Rock Mechanics and Tunneling
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Lecture 17
Laboratory Testing Methods

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Hello everyone, I welcome all of you to the first lecture of module 4. In module 4, we will discuss about the laboratory testing on rock sample and in-situ testing on of rock mass. So, today we will begin with the laboratory testing methods.

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So, today we will try to discuss about the determination of specific gravity and porosity of porous material. As we have seen earlier porosity is very important parameter because it indicates the storage capacity of the rock mass or some rock sample. Hence, we should learn how to find out the porosity as well as the specific gravity. And also, after that, we will discuss about the slake durability test, I hope you remember that determination of durability is one of the important parameter. So, it is one of the important physical properties.

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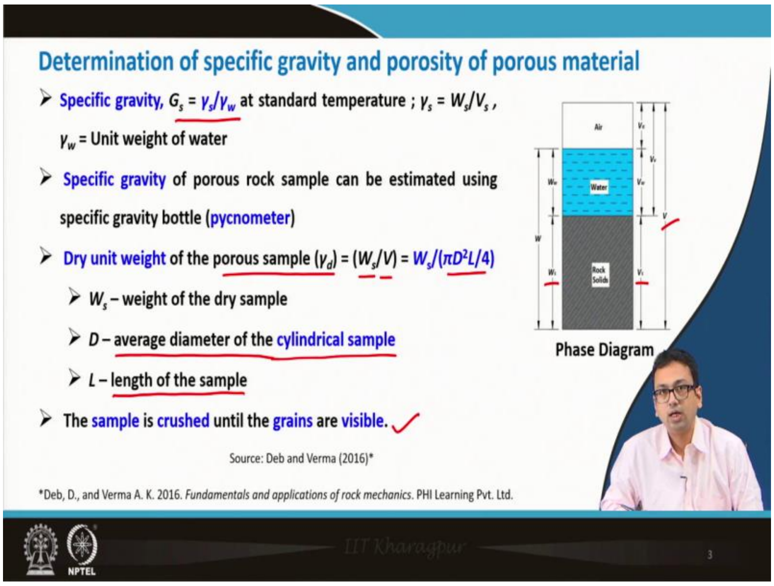

Let us begin with the determination of specific gravity and porosity of porous material. So, as we know G_s is (γ_s / γ_w) as we have seen earlier and it is at a standard temperature where γ_s is (W_s / V_s) and γ_w is unit weight of water. Kindly look into the phase diagram.

So, W_s is the weight of rock solids, V_s is the volume of the rock solid and γ_w is the unit weight of water. Now, specific gravity of porous sample can be estimated using specific gravity bottle which is also called as the pycnometer. Now, what do we do? Let us see.

Suppose, the rock sample is given to us and the dimensions are like we have to measure the average diameter of the sample the cylindrical sample what we will get after rock coring and drilling whatever material we will get that we have to measure. We will measure the diameter and also the length of the representative sample of that core, why?

Because that will give us the volume. And also finally, one part is required that is the dry unit weight of porous material, we will see, that will be required. So, that is nothing but W_s / V, where V is the total volume. So, W_s is the weight of the dry sample or rock solid.

Now, coming to the procedure, first thing is that the sample is needed to be crushed the grains are visible. So, this is what we have to do. So, we will get probably a cylindrical sample that we have to crush. After measuring its dimensions like diameter and height, what we will do, we will crush it until the grains are visible. Then what will we do?

