Availability and Management of Groundwater Resources
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Lecture - 20
Porosity, Permeability, Transmissivity and Storage Coefficient

Welcome you all in the 5th module of the course availability and management of groundwater resources. Today we will discuss the part 1 of the module 5th about the porosity, permeability, transmissivity and storage coefficient. So, we have from the very beginning, from the course number 1, we have started the module 1 as a hydrological cycle. There we have seen that the precipitation, infiltration, percolation plays very, very important role for the storage of groundwater in the rocky formation underneath the earth's surface.

Now after discussing the different themes about the aquifer, now just we are entering into the properties of aquifer which stores the groundwater under the ground surface. So, different types of rock formations, behaves differently as an aquifer. As we know that the unconsolidated formations which are very familiar with the very good type of aquifers. Now in this way we can proceed for the different parameters that is the porosity we have seen in the last few lectures also.

That porosity is the availability of storage of groundwater within a rock formation. Permeability is the availability to transmit the water from one aquifer to another aquifer. So, in this module we will learn about these important parameters which plays very, very important role in the accumulation of water inside the earth's surface in any formation.

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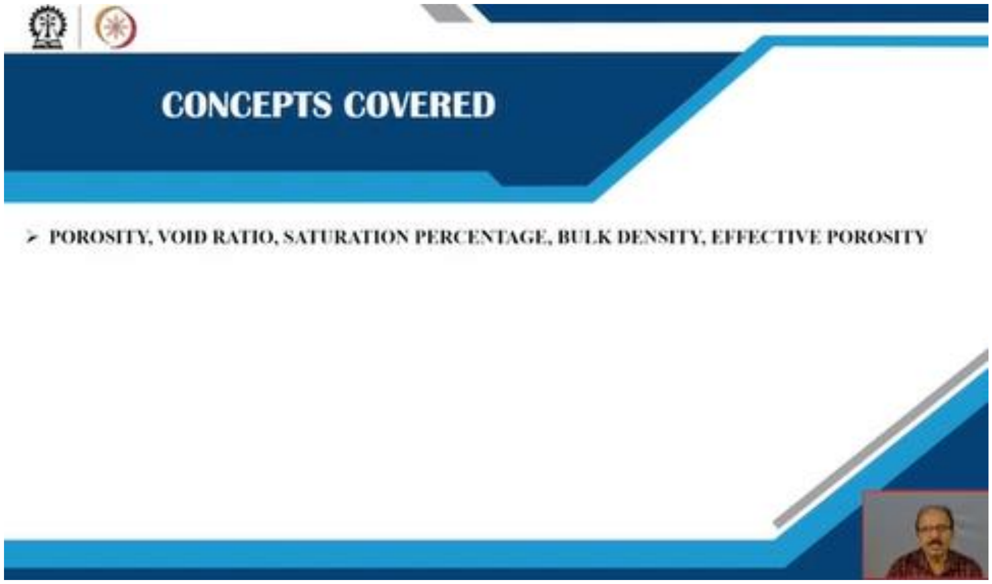

With this concept we will learn about the porosity, void ratio, saturation percentage, bulk density and effective porosity. Today we will discuss this thing and we will learn about these important parameters which are very, very important for any aquifer for any rocky formations which are holding the water.

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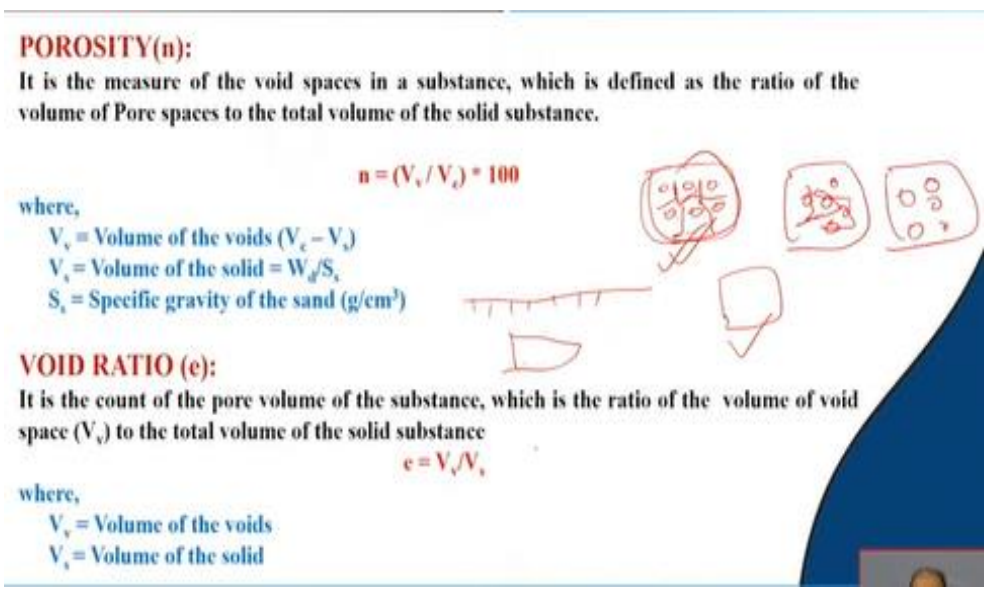

