Rock Mechanics and Tunneling
Professor Debarghya Chakraborty
Department of Civil Engineering
Indian Institute of Technology, Kharagpur
Lecture 18
Laboratory Testing Methods (Contd.)

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Hello everyone, I welcome all of you to the 2nd lecture of module 4. So, in module 4, we are discussing about the laboratory testing on rock sample and in-situ testing of rock mass. So, in our previous lecture, we have discussed about the laboratory testing methods. So, we will continue with that main topic only.

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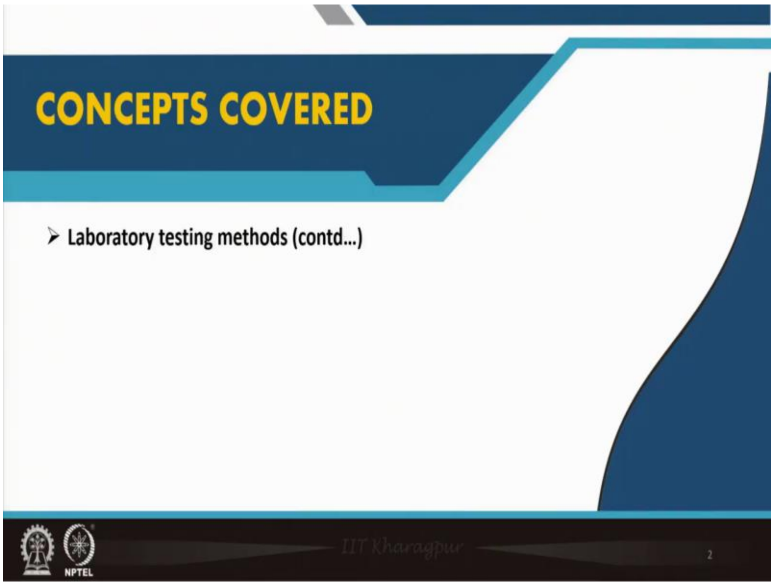

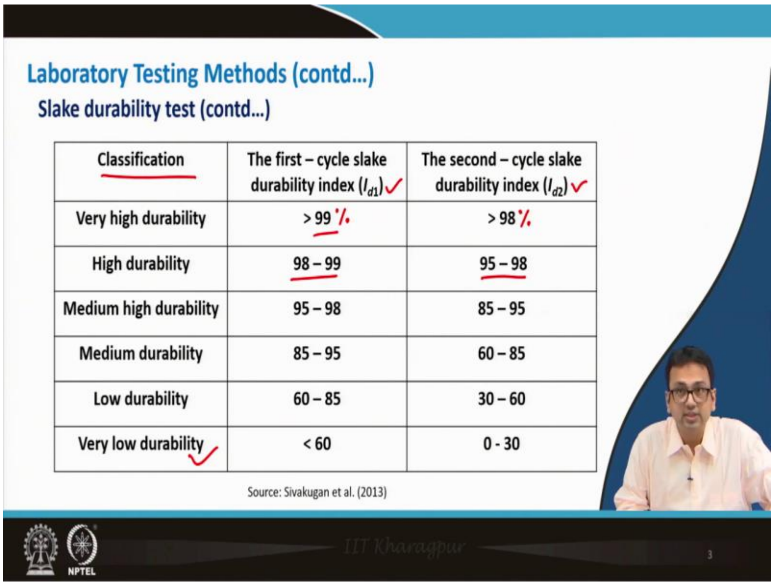

So, today, let us see how many of the laboratory testing methods we can cover. So, in our previous class, towards the end we have discussed about the slake durability test and we have understood that this is very important to conduct the test to know the durability of the rock sample. Now, I hope you remember the table. As we know there are two cycles in slake durability test.

So, after first cycle, we will get the durability index as I_{d1} and after second cycle, we will get the durability index, I_{d2}. If after first cycle, I_{d1} is more than 99%, the rock sample is said to having very high durability.

Similarly, after the second cycle, if the I_{d2} is greater than 98%, then also the sample is said to be very highly durable. On the other hand, if we see that if the range of I_{d1} is varying in between 98 to 99% (i.e., after first cycle) and after a second cycle, I_{d2} is varying in between 95 to 98%, then we call it highly durable sample. So, likewise we have seen up to very low durability, what are the ranges.