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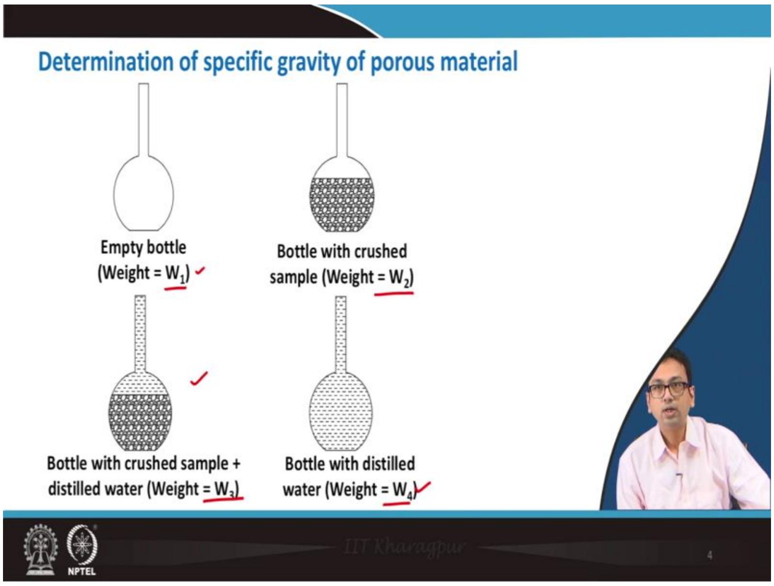

We will first take this empty bottle, we will take the weight, find out the weight with the help of a weighing machine. Then, we fill the crushed sample inside the bottle, as you can see that the crushed samples are there. So, we have to find out the weight of the bottle with crushed sample. Let us consider that is W_2. Let, W_1 be the weight of the empty bottle.

Now, after putting the crushed sample in the empty bottle the weight becomes W_2 now in third step, in that bottle we will also put some distilled water and fill that bottle up to a certain mark. So, now in this stage we have the weight which will consist the weight of the empty bottle then that weight of the crushed sample plus the distilled water. So, let us consider that weight is W_3, then what we will do in our 4th stage, we will again clean the bottle and in that bottle, we will put only the distilled water, means now there is no crushed sample.

So, bottle is filled up to a particular mark with only distilled water. So, we will find out what is the weight of that bottle with the distilled water. So, four stages, first empty bottle's weight (W_1) then bottle with crushed sample that weight is W_2 then bottle with crushed sample plus distilled water it is W_3 and then bottle with distilled water only, so that is W_4.

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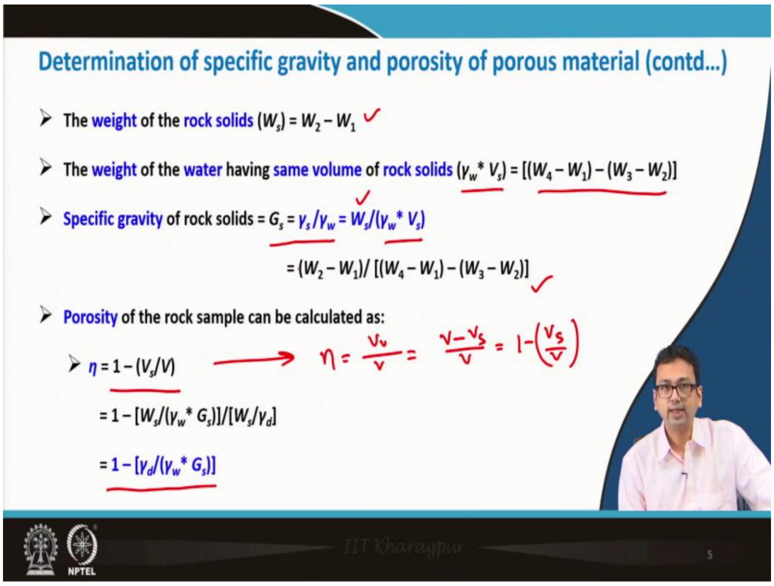

