Rock Mechanics and Tunneling
Professor Debarghya Chakraborty
Department of Civil Engineering
Indian Institute of Technology, Kharagpur
Lecture 14
Topic - Physical properties (Continued)

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Hello everyone, I welcome all of you to the 3rd lecture of Module 3. So, we were discussing about the physico-mechanical properties of rock in Module 3. In our previous two classes, we have discussed about the physical properties. In this lecture also, we will continue our discussion with that. Hopefully we will finish the discussion related to physical properties today only, and from our next lecture we will start the mechanical properties.

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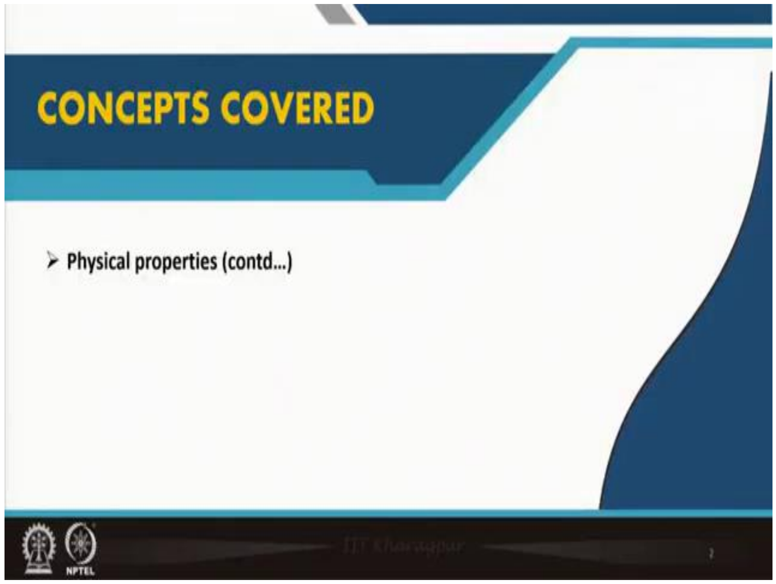

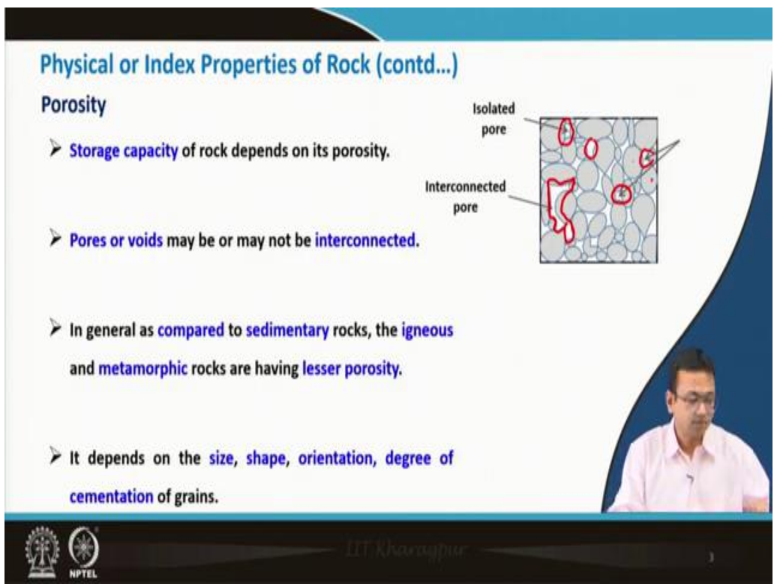

In the last lecture, we have discussed about the porosity. So, let us quickly revise this part because the next property is permeability which is related to the.

We have learnt from the previous lecture that the storage capacity of rock depends on its porosity. The reason is very clear from this diagram as we can see that here these are the grains and in between these grains, pores or voids are there. Now, we can see, some of the pores are isolated, i.e., the pores a not connected with others. Whereas, these pores are interconnected, and these are the isolated pores.

The pores or voids may be or may not be interconnected and it significantly affects the permeability of the rock sample. As we know that in general, the igneous and metamorphic rocks are having lesser porosity as compared to sedimentary rock. Porosity depends on the grain size, grain shape, and orientation of the grains and the degree of cementation of the grain also has a significant effect on the porosity.

