Rock Mechanics and Tunneling
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Lecture 13
Topic - Physical properties (Continued)

Hello everyone, I welcome all of you to the second lecture of module 3. So, in our previous lecture, we have started discussing the different physical properties of rock. Now, we will continue our discussion in that topic only.

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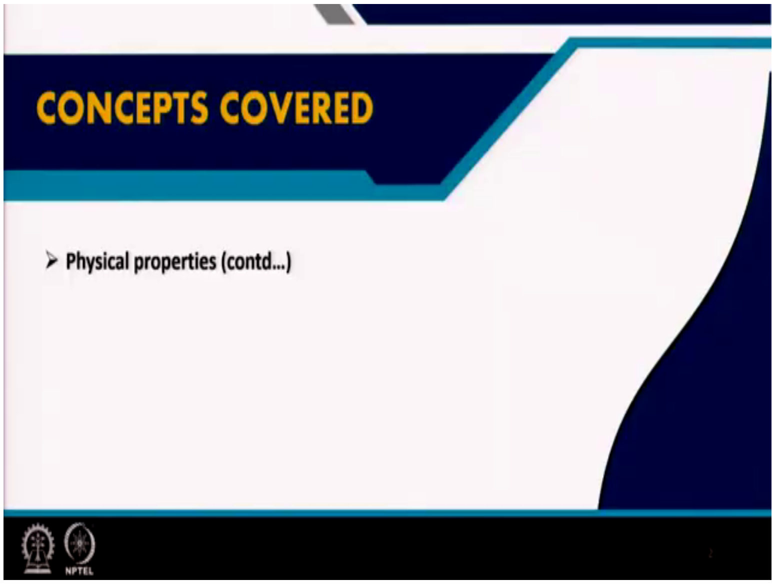

So, we will continue with the physical properties of rock.

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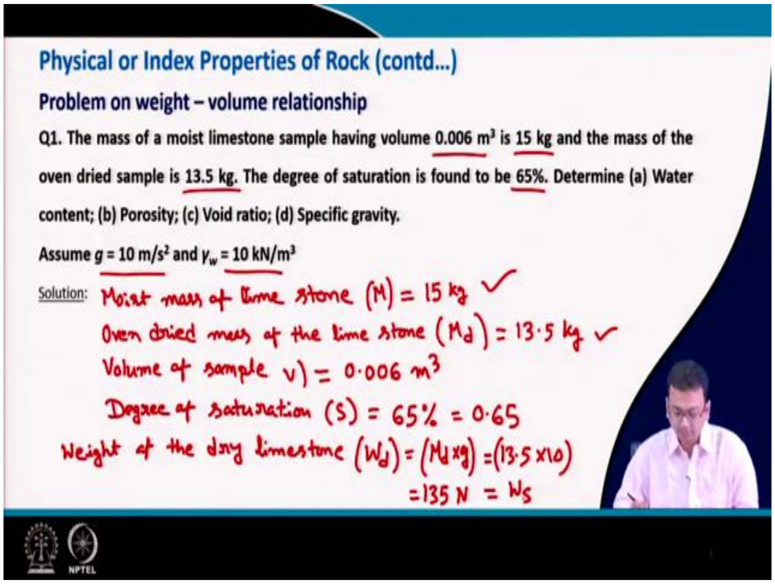

We have learned and discussed different weight-volume relationships in our previous class. Those expressions were essential for obtaining the other properties. For better understanding, a couple of problems will be solved in today's lecture because they are relevant and practical.

So, let us see the first problem. So, what does it say? The mass of a moist limestone sample having a volume of 0.006 m^3 is 15 kg, and the mass of the oven-dried sample is 13.5 kg. The degree of saturation is found to be 65%. So, we have to determine water content, porosity, void ratio, and the specific gravity.

It is also stated that for this problem, we can assume acceleration due to gravity (g) as 10 m/s^2, though we know it is generally 9.81. However, let us consider it as 10 m/s^2 for simplicity and the unit weight of water (γ_w) as 10 kN/m^3. So, these are the two assumptions.