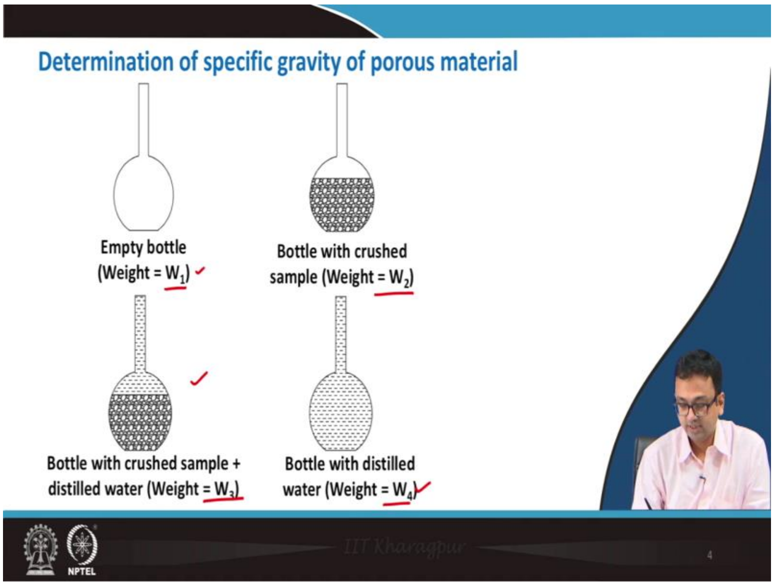

So, what will be the weight of the rock solid? Here, W_2 is the bottle weight plus the weight of the crushed sample and W_1 is the weight of the empty bottle. So, that means $(W_2 – W_1)$ will give us the weight of the rock solids. Then weight of the water having same volume of rock solid, means that is nothing but $\gamma_w \times V_s$ which will be equal to $[(W_4 – W_1) – (W_3 – W_2)]$.

So, let us go back then. So, $(W_4 – W_1)$ will give us only the weight of the water in that bottle. When, the bottle will be filled with crushed sample and water in that case the total weight is W_3 and W_2 is the weight of the bottle plus crushed sample.

So, what will we get if we deduct $(W_3 – W_2)$ from $(W_4 – W_1)$? We will get the weight of the water having same volume of rock solids. So, now, what do we know specific gravity of rock solids, G_s is (γ_s / γ_w). Now, γ_s is nothing but (W_s / V_s) and γ_w is there.

So, if we write it this will give us the specific gravity of rock solid. So, now the porosity of the rock sample can be also be calculated from here, how? We know that the porosity is equal to $(1 – V_s / V)$.

So, we know porosity is V_v / V which is nothing but $(V – V_s) / V$ which is equal to $(1 – V_s / V)$. So, this is what I have written over here. Now, you see this V_s can be written as like this. So, $[W_s / (\gamma_w \times G_s)]$, because, $(\gamma_w \times G_s)$ will give us the γ_s. So, now W_s / γ_s is V_s. And V is equal to the (W_s / γ_d), because γ_d is nothing but (W_s / V).

So, if we further simplify, W_s and W_s are cancelling each other, because it is in there both the numerator and denominator and then we are left with only this quantity. So, porosity is equal to $[1 – [\gamma_d / (\gamma_w \times G_s)]]$. So, we have also obtained γ_d in the first slide of our discussion.

So, γ_d is nothing but (W_s / V) and W_s as we know that $(W_2 – W_1)$ and V is the volume of the cylindrical sample. So, $\frac{\pi D^2 L}{4}$. So, again let us go back there. So, in this way two important parameters, i.e., the specific gravity and the porosity of the rock sample can be calculated.

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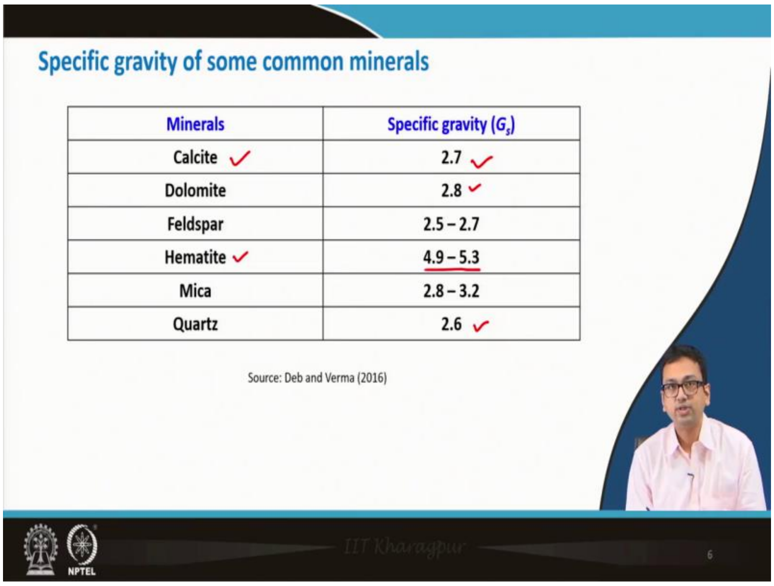