So, first porosity, we have discussed in the previous chapters also. Porosity is the measure of void spaces in any substance, suppose these are the two different substances. And in these two different substances there are the several grains are remaining inside it. So, the porosity depends on the number of grains, how many grains how many white spaces are within it. Important thing is not the grains but the void spaces between grains increases whether the spaces are available or not.

So, this is very important, so this defines the porous behaviour of any material. Suppose one rock is a very consolidated rock, consolidated rock means very hard rock in which there are lesser chances of any space within it. But this is just unconsolidated formation in which we are having so many spaces within it. So, we can say that this rock is much more porous compared to this one because this is a compact rock, hard rock, no pore spaces within it.

So, this defines about the porosity of any rock material. So, it is the measure of void spaces in a substance, in any substance how many void spaces are there? The measurement of the void spaces is generally called as porosity. And defined as it is a ratio of the volume of pore spaces, how many pore spaces are within the rock material, divided by total volume of the substance. So, within if you will divide the pore spaces, volume of porous places by the total volume of the substance then we get the porosity.

In numerically we can write it

$$n = (V_V / V_C) * 100,$$

where,

V_v = Volume of the voids. i.e., $V_c - V_s$, whereas

V_s = Volume of the solids = W_d/S_s and

S_s = Specific gravity of the sand (g/cm^3), here I have taken sand any material specific gravity is taken as S_s. So, this will give us the porosity of any material if we are knowing the volume of the solid or the specific gravity, then also we can find out the volume of the void spaces within it.

So, this is important because we know that underneath the earth's surface the formations should have the porous characteristic. Otherwise, it will not hold the water within it, within the surface it will not hold the water; it should have some porous in nature. Yes, we have also read that different materials, say clay sealed sand, gravel etcetera, different sand materials are having the different types of porosity within it.

The pore spaces are different in different type of materials. So, this porosity is very, very important for the formation, the formation means the rock formations, the rock formations which are holding the water we can say any aquifer. So, then only this aquifer will hold the water, otherwise if the rock formation is having low porosity, then definitely those very rock formations will never hold greater the volume of water within it.

Second important concept with the availability of the groundwater is the void ratio. It is the count of the pore volume of the substance; it is the count of the pore volume substance which is the ratio of the volume of void space to the total volume of the solid substance. So, this is called as 'e' void ratio, void ratio is the count of the pore volume of the substance, it is very important also because this pore volume can be calculated by the volume of the voids divided by the volume of the solid.

$$e = Vv/Vs$$

So, in this way what we have seen that porosity and void ratio is very well related with the available spaces within any rock formations. These available spaces will definitely help in the storing of water within the rock formation.