So, what are the key things about this problem? The weight of the moist sample is provided. The total volume of the sample is provided. Then oven-dried sample weight is provided, and the degree of saturation is also provided. So, we have to obtain water content, porosity, void ratio, and specific gravity with this data.

So, it is given in terms of mass, so we will convert it to weight and solve it. The moist mass of the limestone (M) is given as 15 kg. Now, we have to convert it into weight. For now, we will write it down as 15 kg.

Then the oven-dried mass of the limestone, which is M_d. The oven-dried mass means the sample is free from water, and we are neglecting the weight of air. So, M_d is the oven-dried mass of limestone. Thus, M_d is nothing but the weight of the rock solids. We can represent the mass of the oven-dried sample as M_s, which is the mass of the rock solids. In this problem, it is 13.5 kg.

Now, the total volume of the sample (V) is 0.006 $m^{3,}$ and the degree of saturation (S) is 65% = 0.65. Whenever we see S, we have to replace it with 0.65. Now, we know that the mass of the moist sample is 15 kg and the mass of the oven-dried sample is 13.5 kg.

So, the weight of the dried rock limestone sample or the weight of rock solids = mass of the oven-dried sample (M_d) × g = 13.5 × 10 since g is given as 10 m/s^2. So, we can get the weight of the dry limestone (W_d) = M_d × g = 13.5 × 10 = 135 N, and we can also write it as W_s as it is nothing but the weight of rock solids.

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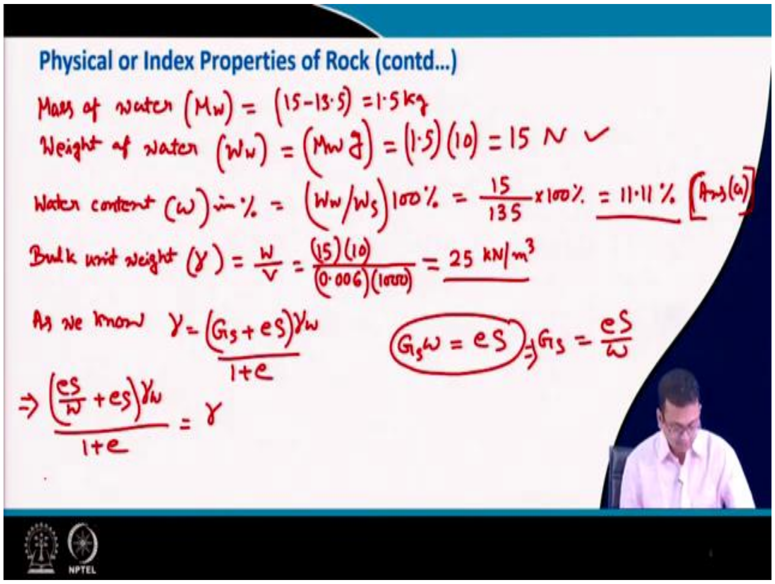

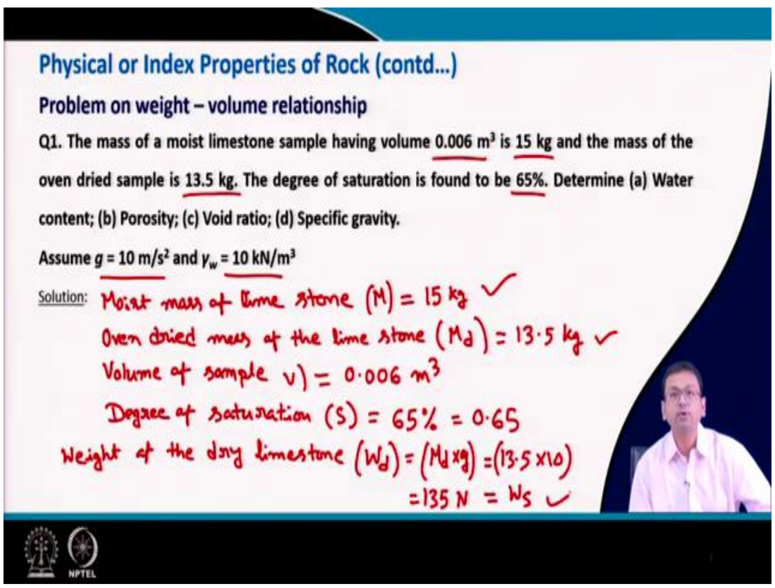

Now, we can also find out the mass of water because the moist mass of limestone is provided, and the oven-dried mass is also provided. So, we can find out the mass of water from there. The mass of water (M_w) = 15 – 13.5 = 1.5 kg. So, we can write the weight of water (W_w) = $M_w \times$ g = 1.5 × 10 = 15 N.