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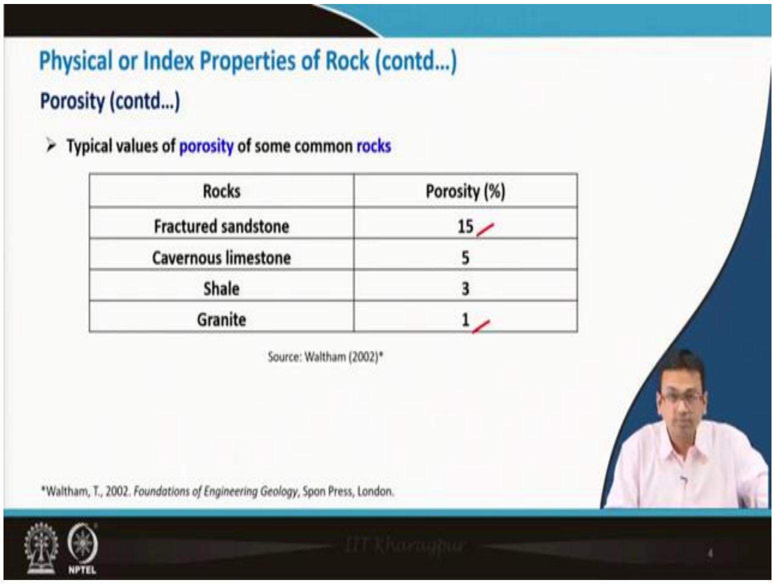

And we also have seen some of the typical values of porosity of some common types of rocks, e.g., for sandstone, it is 15 %, whereas for granite, it is 1%. So, up to this, we have discussed in our previous class.

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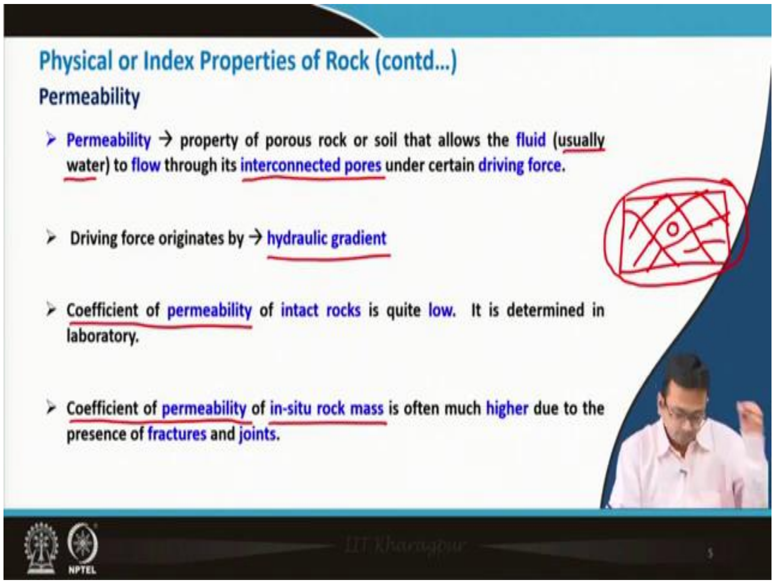

Now, we will gain some knowledge about permeability, which is very much connected to the porosity. So, permeability is the property of porous rock or soil that allows the fluid usually water to flow through its interconnected pores under certain driving force.

The driving force is basically originated by the hydraulic gradient. Then we can say that the coefficient of permeability of intact rocks is quite low, and it is determined in the laboratory.

We generally bring the intact rock sample to the laboratory and there we test it and it is found to be quite low. Whereas coefficient of permeability of in-situ rock mass is often much higher due to the presence of fractures and joints. So, if we consider the rock mass, different types of joints, fractures, and discontinuities are there which most likely increases the permeability of the rock mass.