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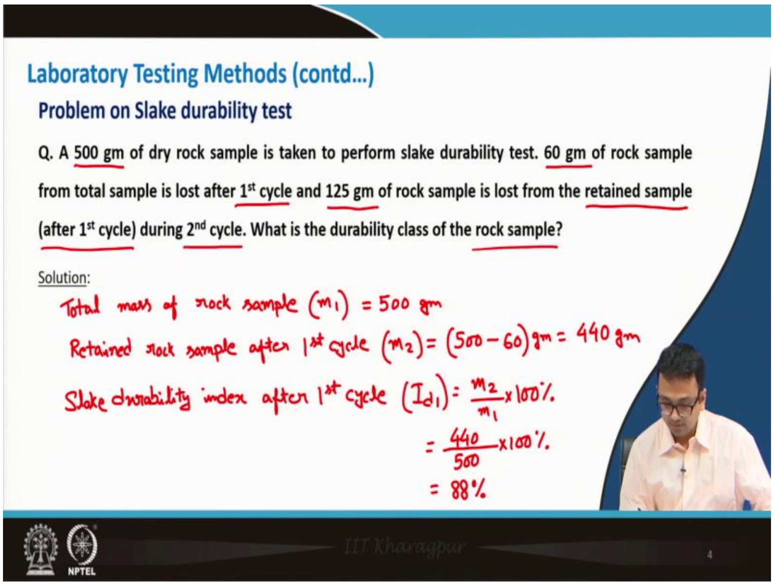