Now, I think the best thing will be to take a problem, let us take one problem. Before that this one also just to give you some idea about the different magnitudes of specific gravity of different mineral in that form like if it is Calcite, it is 2.7 whereas, if you see that, Hematite, it is very high 4.9 to 5.3, Dolomite also 2.8, Quartz 2.6.

So, these are some representative values of the specific gravity of different minerals. So, that is why the specific gravity of these different minerals are also just shown over here to give you some basic idea.

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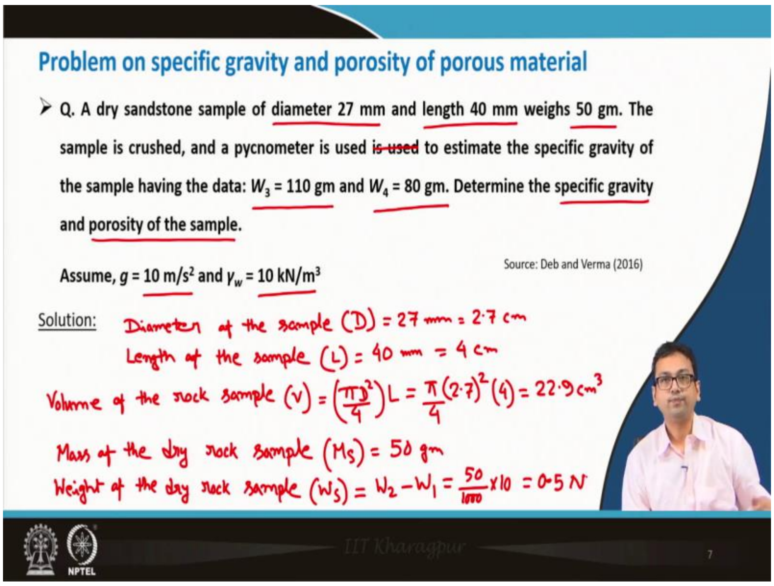

Now, let us take this problem. So, what it says, a dry sandstone sample of diameter 27 mm and length 40 mm. So, diameter and length and weight is 50 gm, the sample is crushed and a pycnometer is used to estimate the specific gravity of the sample having the data like W_3 is 110 gram, W_3 is the weight of the bottle plus crushed sample plus water and W_4 is 80 gram means the weight of the bottle plus only water up to a particular mark in that bottle.

So, the question is to determine the specific gravity and the porosity of the sample. So, it is asked to assume g as 10 m/s^2 and γ_w is 10 kN/m^3. So, we can definitely find out the volume of the rock sample. So, let us write down that one. So, diameter of the sample that is D is equal to 27 mm then which is nothing but 2.7 cm.

Now, length of the sample, length of the sample is 40 mm. So, length of the sample that is L is equal to 40 mm, i.e., 4 cm. So, what is the volume of the sample, let us find out. The volume of the rock sample (V) is $\frac{\pi D^2 L}{4}$. So, if you replace the corresponding values like $\frac{\pi \times 2.7^2 \times 4}{4}$. So, this is becoming 22.9 cm^3.

The mass of the dry sandstone sample of diameter 27 mm, length 40 mm weighs 50 gm. So, the mass of the dry sandstone sample is also known to us, so that is mass of the dry rock sample. Suppose, let us consider mass, M_s is equal to 50 gram. So, that means, what is given to us is the directly the dry mass of the sample is given means the mass of the rock solid is given to us because it is dry because we neglect the weight of the air.