So, the first question was to find out the water content. So, water content (ω) = $\frac{W_w}{W_s}$. We already have W_s, and we have obtained W_w. Hence, we will find out the water content first. So, the water content (ω) in % = $\frac{W_w}{W_s} \times 100\%$ = $\frac{15}{135} \times 100\%$ = 11.11%. This is the answer of part (a) = 11.11 %.

The second question was porosity, then void ratio, and then specific gravity. Let us focus on the porosity. To determine the porosity, we will first find out the bulk unit weight (γ), and from there we have to go for some derivation. Then we can get the value of porosity.

So, the bulk unit weight (γ) = $\frac{W}{V}$. Now, W = 15×10 = 150 N. We convert the mass to weight by multiplying it with g. The total volume of the sample (V) is 0.006 m^3.

The weight of the moist sample is in N, and the total volume of the sample is in m^3. We want to present the sample's bulk unit weight in terms of kN/m^3. So, again we have to divide it by 1000, i.e., $\gamma = \frac{150}{0.006 \times 1000}$. So, if we do that, we will get it as 25 kN/m^3.

From the previous lecture, we know that the bulk unit weight, $\gamma = \left(\frac{G_s + Se}{1 + e} \right) \times \gamma_w$. Now, in this expression, what are the things known to us? G_s can be represented as $\frac{Se}{\omega}$.

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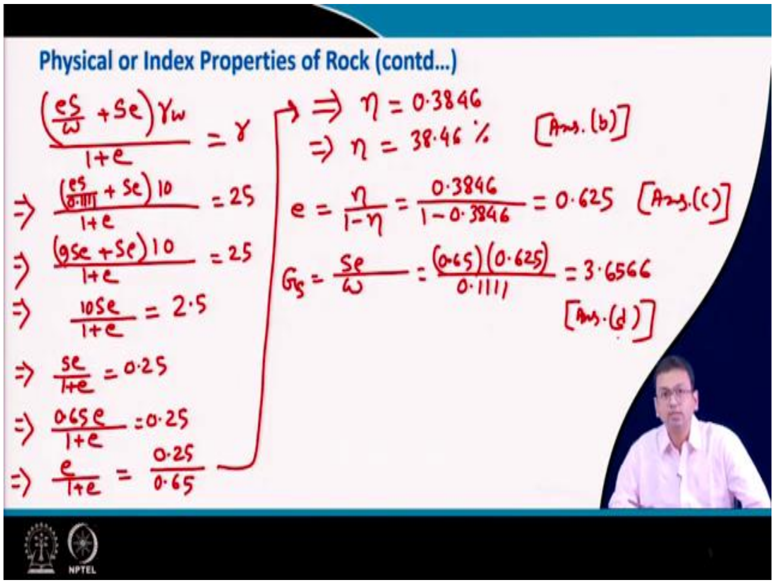

Let us go to the next page. So, if we replace $G_s = \dfrac{Se}{\omega}$ in the expression, we will get $\gamma = \left(\dfrac{\dfrac{Se}{\omega} + Se}{1+e} \right) \times \gamma_w$. So, let us write down $\gamma = \left(\dfrac{\dfrac{Se}{0.1111} + Se}{1+e} \right) \times \gamma_w$ as we have calculated the moisture content as 11.11%, which is nothing but 0.1111.