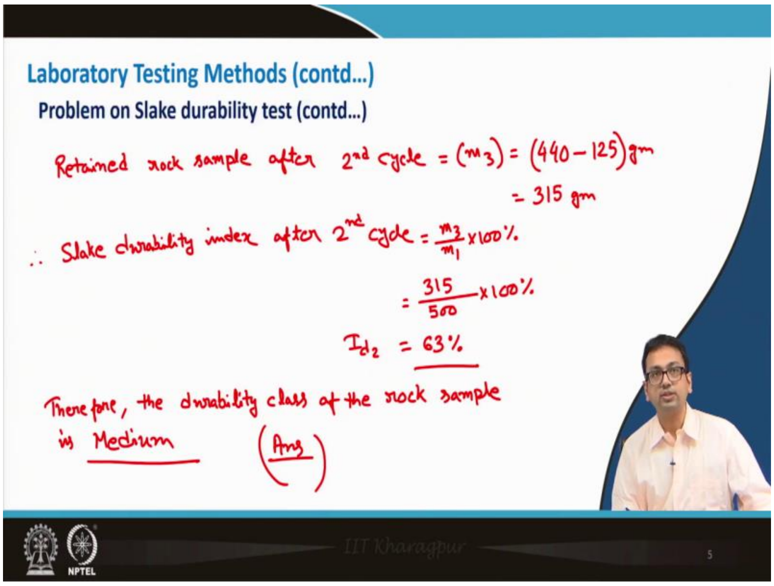

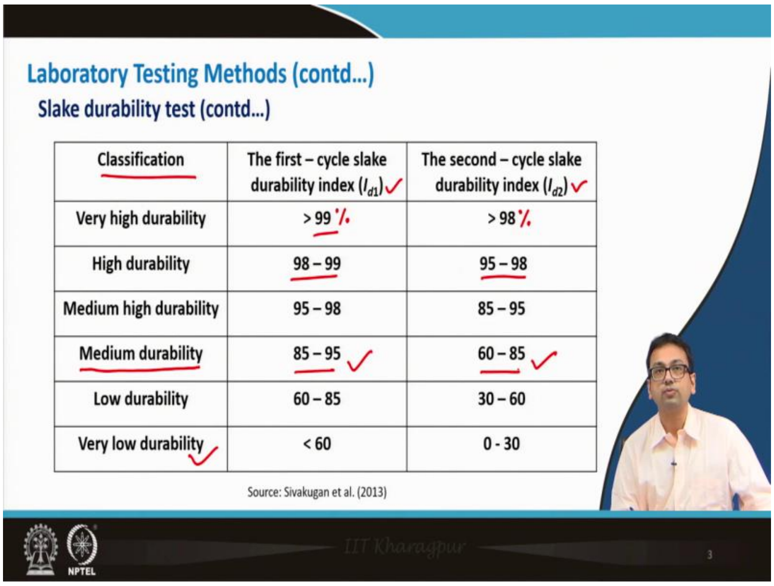

So, let us take a problem and let us clear our doubts and the problem says like this, if 500 gm of dry rock sample is taken to perform slake durability test. Now, 60 gm of the rock sample from total sample is lost after first cycle.

And 125 gm of rock sample is lost from the retain sample after first cycle during the second cycle. So, what was retaining after first cycle, from there again 125 gm has lost during this second cycle. So, the question is that what is the durability class of the rock sample? So, we have to find out I_{d1} and I_{d2}, and from there we have to find out in which range it is falling.

So, we will classify the rock accordingly. So, the total mass of the rock sample is given that is 500 gm, i.e., 500 gm of dry rock sample is taken. Hence, m_1 = 500 gm.

Now, 60 gm of rock sample from the total sample is lost after first cycle. So, the retained rock sample after the first cycle will be (500 – 60) gm = 440 gm. So, let us give this name as m_2. So, m_2 = 440 gm.

So, the slake durability index after first cycle. So, we generally write like $I_{d1} = (m_2 / m_1) \times 100\%$. So, $(440 / 500) \times 100\% = 88\%$. So, we have obtained I_{d1}. Now, we have to obtain I_{d2}. So, 125 gm of rock sample is lost in the second cycle from the retained sample after the first cycle.

So, the retained rock sample after first cycle is for 440 gm. Now, from there, 125 gm has lost. So, we can write retained rock sample after second cycle is equal to m_3. So, m_3 = (440 – 125) gm = 315 gm.

So, we can obtain this slake durability index after the second cycle. Therefore, the slake durability index after second cycle is equal to $I_{d2} = (m_3 / m_1) \times 100\%$. So, $I_{d2} = (315 / 500) \times 100\% = 63\%$. So, the slake durability index is 63% after the second cycle.

So, now I_{d1} = 88% and I_{d2} = 63%. Now, let us go to the table and let us try to find out where it is falling. So, after first cycle, I_{d1} is 88, so it is falling in the 'medium durability' range. And after a second cycle 63 percent means it is also falling in the 'medium durability' range. So, we can definitely call that the rock sample is having medium durability.

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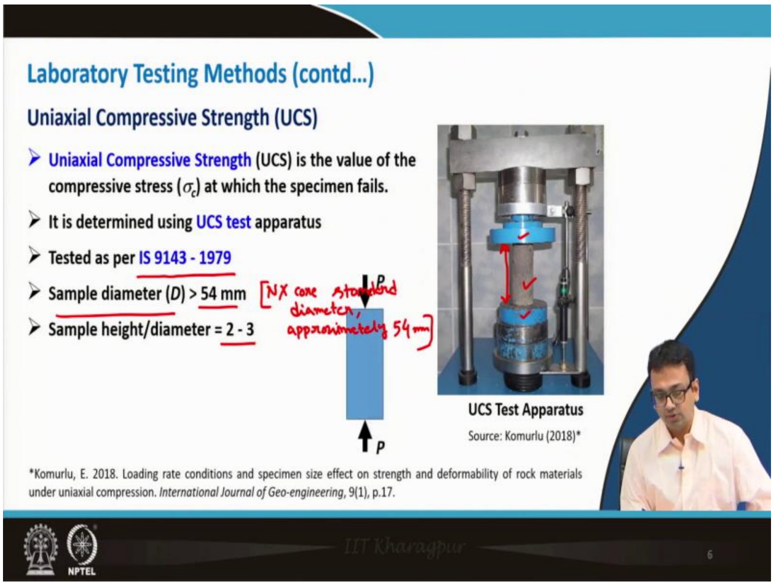