So, basically as we know if we consider this rock mass and if there are suppose different joints are present fractures joint, different discontinuities are there like this suppose, suppose like these different joint sets are present. If we consider only the intact rock sample and if we test it to find out its permeability, it is expected to be quite low as compared to that of the in-situ rock mass as these fractures and joints also take part in case of rock mass. Because of that the coefficient of permeability of in-situ rock mass is generally much higher as compared to the intact rock.

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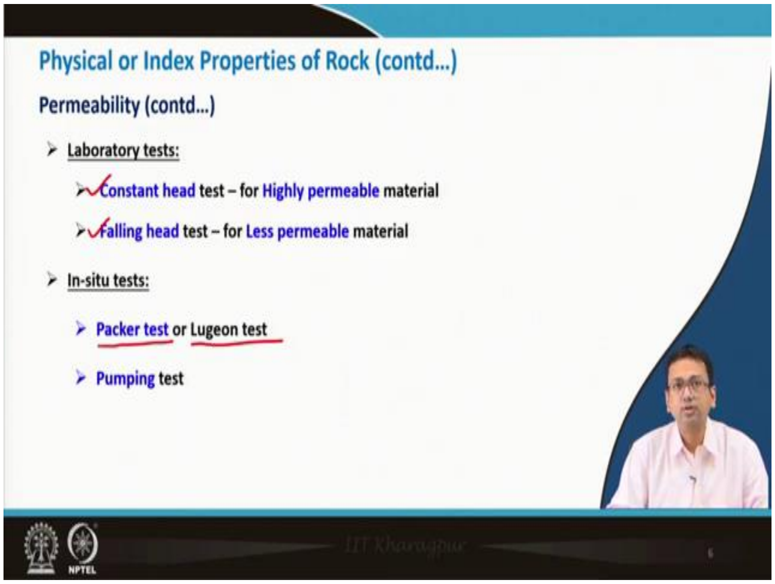

As we know that the constant head test is generally performed for highly permeable material, and the falling head test is for less permeable material.

The field tests are very important as the coefficient of permeability of in-situ rock mass is much higher because of the presence of fractures and joints which reflects the real scenario at a particular site. There will be some discontinuity present in the rock mass and that is why in-situ tests are very important.

Packer test is generally used to find out the coefficient of permeability of in-situ rock mass. This test is also known as the Lugeon test. Other than that pumping tests are also there. So, these are mainly the different laboratory and in-situ test that we perform to find out the permeability of intact rock and rock mass.

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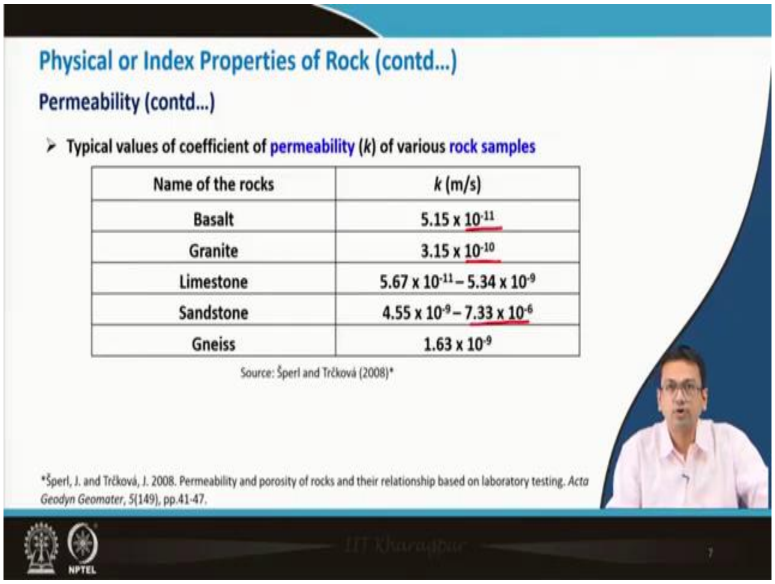

Now, the table shows some of the typical values of coefficient of permeability of various rock samples. We can see that the coefficient of permeability of sandstone as expected is in the order of 10^{-6}. Whereas, for granite, it is 10^{-10}, and for basalt, it is in the order of 10^{-11}.