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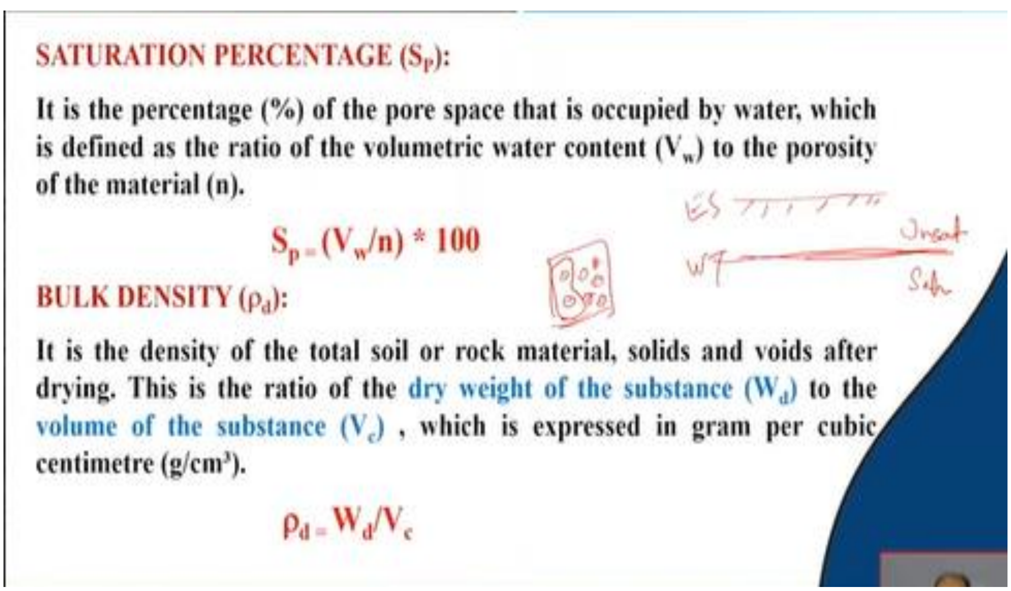

Next saturation percentage, we have seen already while discussion of the previous lecture you have seen that saturation formations we are getting after, if this is the earth surface then first, we are getting the unsaturated formation and then we are getting the saturated formation. We are also, knowing that the upper part of the saturated formation is the water table, this is the water table. So, now the point is suppose we get any problem and we have to identify the saturation percentage of the underlying rock formations.

Then how we can calculate it? So, first we should know what is saturation percentage? It is the percentage of the pore space that is occupied by water. A rock is there, in rock there are several pore spaces are there, several pore spaces are there. So, what is the percentage of pore space which is occupied by water, some pore space may not fill with some other material, some mineral matter etcetera. But some pore spaces will always filled up with the water.

So, the saturation percentage (Sp) can be calculated by knowing the percentage of the pore space that is occupied by water. It is defined as the ratio of volumetric water content V_w divided by the porosity of the material,

$Sp = (V_w /n) *100$

what is the porosity of the material? If you will just put the value of the volumetric water content and the porosity of the material, definitely we can get the percentage of the pore spaces that is the saturation percentage of any rock formations which is holding the water.

So, this is also very well related with the porosity and permeability of any rock, say I have told you that porosity and permeability these are very, very important parameters, specifically also very important parameter. Because of the porosity and permeability, we can identify a good aquifer, a bad aquifer. And for this we should know the different aspects of the criteria for defining the aquifer also.

So, based on this we are discussing the saturation percentage, void ratio, bulk density etcetera. Now next is the bulk density, it is the density of the total soil or rock material, solids and voids after drying. So, after drying what is the density of the total soil or rock material, solids and whites after drying? This is the ratio of the, definitely after drying means it is the ratio of the dry weight of the substance to the volume of the substance which is expressed in g/cm^3

We can see

$$\rho_d = Wd /Vc$$

So, this bulk density gives a important concepts for knowing about the different types of porous behaviour of the rocks.