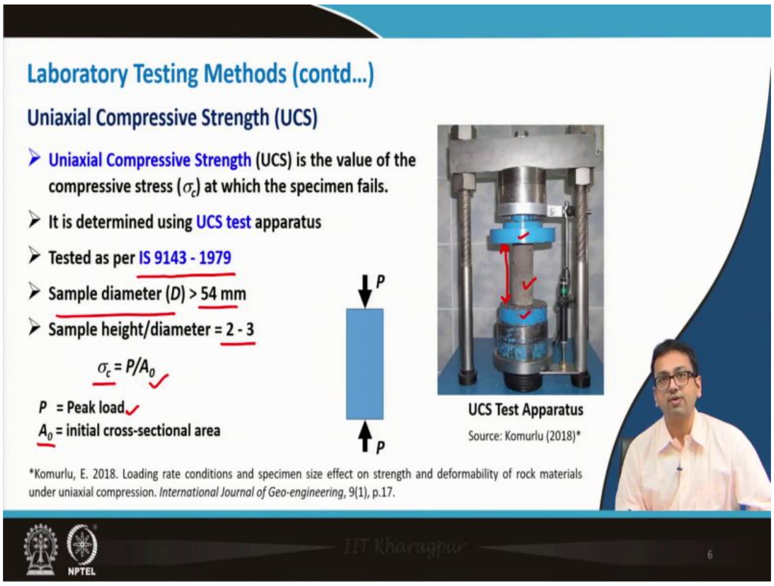

Now, let us start discussing about another very important test, about which we have spent a good amount of time in our previous module also, but let us see what the basic test procedure is. So, uniaxial compressive strength (UCS) is the value of the compressive strength at which specimen fails. Now, it is determined using this UCS test apparatus and the IS 9143 - 1979 can be followed to conduct this test.

So, now, this is a typical nice picture from here you can clearly see that this is the uniaxial compressive strength testing apparatus where you see the sample is kept over here. And, it is placed between this plate and this plate and the compressive load will be applied to find out the maximum compressive strength means at which it is failing that we have to find out.

Now, the sample diameter is kept more than 54 mm. So, this 54 mm, this term you may hear again and again because it is also called as the NX core standard diameter. More accurately, the diameter is close to 54.7 mm. So, as per IS code specification, the sample diameter should be greater than 54 mm.

The height of the sample to the diameter of the sample is kept as 2 to 3. Now, we are only applying the axial loading. So, now, here σ_c is nothing but the uniaxial compressive strength which is equal to (P/A_0), where P is peak load and A_0 is the initial cross-sectional area.

So, this will give us the stress strain diagram as we have seen earlier and how to use those stress strain diagrams to find out the Young's modulus. The Young's modulus can be of different types like Average Young's modulus, Secondary Young's modulus, and Tangent Young's modulus. How to find those modulus, we have learnt in our previous module.

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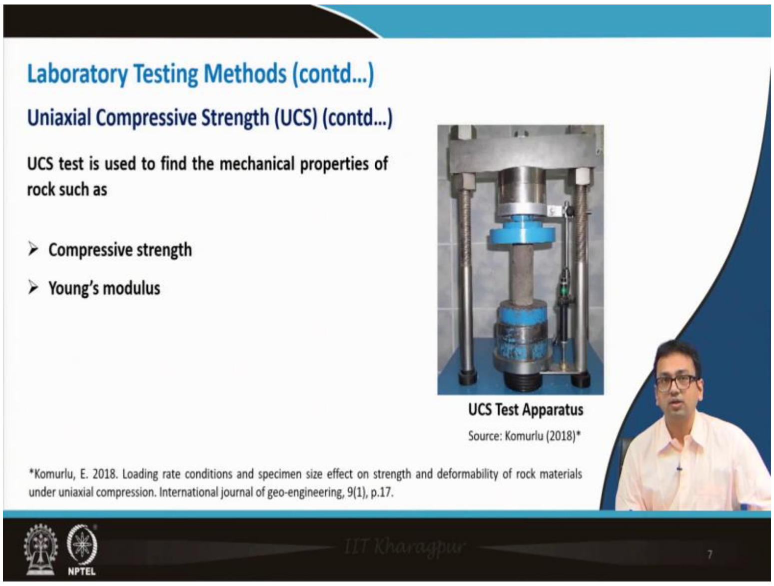

So, the UCS test is used to find the mechanical properties of rock such as compressive strength, Young's modulus, Poisson's ratio, and etcetera.