So, what we can write from here, so weight of the dry rock sample which is W_s which is nothing but equal to ($W_2 - W_1$). W_2 is what? Weight of the bottle plus the crushed sample, weight of crushed sample and W_1 is the only empty weight of the bottle. So, this is all directly given to us as the mass is 50 gm. So, if we want to convert mass to weight. So, 50 by gram to kilogram and then g is given as 10 m/s^2. So, it becomes 0.5 N. Now, if we further proceed.

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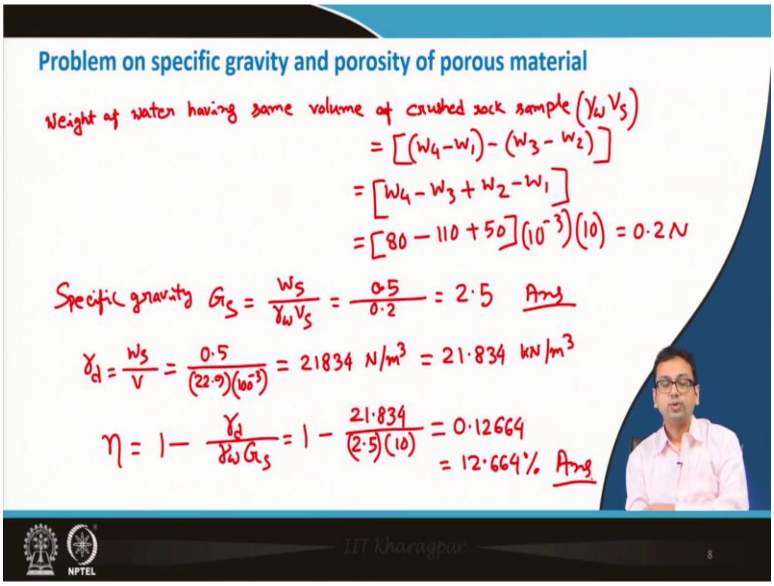

In the equation of specific gravity, in the numerator, we have ($W_2 - W_1$), which is nothing but W_s already we have obtained. So, we need now the denominator that is [($W_4 - W_1$) – ($W_3 - W_2$)] as you know. So, let us write down that one. So, now, what we can write as you can see over here what we wrote the weight of the water having same volume of rock solid, so same thing we can write over here. Weight of water having same volume of crushed rock sample.

So, this is nothing but what we are writing the $\gamma_w \times V_s$. So, same thing this is equal to [($W_4 - W_1$) – ($W_3 - W_2$)]. So, if we simplify this one, W_3 and W_4 are already given to us. W_3 is 110 gm, W_4 is 80 gm. So, we can rearrange these terms and we can write it as simply.

After simplifying, we will get, [($W_4 - W_3$) + ($W_2 - W_1$)]. So, now, W_4 is as we have seen then that is 80, W_3 is 110, and ($W_2 - W_1$) is the W_s, which is nothing but 0.5 N, but here we are writing it first in the mass and then from there we will convert it to weight. So, 50 we can write over there.

So, this quantity is 50 gm and this needs to be in N, this is in gm, so we can multiply it with 10^{-3} to convert into kg and then multiply 10 to convert it into N. So, if we do that, we will get $\gamma_w \times V_s$ as equal to 0.2 N. So, now, what do we know the specific gravity is G_s which is equal to as we know just we have seen W_s / ($\gamma_w \times V_s$). So, if we replace it, you will get it as (0.5 / 0.2) which is equal to 2.5 this is the answer 1.

So, that next stage is we need to find out the porosity also. Now, for porosity, we need to find out the γ_d also. So, that γ_d is nothing but (W_s / V) now, W_s is how much, just now we have obtained 0.5 N. So, 0.5 and we have also obtained the V previously. V is 22.9 cm^3. And it needs to be converted into m^3.

So, this into maybe 100^{-3} or 10^{-6} we could have written and this will give the γ_d in N/m^3. So, if you check that it will be 21834 N/m^3. So, which if we convert into kN, so that is 21.834 kN/m^3. Now, what is porosity? Porosity is equal to $\left(1-\frac{\gamma_d}{\gamma_w \times G_s}\right)$.