So, these values clearly indicates that which rock is how much permeable. As we can observe that for igneous rock, the permeability is relatively less. Hence, the coefficient of permeability is in the order of 10^{-10} - 10^{-11}.

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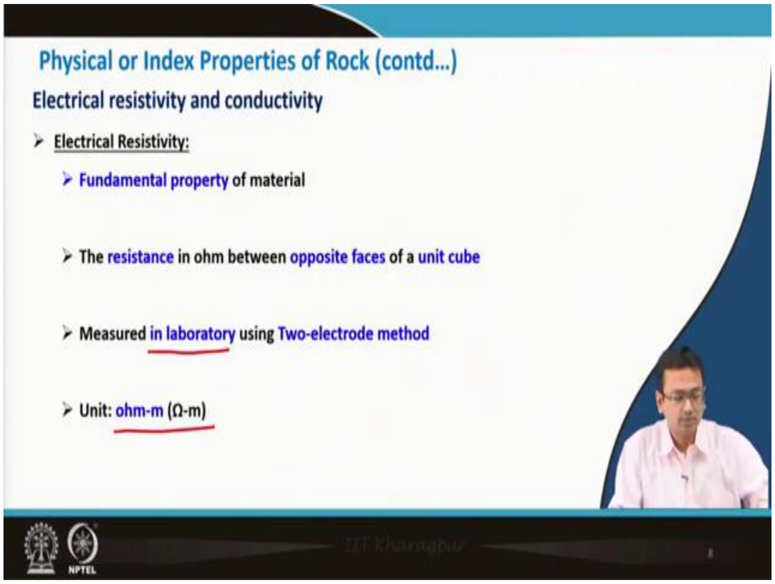

Now, next physical properties are the electrical resistivity and electrical conductivity. Electrical resistivity it is a fundamental property of material. Since it is a fundamental property of material, we can use it to identify different type of rocks.

So, now the resistance in ohm between opposite faces of unit cube which we actually try to find out and in laboratory. In laboratory, the two electrode method is generally used to find out the electrical resistivity of rock samples. In our next module, we will discuss about the in-situ electrical resistivity determination procedure to some extent in detail.

In laboratory, two electrode method is generally used where simple arrangement is required but a little bit of complicated arrangement is used in field. So, the unit of the electrical resistivity is ohm-m.

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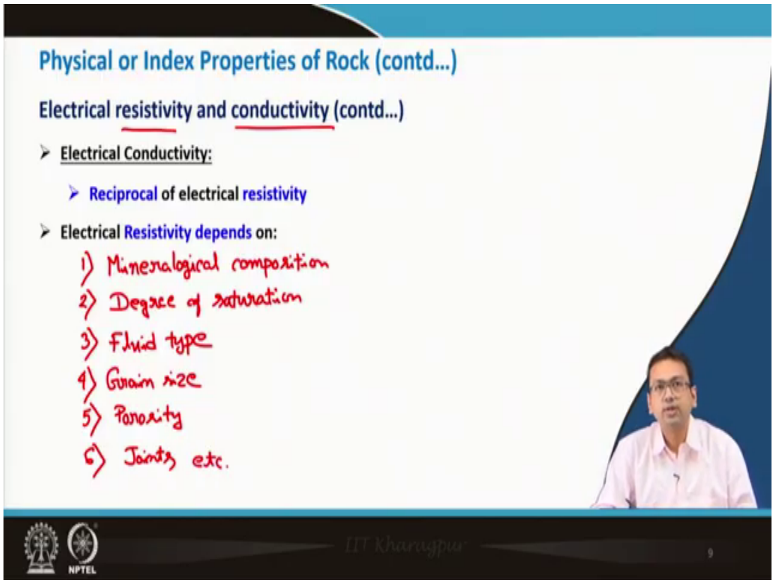

Along with the electrical resistivity, another physical property is there known as the electrical conductivity. So, the electrical conductivity is the reciprocal of electrical resistivity. Since resistivity is a fundamental property and the conductivity is the reciprocal of resistivity. Hence, a particular type of rock mass can also be identified using the electrical conductivity.