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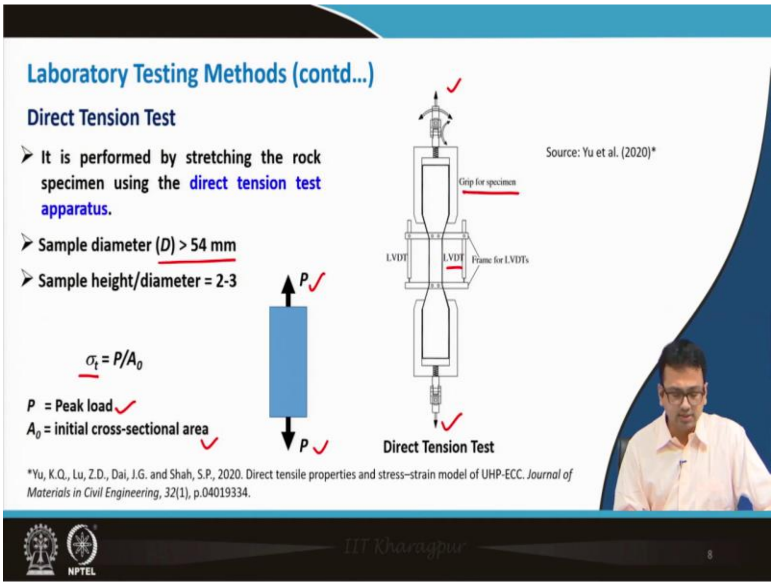

So, now, let us discuss about the tension test. So, the first one is the direct tension test. From the diagram, you will understand clearly why it is called as direct tension test. And since we are discussing a direct tension test, so we will also discuss here about the indirect tension test also. So, firstly, let us see the direct tension test. It is performed by stretching the rock some the specimen using the direct tension test apparatus.

So, the specimen will be like this and we are applying the tensile force like this and with the help of this tensile force we are stretching the sample and as you can see it is in the grip for the specimen then the LVDTs are there to measure different displacements. So, anyway, the main idea is that it is performed by stretching the rock specimen using the direct tension test apparatus.

So, here also, the sample diameter (D) is kept greater than 54 mm. So, as I have stated that NX core standard diameter, which is approximately 54 mm, actually 54.7 mm. However, as per IS code, you have to keep the diameter greater than 54 mm and the sample height to diameter is 2 to 3 as we have considered for the compressive strength test. Here, we can get the tensile strength of the sample = (P / A_0), where P is the peak load, A_0 is the initial cross-sectional area and this is what we are doing opposite to the UCS test. So, this will give us directly the σ_t.

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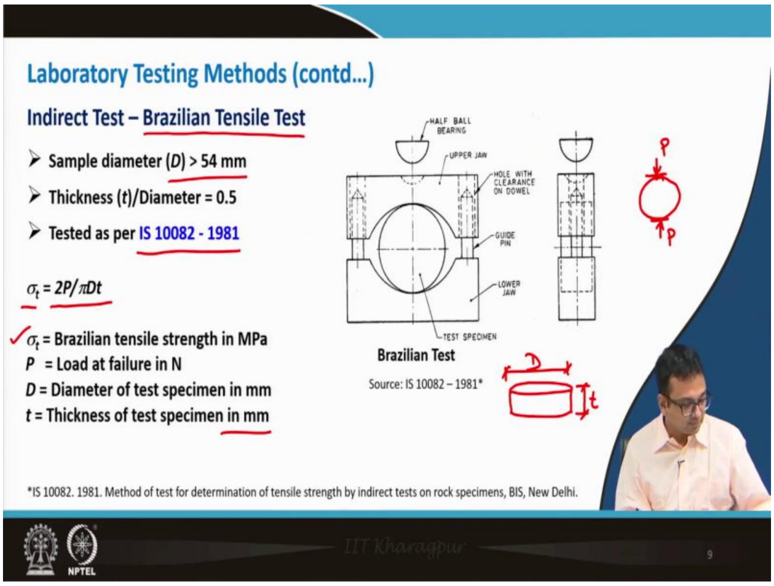

Now, another test procedure we will discuss here that is called as the indirect tensile test, also known as the Brazilian Tensile Test, so it will give indirectly the tensile strength of the rock sample. In the case of direct tension test, we are applying tension directly and getting the tensile strength by stretching the sample or specimen.