So, all the quantities are known to us, i.e., $\left(1-\frac{21.834}{10 \times 2.5}\right)$ = 0.12664 = 12.664%. So, another answer is this one. So, in this way we can very easily obtain the porosity of the rock sample. So, these two are very important.

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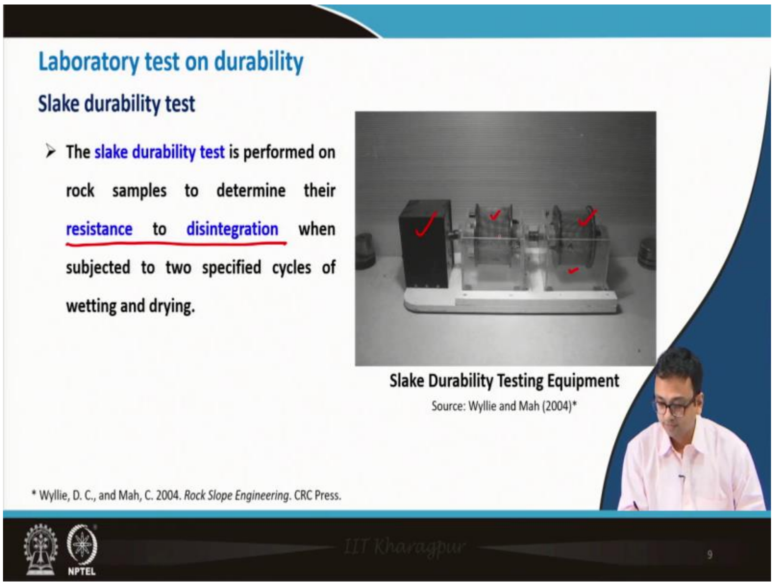

Now, next thing is laboratory test on durability. So, let us discuss because we know for that we need to do this slake durability test. So, the slake durability test is performed on rock samples to determine their resistance to disintegration. So, resistance to disintegration when subjected to two specified cycles of wetting and drying.

So, let us read it once again, the slake durability test is performed on rock samples to determine the resistance to disintegration when subjected to two specified cycles of wetting and drying. So, this is a typical illustration of a slake durability test equipment. So, you can see these drums are there, there is a motor arrangement and the drums are submerged in some fluid. So, that is the slaking fluid.

So, generally tap water or sometimes sea water is used as slaking fluid, depending on the actual situation. So, whether the rock mass will be susceptible to saline water or normal tap water kind of environment, depending on that this fluid is used and the drum you can see over there the rock samples are kept inside that drum. So, now, let us see what the procedure is.

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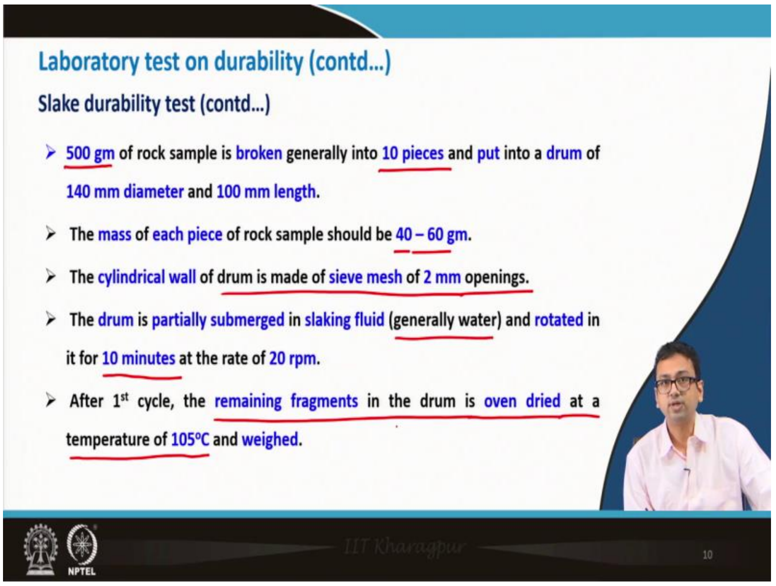