Now, let us know about the factors affecting the electrical resistivity. The electrical resistivity depends on quite a few things from which the first one is the mineralogical composition. It is expected that different minerals are having different resistivity or conductivity.

In case of a particular rock sample, which type of mineral is more present, depending on that its resistivity also varies. Then, it also depends on the degree of saturation. It also depends on the type of fluid is present there in the rock sample.

As we know that if it is saline water, its conductivity will increase. Thus, we can say that the electrical resistivity depends on the type of fluid present in the sample. Other than that, porosity, joints, fracture or discontinuities significantly affects the electrical conductivity and resistivity.

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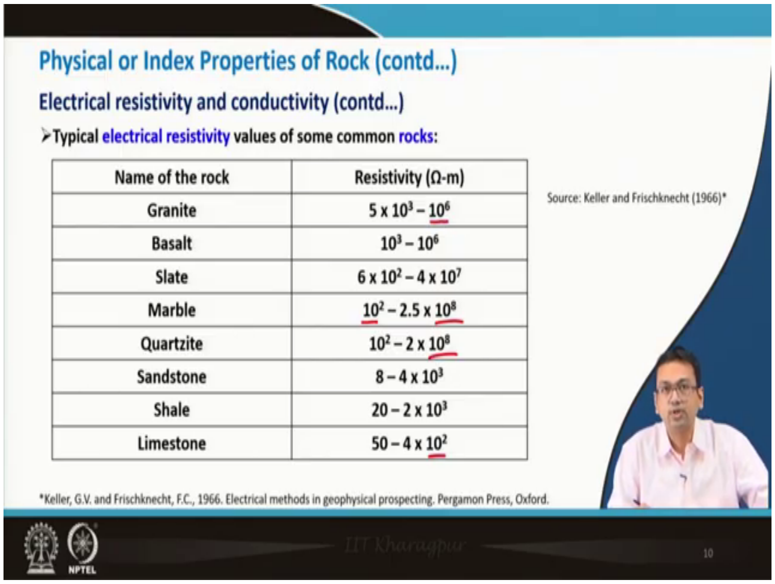

The typical values of the electrical resistivity of some of the common rocks are provided in the table. Different ranges have been provided for different types of rocks. For granite, it is from $5\times10^3 - 3\times10^6$, whereas for sandstone, it is from $8 - 4\times10^3$. The electrical resistivity values for limestone is quite different from others. The highest order of resistivity for limestone is 10^2.

Whereas for marble, it is 10^8; for quartzite also, it is 10^8. These values are quite different from each other. Hence, by performing this electrical resistivity test we can get some basic insight into the type of rock mass or rock sample. For example, in the case of marble, it is varies in a wide range, i.e., from $10^2 – 10^8$.

For limestone, the electrical resistivity is in the order of 10^2. For granite, it is in the order of 10^6. So, they are quite different from each other. At least, we can get some idea that if the electrical resistivity is in the order of suppose 10^8, the rock sample may not be limestone, shale or sandstone or granite. We can get these kind of basic idea from this electrical resistivity test. So, this is one of the important physical properties.

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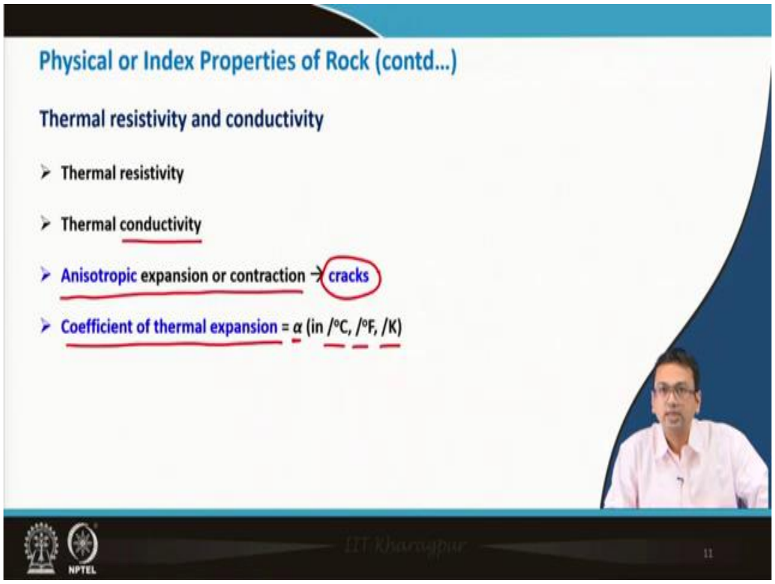

