Underground Space Technology
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Lecture – 54
Permeability and Groutability -01

Hello everyone, In the previous class we discussed various aspects related to rock bolts. So, today we will learn about grouting through rocks, but before that we will learn few aspects related to permeability and groutability, how these two terms are connected with each other. So, let us take a look first on the permeability. So, what exactly is the definition of this term?

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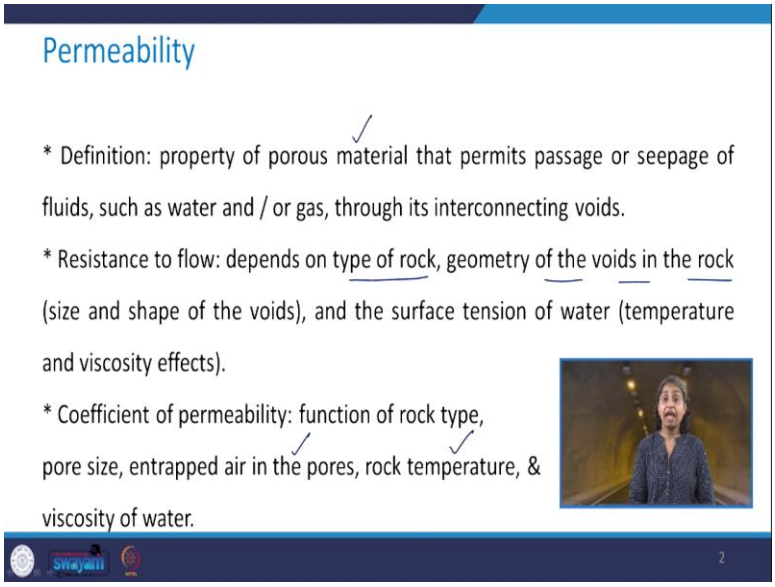

Basically, this defines the property of the porous material that permits the passage or seepage of fluids such as water or gas or both through its interconnecting voids. You must have learned this in soil mechanics that, permeability is defined as the ease with which water flows through the soil. So, it is a similar definition here that is the property of the porous material. The resistance to flow depends on the type of the rock, geometry of the voids, in the rock that is size and shape of the voids, and the surface tension of the water which depends upon the temperature and the viscosity effects.

Coefficient of permeability is a function of rock type, pore size, entrapped air in the pores, temperature of the rock, and viscosity of the water.

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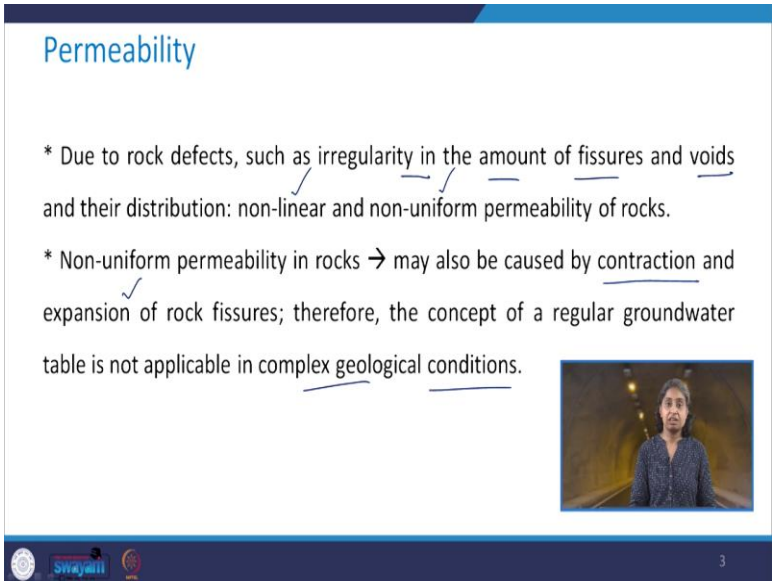

Now, due to these rock defects such as irregularity in the amount of fissures and voids and their distribution, permeability of the rocks are non-linear and non-uniform. So, this non-uniform permeability in rocks, these may also be caused by the contraction and expansion of rock fissures and therefore the concept of a regular groundwater table is typically not applicable in the complex geological conditions.