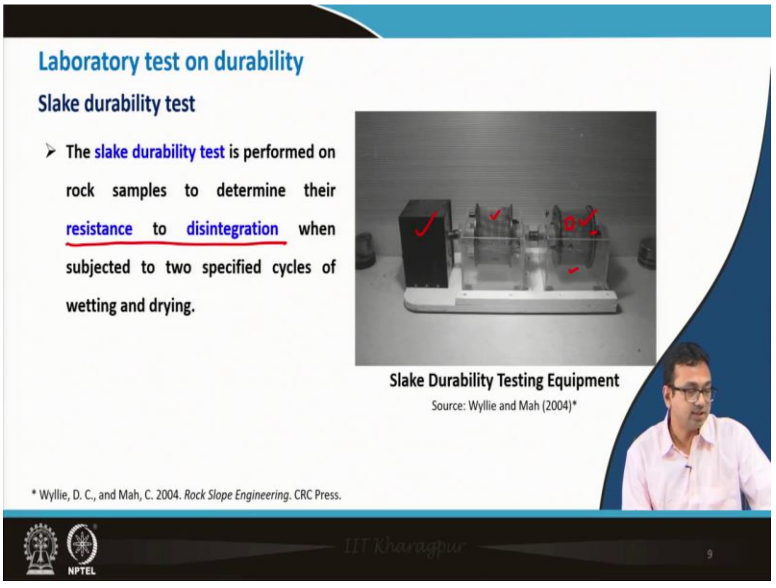

Generally, 500 gm of rock sample is taken which may vary in between 450 gm to 550 gm. Thus, 500 gram of rock sample is broken generally into 10 pieces and put into a drum of 140 mm in diameter and 100 mm in length. Now, the mass of each piece of rock sample should be in the range of 40 to 60 gm, nor less than that nor more than that.

So, these 10 pieces which you are taking, the weight of individual pieces should be in this range of 40 gm to 60 gm. So, on an average total weight has to be 500 gm. As we know that, the average of 40 and 60 is 50 gm, so 10 pieces 500 gm. And the cylindrical wall of the drum what I have shown is made of sieve of 2 mm opening.

So, as you can see from the diagram that this is the sieve. So, size of the opening is 2 mm. Then the drum is partially submerged in slaking fluid (generally, water). So, it may be tap water or saline water means sea water depending on the situation. Then the drum is rotated for 10 minutes at the rate of 20 rpm, i.e., 20 revelation per minute.

Then after its first cycle the remaining fragments in the drum is oven dried at a temperature of 105°C and weighed. So, after the revolution is done for 10 minutes with 20 revolution per minute of the first cycle remaining fragments in the drum is oven dried at a temperature of 105°C and weighed.

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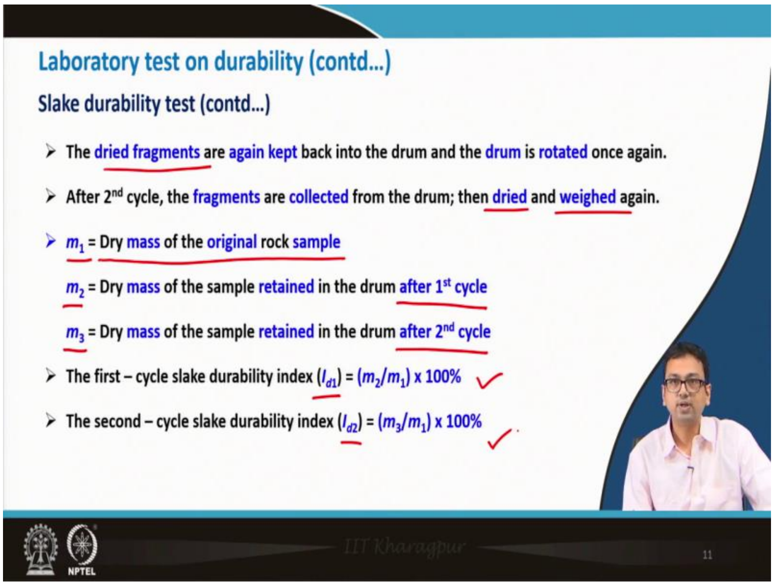