Now, similar to the electrical resistivity and conductivity, we have another important properties of rock such as thermal properties which include the thermal resistivity and thermal conductivity. As we have discussed that the electrical conductivity is the reciprocal of electrical resistivity, similarly, the thermal conductivity is the reciprocal of thermal resistivity.

It should be mentioned that the cracks may develop in the rock sample due to anisotropic expansion or contraction. Another important parameter related to thermal property is the coefficient of thermal expansion. Different materials are having different coefficients of thermal expansion and that depends on different factors.

The coefficient of thermal expansion generally presented as α, and the unit is /ºC or /ºF or /K. So, the thermal resistivity or conductivity of different rock samples will be different from each other as we have seen for electrical resistivity or conductivity. So, with the help of thermal properties also, we can identify a particular type of rock.

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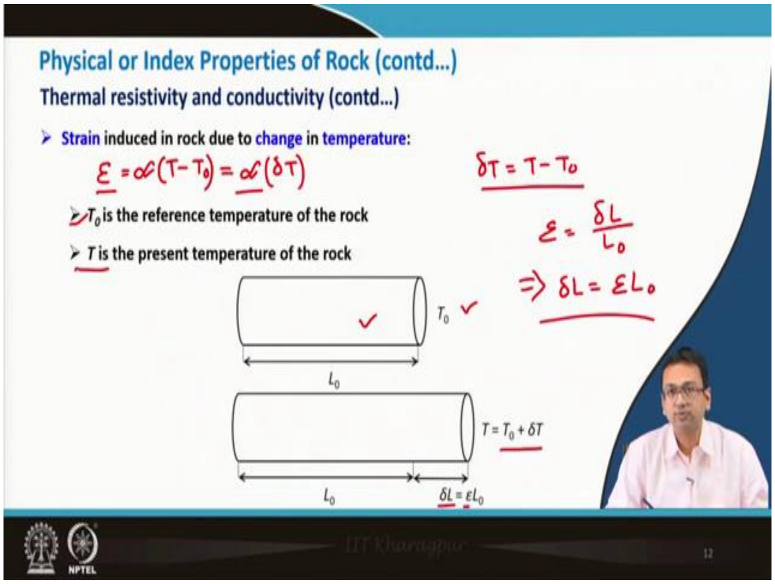

Strain induced in rock due to the change in temperature: Suppose, the initial length of the rock sample is about L_0 at a temperature of T_0. If the temperature is increases to T, where $T = T_0 + \delta T$, the length of the rock sample will also increase due to the increase in the temperature. If the length of the sample increases by δL, the δL can be expressed as εL_0. ε is the induced strain in rock sample.

Now, the strain ε can be obtained very easily. So, $\varepsilon = \alpha \times (T - T_0) = \alpha \times \delta T$, where $\delta T = T - T_0$. We also know that $\varepsilon = \frac{\delta T}{T_0}$. So, the coefficient of thermal expansion (α) and temperature difference are known, the strain induced in the rock sample can be easily calculated and when the stain is evaluated, the increase in length of the sample δL can be evaluated, where $\delta L = \varepsilon L_0$.

Thus, thermal property is a very essential as it has been stated for anisotropic expansion or contraction, cracks may develop. So, it may help to estimate the probable chance of developing crack in the rock sample.