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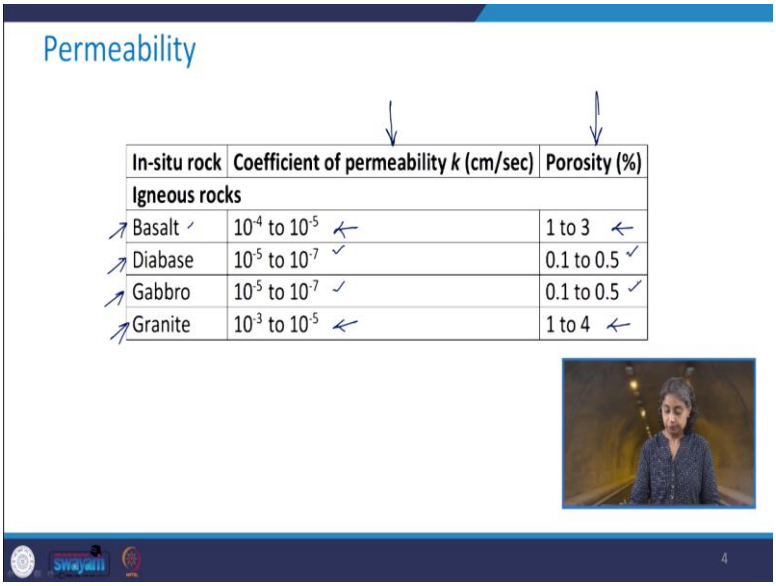

Coming to some of the basic rocks and their coefficient of permeability along with their porosity. So, here is the table which deals with some typical igneous rocks such as basalt, diabase, gabbro, and granite. So, the next column gives you the idea about the coefficient of permeability in centimeter per second and the third column provides us the range of the porosity in percentage.

So, for the basalt it is varying between 10 to the power of – 4 to 10 to the power of -5 and the porosity is between 1% to 3%. However, in case of granite, it is 10 to the power of – 3 to 10 to the power of – 5 with the porosity 1% to 4% and similarly, the values are given for diabase and gabbro.

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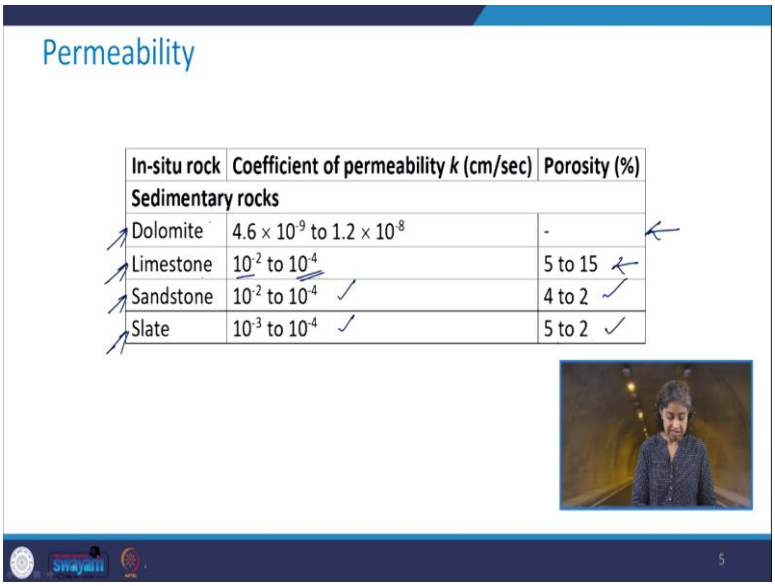

Now, coming to the sedimentary rocks so here four rocks are given, dolomite, limestone, sandstone, and slate and the typical range of the coefficient of permeability in centimeter per second is given for each of these for the dolomite this is not available, but in case of the limestone you see the permeability coefficient of permeability it varies from 10 to the power – 2 to 10 to the power of – 4 centimeter per second with the porosity varying from 5% to 15%.