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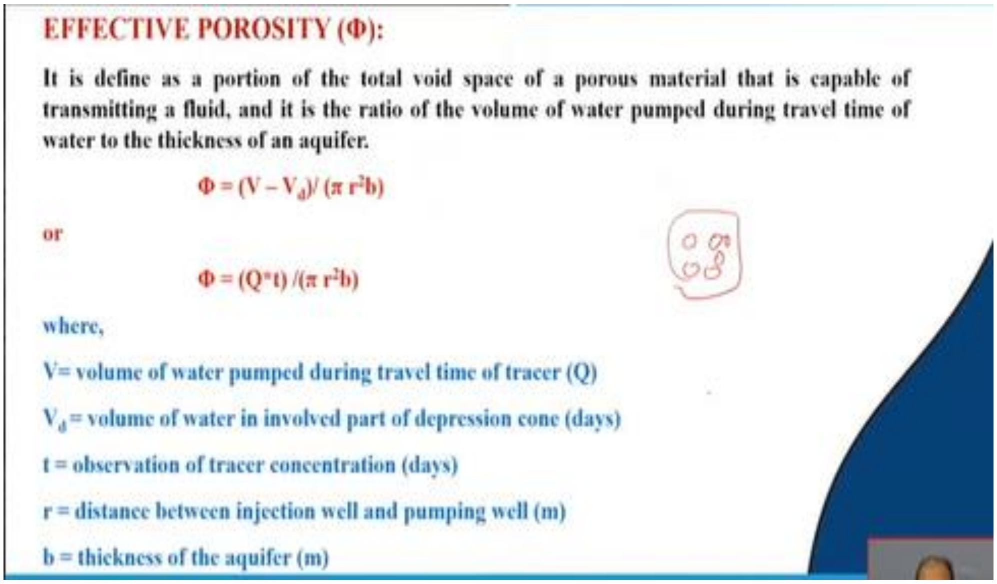

Next is the effective porosity, effective porosity is also one of the important parameter of porosity. It is defined as the portion of the total void space, whatever total void, suppose this is a rock number of pores are there, so total void space of the porous material, this is porous material which is capable of transmitting a fluid means what? Liquid as well as gas. And it is the ratio of the volume of water pump during travel time of the water to the thickness of aquifer.

$$\Phi = (V - V_d)/ (\pi r^2 b)$$

It is just a ratio of the volume of water pump during travel time of water to the thickness of an aquifer. So, $\pi r^2 b$ is the thickness of an aquifer we have considered and in this way the bulk density $V - V_d$, where

V = volume of water pump during the travel time of any tracer I have taken, generally tracer through the tester we are identifying the flow of the contaminants. So, travel time of water is there,

V_d = volume of water in involved part of the depression cone, how much water has gone just inside.

t = observation of tracer concentration,

r = distance between injections well and the pumping well, a few things we have discussed in the previous chapters also. But some other concepts of the pumping test etcetera we will discuss in the later course classes.

b = thickness of aquifer, it is also very important criteria for knowing the extent of the aquifer.

What is the extent of the aquifer? So, this effect is generally effective porosity we can find out with the help of these important parameters with and actually it means the total void space which is entirely responsible for carrying the liquid as well as fluid.

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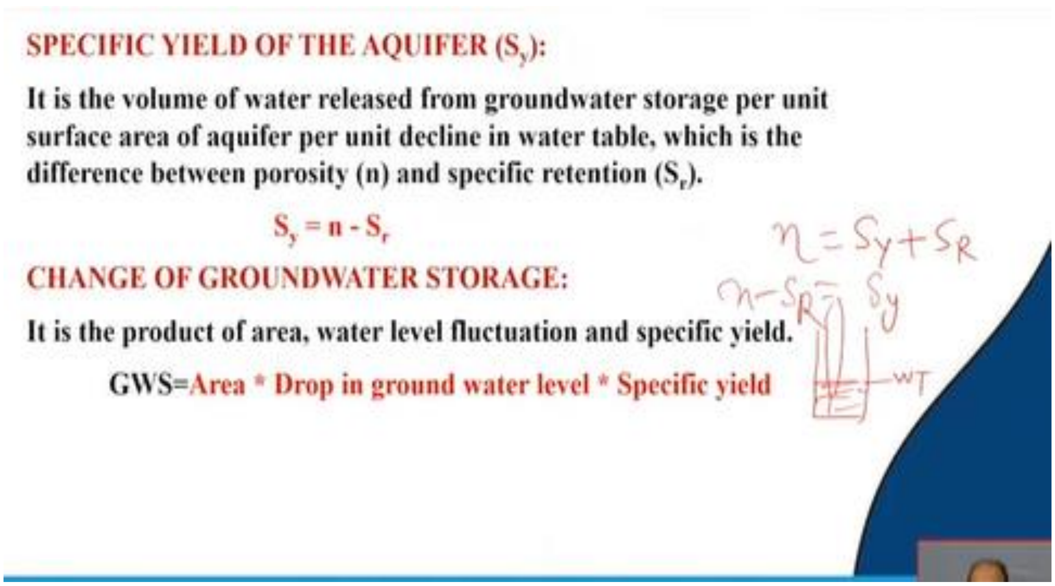

Now specific yield we have discussed earlier also, it is the volume of water released from groundwater storage per unit surface area of aquifer per unit decline in water table,

$$S_y = n - S_r.$$

In the previous lecture also, we have discussed that porosity is the specific yield plus specific retention, means when we are just withdrawing the water from a well, just if this is the well and then it water is there, this is the water table.