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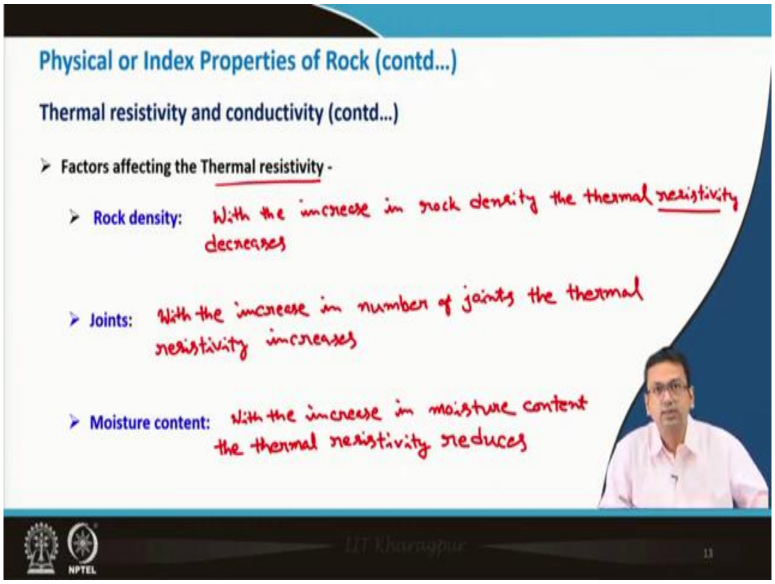

Now, we will discuss about the factors affecting the thermal resistivity. There are three prime factors that have a significant effect on the thermal resistivity. These factors are (a) rock density, (b) presence of joints, and (c) moisture content.

The thermal resistivity decreases as the rock density increases. Since the thermal resistivity decreases, the thermal conductivity will obviously increase. With the increase in number of joints the thermal resistivity increases, and the thermal resistivity decreases as the moisture content of the sample increases.

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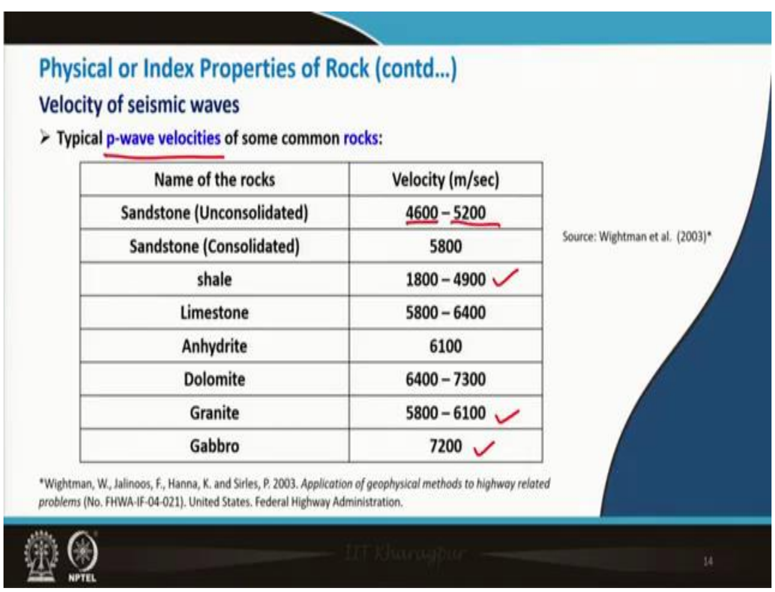

Now, next is the thing is the velocity of seismic wave that we have learnt in the previous module (Module 2). However, one slide on this topic has been demonstrated here for the sake of completeness. As we know that the velocity of seismic waves will be different for different type of rocks.

The typical values of *p* wave velocities of some common rocks are provided in the table. So, as we can see, for granite, it is in the range of 5800 – 6100 m/s; whereas, for shale, it is in the range of 1800 – 4900 m/s. In the case of gabbro, it is quite higher, i.e., 7200 m/s. In the case of unconsolidated sandstone, the lower range is about 4600 m/s, whereas the upper range is 5200 m/s.

So, with the help of these values, we can get some basic idea about the type of rock and that is why this velocity of different seismic waves can be quite useful physical property.