Then what is done then the dried fragments are again kept back into the drum and the drum is rotated once again. So, the second cycle starts, the dried fragments are again kept back into the drum and the drum is rotated once again. After the second cycle, the fragments are collected from the drum and then dries and weighted again. So, second cycle is now done.

After doing all this exercise, we will get m_1 which is the dry mass of the original rock sample. So, initially what we have taken. Then m_2 is the dry mass of the sample retained in the drum after first cycle. And m_3 is the dry mass of the sample retained in the drum after second cycle.

Now, if you obtain these three values, i.e., m_1, m_2, and m_3 which are the dry masses of the original rock mass, then the after first cycle what is remained and after the second cycle what is remained, respectively. Hence, the first cycle slake durability index that is I_{d1} is $(m_2 / m_1) \times$

100 %, it is presented in terms of percent. And similarly, the second cycle slake durability index I_{d2} is written as $(m_3 / m_1) \times 100\%$.

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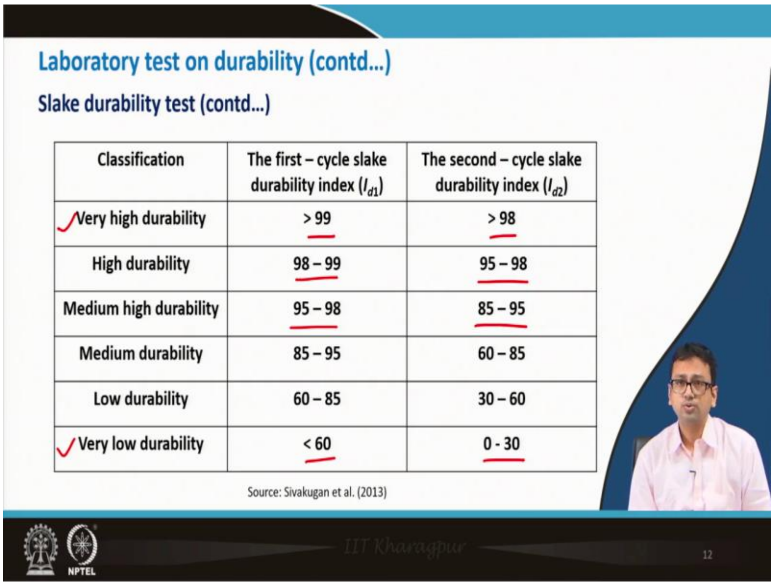

Thus, we can get these two indices after first and second cycle. Now, here is a table based on you can comment that what type of rock sample is this whether the sample is very highly durable, which means the sample is having high durability or very low durability. So, these numbers are provided for that.

And you can see that after the first cycle it becomes greater than 99% and after second cycle it becomes greater than 98%, then we can say the rock sample is having very high durability or this is very highly durable rock sample. Now, if it is only high durability, i.e., if you have to comment like that it the rock sample the highly durable then this Id_1 should be 98 to 99% and the Id_2 (after a second cycle) should be 95 to 98%.

Obviously, after second cycle the numbers will be lesser because in the 2nd cycle, the sample is again rotated for 10 minutes at the rate of 20 rpm, so some disintegration will happen. So, obviously, the Id_2 will be less than Id_1. So, likewise, for medium high durability, Id_1 should be 95 to 98%, and Id_2 is 85 to 95%. In this way, if the Id_1 is less than 60% and if the Id_2 is in between 0 – 30%, it is can be called as the very low durability of rock sample.

So, with this let us conclude our today's class. In our next class, we will begin with a problem on slake durability index determination. And then subsequently we will discuss the other experiments also. So, thank you.