Similarly, we have the range for sandstone and slate and the corresponding range for the porosity which is 4 to 2 for sandstone and 5 to 2 for slate.

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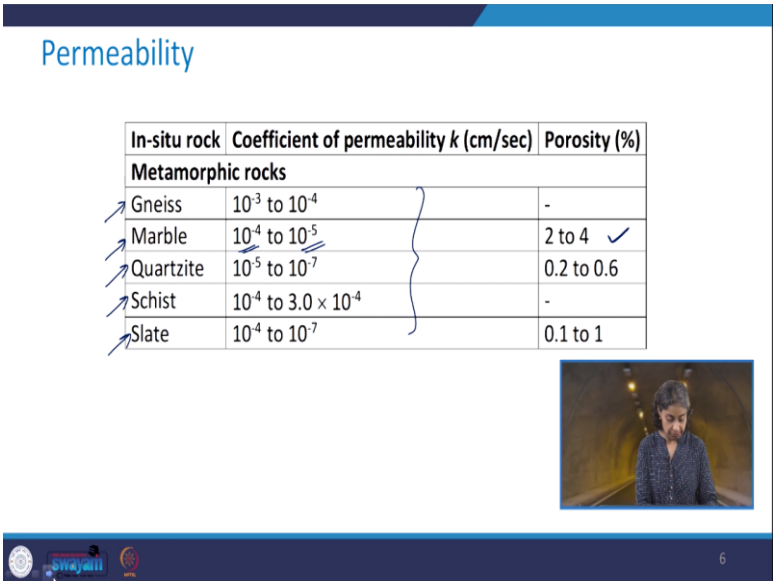

The third type of rock which are metamorphic rocks and here 5 rocks are given which belong to this metamorphic rock category that is Gneiss, marble, quartzite, schist, and slate. So, the range of let us say typically for marble it is 10 to the power of – 4 to 10 to the power of -5 centimeter per second and the corresponding porosity is 2% to 4%. So, similarly, you can just take a look at this table and get the idea about the range of the coefficient of permeability in centimeter per second for some typical rock type.

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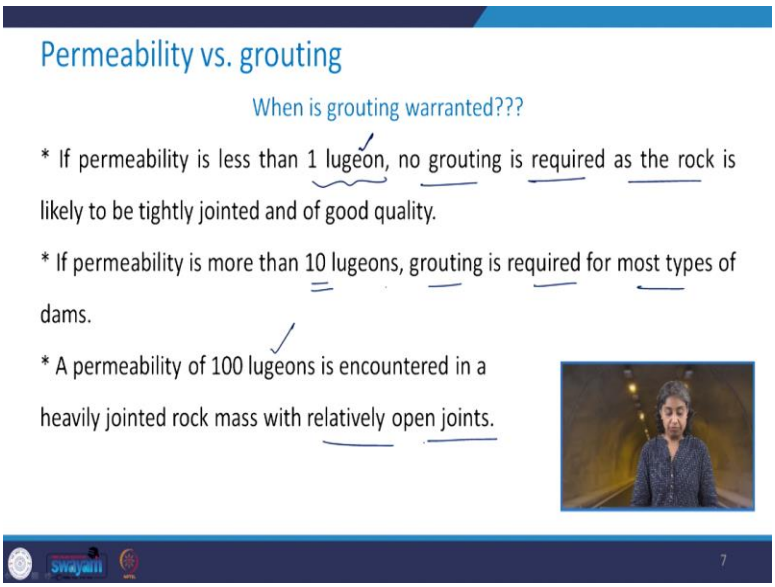

The question is when we say that permeability versus grouting or a big question in front of us is when should we go for grouting? So, the answer here is given with the help of a flowchart which I will be taking up in subsequent slides, but then before that they say that, if the permeability is less than 1 lugeon, then no grouting is required as the rock is likely to be tightly jointed and of good quality.