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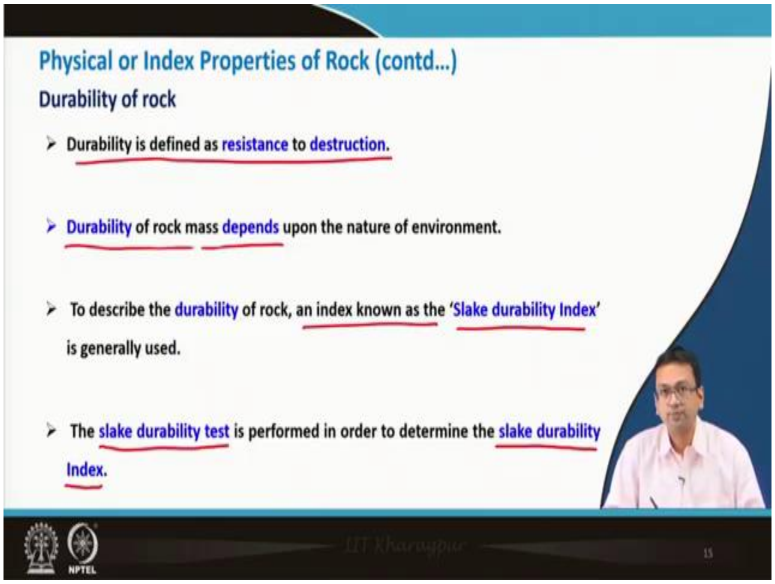

Now, we will discuss another physical property that is the durability of rock. Durability is defined as the resistance to the destruction. If a rock is said to be more durable which indicates that the rock sample will sustain for longer periods under the different loading condition that. Hence, determination of durability is very important when we try to construct any structure with that rock or on that rock or in that rock. So, it is very much essential to check the durability of the rock.

Now, this durability of rock depends upon nature of the environment, means the climate of the area, variation in day to day weather, whether it is very hot weather or very cold weather, depending on these aspects, the durability of the rock is actually determined. Hence, the nature of environment is very important as far as durability of rock mass is concerned.

Now, an index known as the 'Slake durability Index' is generally used to describe the durability of rock. So, the Slake durability Index will be discussed in the next module. So, just for the time being it should be remembered that the Slake durability Index is used to describe durability of rock.

For the slake durability test, a special type of equipment is there which is used to determine the slake durability index, which will be discussed in the next module.

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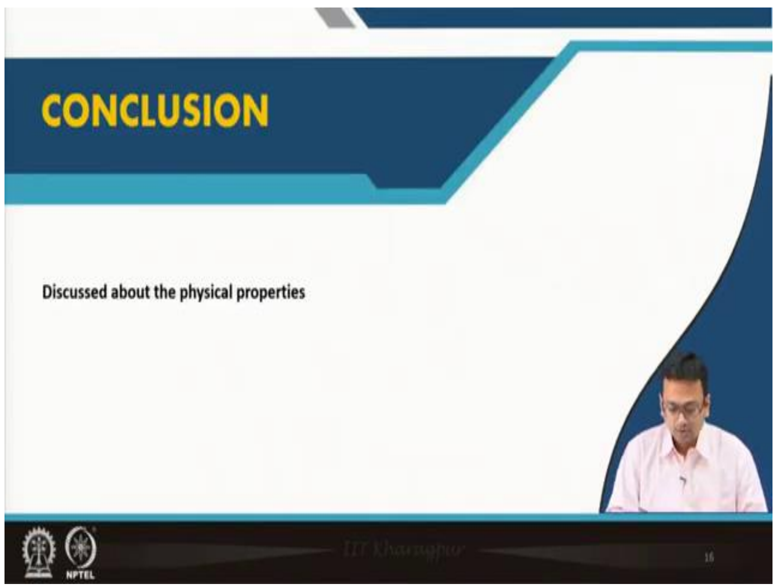

In the part of the physical properties part, we started with the weight – volume relationship which is very important.

So, we have solved a couple of problems related to that and we have discussed in detail about different weight volume relationships. Then, we have discussed one by one about different physical properties starting from porosity, permeability, electrical conductivity, thermal conductivity, then this seismic wave, then durability. We have discussed all these things.

And some of the test procedure we will learn as I have stated in our next module. From our next lecture we will start discussing about the mechanical properties of rock sample or rock mass or intact rock which is extremely important for our engineering design purpose. Thank you.