Now, here indirectly we will get, how let us see that. So, this is the test apparatus you can see, again here also the sample diameter (*D*) is kept greater than 54 mm. Now, thickness to diameter ratio is kept as 0.5. Suppose, this is the thickness (*t*) and this is the diameter (*D*). So, the thickness to diameter is kept as 0.5.

So, the test specimen is kept in this Brazilian testing machine in this way as shown in the figure. The IS code what you can follow to perform this test is the IS 10082 – 1981. So, as per this test, the tensile strength can be expressed as $\sigma_t = \frac{2P}{\pi Dt}$. What are they? So, σ_t is the Brazilian tensile strength in MPa, and *P* is that load at failure in N.

In the case of indirect tensile strength test, the specimen is subjected to the vertical compressive loading. We can draw a small diagram over here, this is P, this way the load is being applied. So, this P is the load at failure in N, if *D* is the diameter of the test specimen in mm, which is as per recommendation should be greater than 54 mm and *t* is the thickness of the test specimen in mm. If it is also stated that the thickness to diameter ratio is 0.5, then we can obtain the Brazilian tensile strength as $\sigma_t = \frac{2P}{\pi Dt}$.

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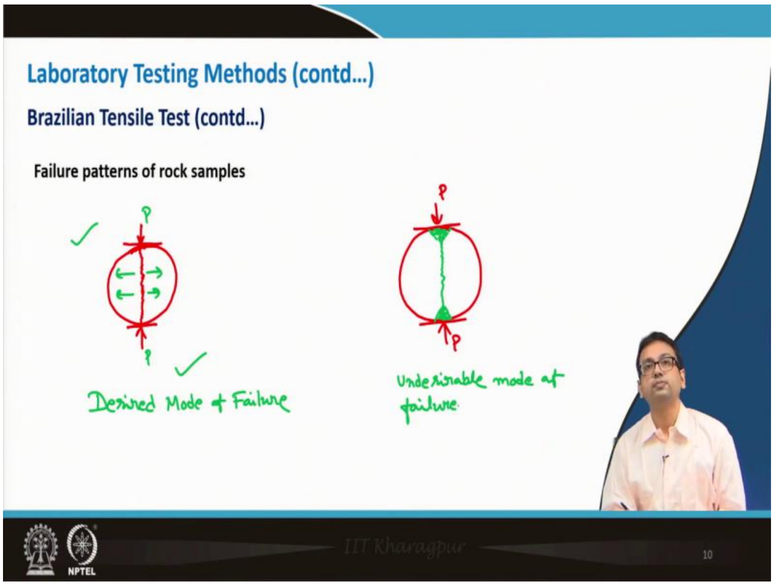

Now, let us see, what the different failure patterns of rock samples are in case of the Brazilian tensile strength test. *P* is the applied load to the sample as shown in the figure. So, what is expected there that this kind of crack will develop means under this *P* loading, the tensile forces developing in this direction and because of that the sample is failing. So, this is the expected failure pattern.

Whereas, if we see this type of failure sample, when it is subjected to same loading *P*, but what is happening over here that the wedge is forming and the crack or fracture is developing over there and this way it is failing. So, there is a wedge at top and at the bottom of the specimen and a crack is developing and this type of failure is happening.

So, here locally, in this region, a wedge failure is happening, and a crack is developing. It is considered as the undesired mode of failure. The equation, $\sigma_t = \dfrac{2P}{\pi Dt}$ is only applicable for desired or expected mode of failure. So, this is the undesirable mode of failure.

So, in our next class we will continue with this laboratory testing, and at the beginning we will solve a problem onss Brazilian tensile strength test. Thank you.