Now, what exactly is this lugeon, how to determine this we will just learn in a while. If permeability is more than 10 lugeon then grouting is required for most type of the dam in case if the permeability of 100 lugeons is encountered in a heavily jointed rock mass with relatively open joint, so, there one needs to go for grouting.

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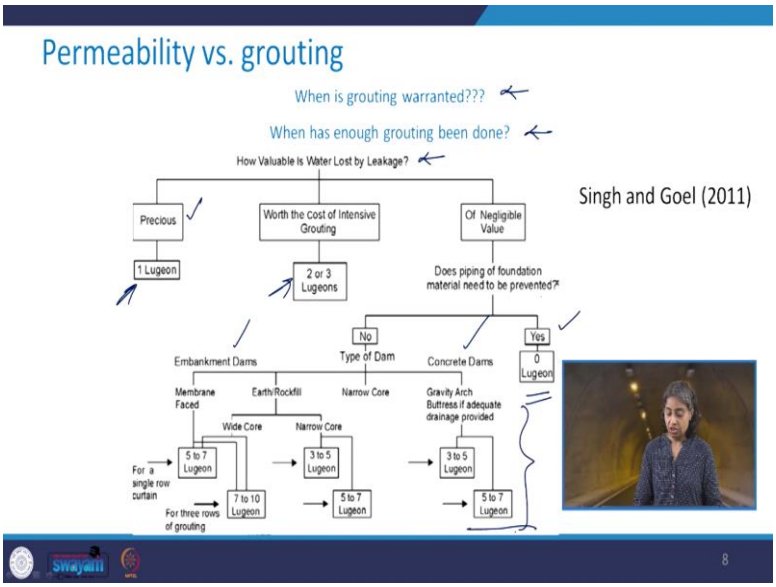

Now, here is the flowchart that I was talking about. So, when you have these two questions that is when is grouting warranted and when has enough grouting been done. So, we come back and take a look here and then decide accordingly. So, it starts from the fact that how valuable is the water which is lost by leakage. If it is precious, then we say that it is one lugeon worth the cost of intensive grouting then it is 2 to 3 lugeons.

And of negligible value, then, again the question comes whether the piping of the foundation material need to be prevented or not. So, if it is yes, then it is 0 lugeon and, if it is no then again, we have to see, what type of dam that one has to construct. So, whether is embankment dam or the concrete dam and likewise the tree goes on up to this particular point.

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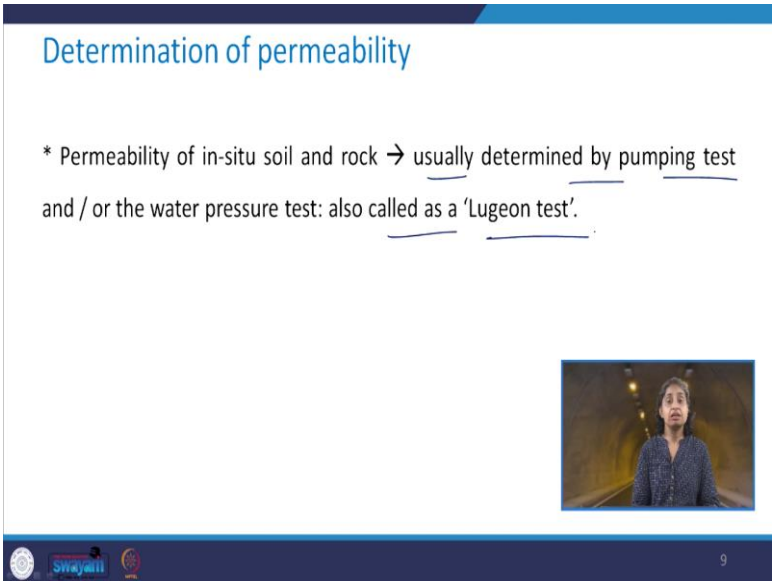

So, the permeability of in-situ soil and rock, these are usually determined by the pumping test and or the water pressure test which is also called as the lugeon test.