So, when we are withdrawing the water from the well what is happening? The well is just taking out the water but few more volume of water still retain with that material, that material means the soil material or rock material because of the molecular attraction it remains there. So, this combined with retention plus specifically gives us the porosity. So, specific yield is the porosity minus specific retention.

So, it is also one of the very, very important parameter for knowing about the availability of groundwater inside the rock formations. Now next is the change of groundwater storage, next concept change of groundwater storage. This is important, it is the product, it is generally calculated by multiplying the area of the aquifer or rock into the dropping groundwater level in that, what is just change in the groundwater table of the formation and multiplied by specific yield.

So, this gives us the change of groundwater storage within that very formation, what are the different changes in the groundwater storage? We can find out if we are knowing about the details about the area of the formation and the drop in the groundwater level and the multiplied by specific yield. So, these concepts are very, very important for finding the porous behaviour or the permeable behaviour of any formations which are holding the groundwater inside the earth surface. Now based on this just we will solve a numerical, then it will be more clear to all of us.

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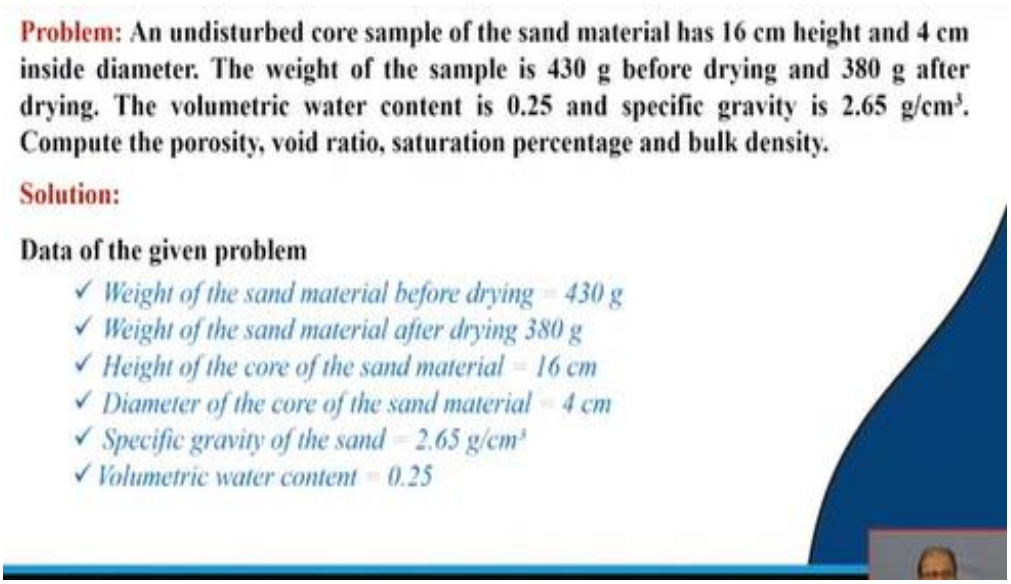

The problem is that an undisturbed core sample of the sand material has 16 cm height and 4 centimetre inside diameter. So, the sand material is of 16 cm height, diameter is 4 cm inside the weight of the sample in the core sample is 430 g before drying and 380 g after drying, so 430 g before drying and 380 gram after drying. The volume of volumetric water content is 0.25 and the specific gravity is 2.65 gram per centimetre cube. Calculate the porosity, void ratio, saturation percentage and bulk density of the material, this is the question.

Data of the given problem

Weight of the sand material before drying = 430 g

Weight of the sand material after drying 380 g

Height of the core of the sand material = 16 cm

Diameter of the core of the sand material = 4 cm

Specific gravity of the sand = 2.65 g/cm³

Volumetric water content = 0.25

Everything whatever has given we will first note it down. So, we have noted all the different parameters here in the problem whatever has been told us, we have already written here.