Now, we can replace γ_w as 10, and the bulk unit weight as 25. And $\dfrac{Se}{0.1111}$ will give 9*Se*. Thus, we will get $25 = \dfrac{9Se + Se}{1+e} \times 10$. If we simplify it, we will get $2.5 = \dfrac{10Se}{1+e}$

After further simplification, we can get $0.25 = \dfrac{Se}{1+e}$. Now, we know that the degree of saturation (S) is equal to 65%. So, we can write, $S = 0.65$. Thus, $\dfrac{0.65 \times e}{1+e} = 0.25$. If we further simply it, we will get $\dfrac{e}{1+e} = \dfrac{0.25}{0.65}$. Now, $\dfrac{e}{1+e}$ is nothing but the porosity (η).

So, $\frac{e}{1+e}$ gives the porosity of the sample, which is equal to 0.3846, i.e., 38.46%. Hence, this is the answer of part (b). Next, we need to find out the void ratio. As we know, $e = \frac{\eta}{1-\eta}$.

So, $e = \frac{0.3846}{1-0.3846} = 0.625$. Hence, this is the answer to part (c). And last one, we have to calculate the specific gravity of the rock solids. The specific gravity of the rock solids (G_s) = $\frac{Se}{\omega}$, i.e., $G_s = \frac{0.65 \times 0.625}{0.1111}$.

So, if we simplify, we will get it as 3.6566. Hence, it is the answer to part (d). So, several things we could able to know from the given data. So, in this way you can solve these problems.

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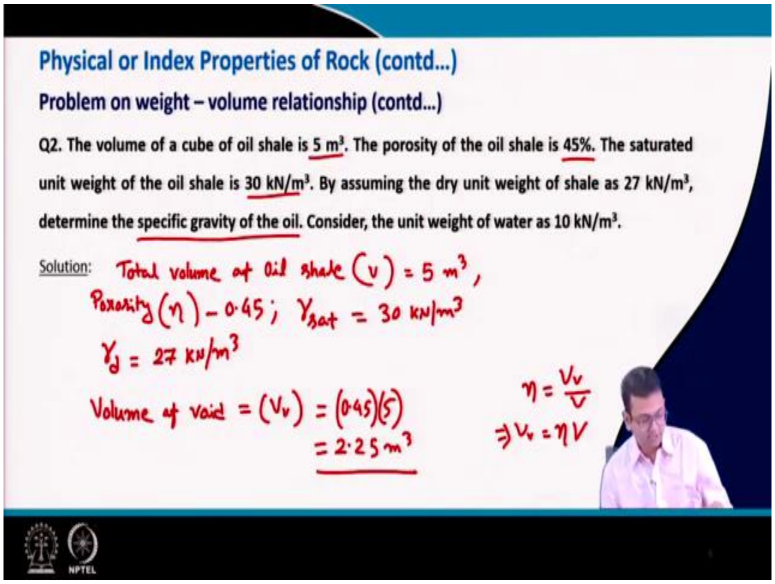

Now, we will solve another practical and exciting small problem. The volume and the porosity of a cube of oil shale are 5 m^3 and 45%, respectively. The saturated unit weight of the oil shale is 30 kN/m^3. Assuming the dry unit weight of shale as 27 kN/m^3, determine the specific gravity of the oil. So, only one question is the specific gravity of oil that we need to find out. Consider the unit weight of water as 10 kN/m^3.

So, it is a straightforward problem but quite helpful. So, what are the things given to us? The total volume of oil shale (V) equals 5 m^3. Then porosity is given as 0.45. The saturated unit weight (γ_{sat}) is given as 30 kN/m^3, and the dry unit weight (γ_d) is given as 27 kN/m^3. So, we are provided with these are the pieces of information.

Now, first, we can find out the volume of voids. So, how to get the volume of void (V_v)? As we know, the porosity of a sample $\eta = \frac{V_v}{V}$. So, the volume of voids (V_v) = $\eta \times V_v$. So, the porosity of the oil cube is given as 0.45, and the total volume is 5 m^3. So, the volume of voids (V_v) = $0.45 \times 5 = 2.25$ m^3.

