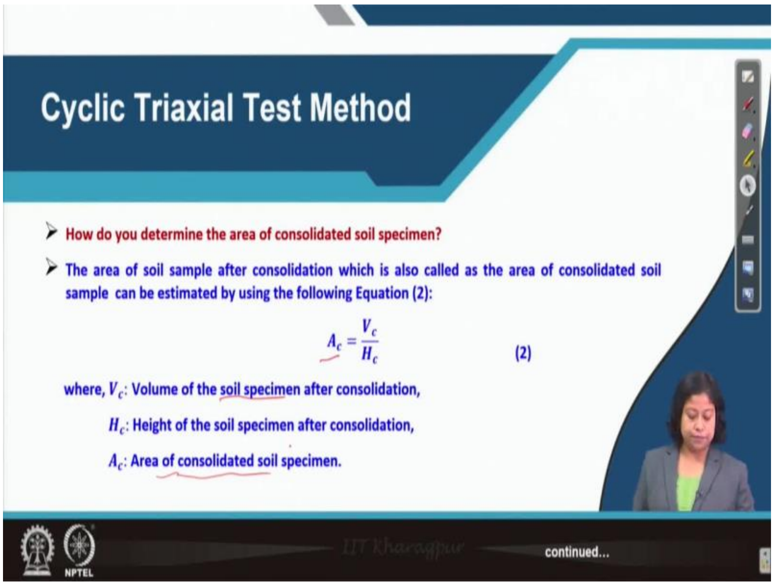

Another important question how do we determine the area of consolidated soil sample that I have already the term I have already used. So, there is a particular procedure following which we can calculate the area of the consolidated soil specimen using this equation 2 V c divided by A c, what is V c and what is A c here? V c is the volume of soil specimen after consolidation.

So, at the beginning we know what is the volume of the soil specimen during consolidation, how much water that means pore water dissipate from the soil, that volume is also known to us. Now, if we will subtract that volume from the initial volume of the soil sample, then we will get V c, which is the volume of the consolidated soil specimen. Also we can calculate height of the soil specimen after consolidation from which we can find out the area of consolidated soil specimen.

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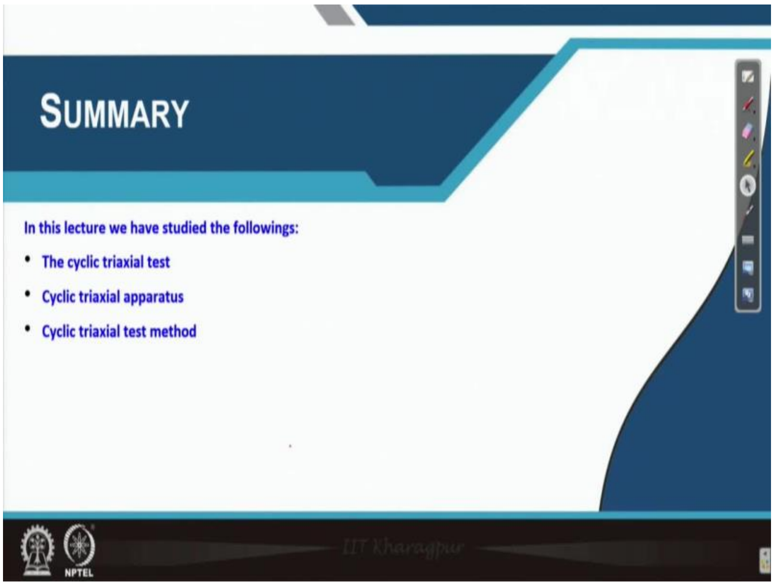

So, come to the summary of today's lecture. Today, we have discussed the cyclic triaxial test, which is one of the high strain level laboratory tests. Thereafter we have seen the schematic diagram of the cyclic triaxial test apparatus. Then, we have discussed the method of cyclic triaxial test.

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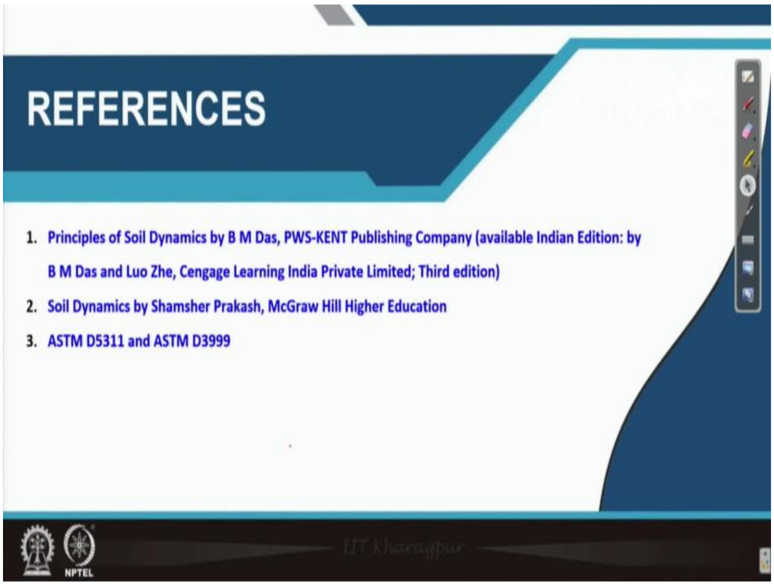

Here you can see the references which I have used for today's lecture. With this I am stopping here. Thank you.