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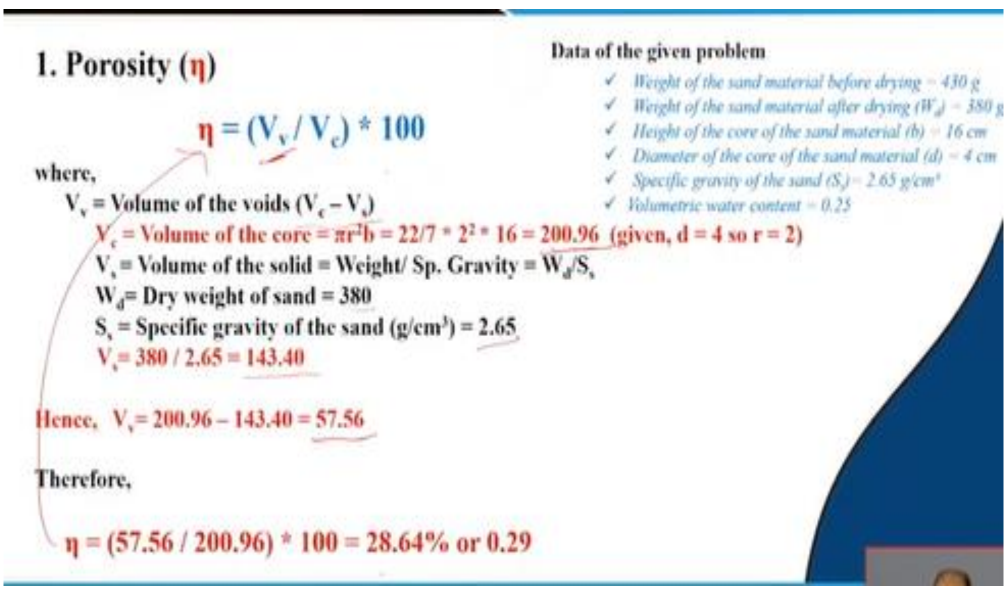

Now just ask first thing was the porosity calculation of porosity.

$$\eta = (Vv / Vc) * 100$$

V_v = Volume of the voids ($V_c – V_s$)

V_c = Volume of the core = $\pi r^2 b$ = 22/7 * 2^2 * 16 = 200.96 (given, d = 4 so r = 2)

V_s = Volume of the solid = Weight/ Sp. Gravity = W_d/S_s

W_d = Dry weight of sand = 380 g

S_s = Specific gravity of the sand (g/cm^3) = 2.65

V_s= 380 / 2.65 = 143.40

Hence,

V_v = 200.96 – 143.40 = 57.56

Therefore,

η = (57.56 / 200.96) * 100

= 28.64% or 0.29

this much we are getting the value of porosity in the shade sand formation which are given in the problem, so first we have calculated the porosity.

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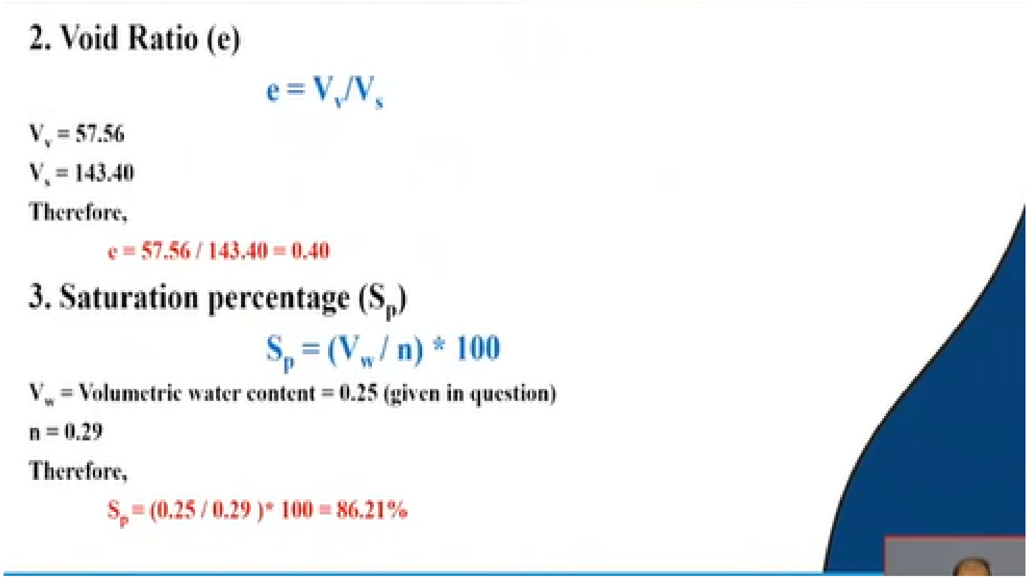