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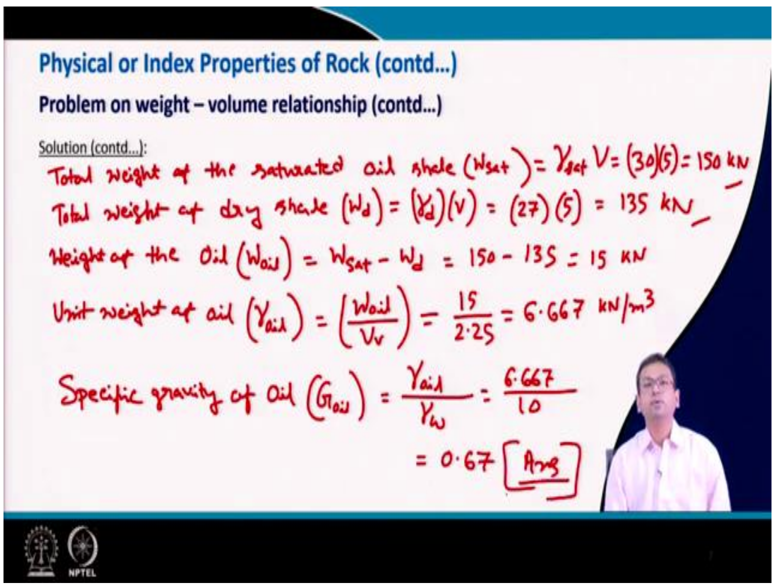

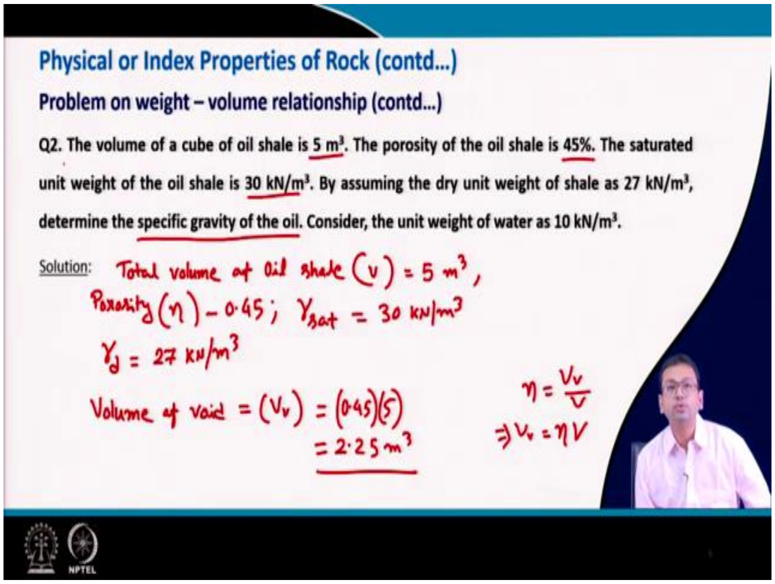

Finally, we have to obtain the specific gravity of the rock sample. So, the total weight of saturated rock shale is $W_{sat} = \gamma_{sat} \times V$.

So, γ_{sat} = 30 kN/m^3 and V = 5 m^3. The weight of the saturated oil shale (W_{sat}) = 30×5 = 150 kN. The total weight of dry shale (W_d or W_s) = $\gamma_d \times V$ = 27×5 = 135 kN.

So, the saturated weight of the oil shale = 150 kN, and the dry unit weight of the shale = 135 kN. The weight of the oil present in the shale = W_{sat} - W_d = 150 – 135 = 15 kN.

So, the unit weight of oil (γ_{oil}) = $\frac{W_{oil}}{V_v} = \frac{15}{2.25}$ = 6.667 kN/m^3. So, therefore the specific gravity of oil (G_{oil}) = $\frac{\gamma_{oil}}{\gamma_w} = \frac{6.667}{10}$ = 0.67 (approximately). So, the specific gravity of oil = 0.67. So, this way we can solve the problems with the help of these things.

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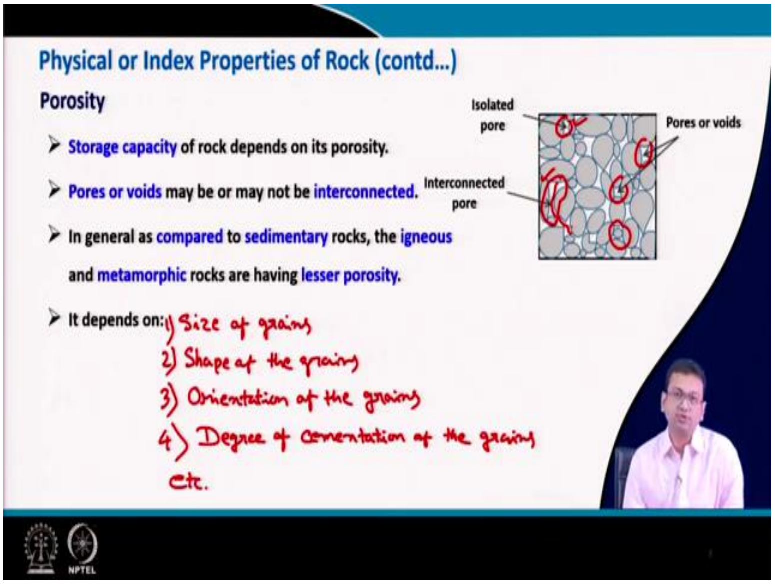

Now we will discuss the porosity. The physical significance of porosity is that the storage capacity of rock depends on the porosity. As expected, if the porosity of a rock sample is more, the storage capacity will increase.

As we can see from the three-phase diagram, some pores are isolated, and some pores are interconnected. So, now the oil or water may be stored inside these pores. So, the storage capacity of rock depends on its porosity.

Now, these pores or voids may or may not be interconnected. We can see that these are interconnected, whereas here, they are isolated, which is very important. In general, as compared to sedimentary rock, the igneous and metamorphic rocks have lesser porosity. However, there may be exceptions.

Now, the porosity depends on several things, such as the size and shape of the grains. Apart from these, porosity may depend on the orientation of the grain. The size and shape of grains may be the same for two rock samples, but their porosity may change depending on orientation.

Apart from the orientation of the grains, the porosity depends on the degree of cementation. These are the prime factors upon which the porosity of rock samples depends. We can also observe the interconnectivity among the pores from the phase diagram. It is evident that if the interconnectivity is more, the permeability will be more. It will be explored in the latter part of the course.

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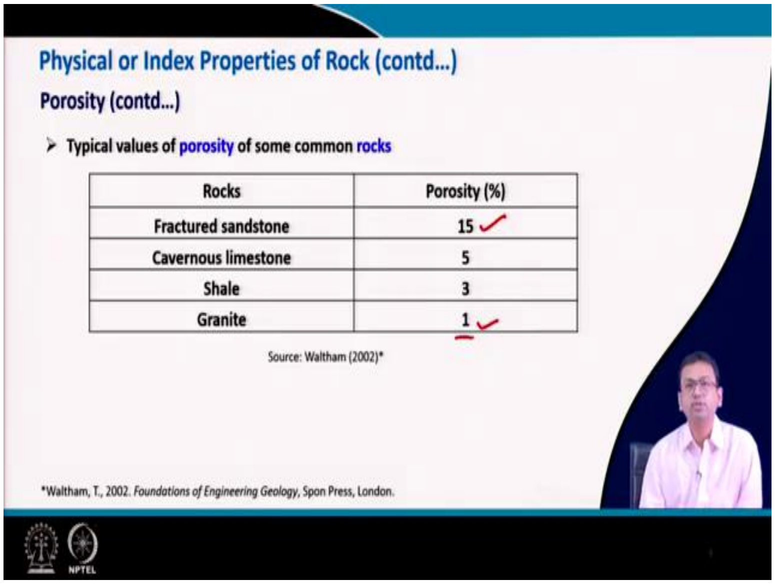

Some of the typical porosity values of some common rocks are given here. We can see fracture sandstone and cavernous limestone, shale, and granite. Four typical rocks are considered. We can see that the porosity of sandstone is 15%, whereas, for granite, it is only 1%.

So, it indicates that the storage capacity, whether it is water or oil, the storage capacity of granite must be significantly less means 15 times less than the fractured sandstone. So, in the case of sandstone, it is pretty high. So, let us stop here today, and we will continue our lecture on these physical properties in our next class. Thank you.