Now next is the void ratio, this is also one of the parameters in the question it has been asked. So, now for finding this; what we have taken? We have taken the value

$e = V_v/V_s$

V_v = 57.56

V_s = 143.40

Therefore,

e = 57.56 / 143.40 = 0.40

Now third calculation where of the; Saturation percentage (Sp)

$Sp= (V_w / n) * 100$

V_w = Volumetric water content = 0.25 (given in question)

n = 0.29

Therefore,

Sp = (0.25 / 0.29) * 100

= 86.21%

So, this saturation percentage 86.21% means it is a good formation which is holding the water, 86% is not a bad one but since it is a sand material.

In the question also if you will just recall the question, it was a sand material, so it is having a good porosity also and it is holding the water saturation percentage of 86.21.

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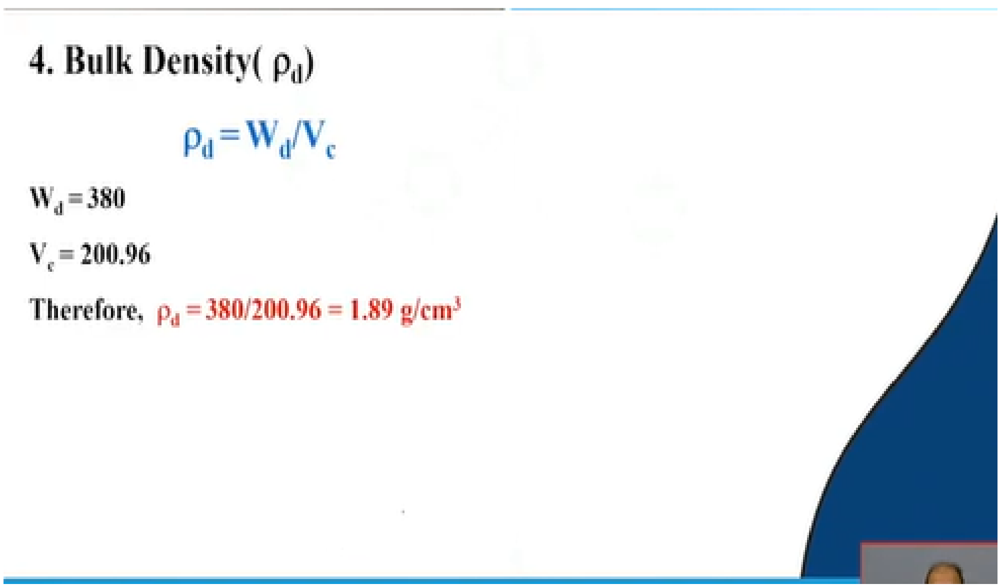

Now next bulk density,

ρ_d = Wd/Vc

Wd = 380

Vc = 200.96

Therefore,

ρ_d = 380/200.96

= 1.89 g/cm^3

The point is that, as we have seen in the problem the formation is undisturbed core sample of the sand material, it is not disturbed. If disturbance will come definitely some sort of your core spaces will be affected.

So, it is undisturbed core sample of the sand material of 16 cm height and 4 cm inside the meter. So, in this way there are several formations which are generally remaining undisturbed also, from where we can find out about the available your porous behaviour of the rock formations which are remaining present and which are very, very responsible for finding the different amount of the, different volume of the water within it.

That is why porosity first we have calculated it was coming 28.64% here about 0.29 we can write it. And then after knowing the porosity of the sand material undisturbed core sample, then the void ratio we have calculated it is coming about 0.40 and the saturation percentage is coming 86.21%. So, every calculation is very well related with this concept. If you are knowing the concept you can know about the details about the rock formations which are holding the water.

And this is very much important for finding the porous behaviour of any material which is holding the water. Thank you very much.