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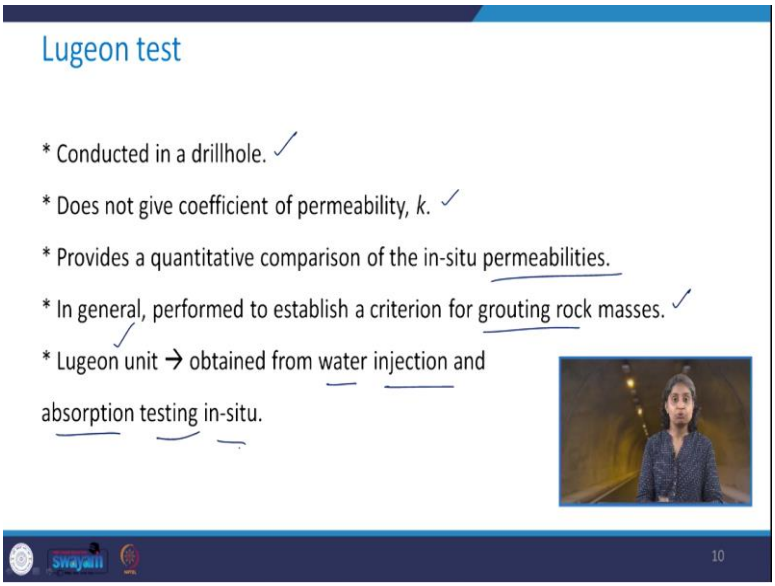

Coming to some aspects related to this test, I will not be discussing in detail, but we will try to give you an overall idea, what this test is all about. So, basically this is conducted in a drill hole it really does not give us the coefficient of permeability. However, it provides a quantitative comparison of the in-situ permeabilities. So, in general these test are performed to establish a criterion for grouting the rock masses.

As I mentioned to you in the previous flowchart that, depending upon its value you will decide whether to grout the rock mass or whether there is a need to grout the rock mass, then

this lugeon unit it is obtained from water injection and absorption testing in situ that is done in the field.

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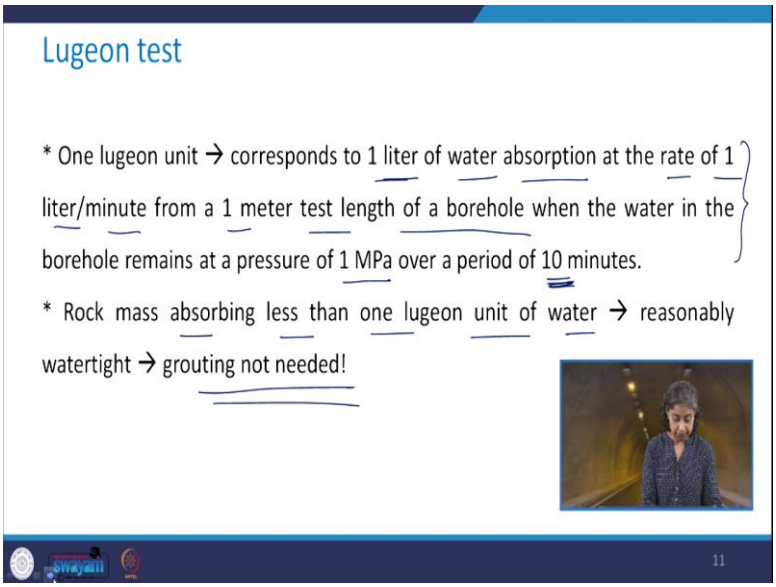

So, what do we mean by one lugeon unit? See, this is a bit long definition, but focus and then, you will realize that, it is very easy to follow. So, one lugeon unit corresponds to one liter of water absorption at a rate of 1 liter per minute from a 1-meter test length of the borehole, when the water in the borehole remains at a pressure of 1 megapascal over a period of 10 minutes.

So, you see everywhere you have one except for this time which is 10 minutes. So, please keep this definition in mind. So, basically this corresponds to one liter of water absorption at some specified rate in specified length or I should say one meter length of the borehole. So, rock mass absorbing less than one lugeon unit of water, can be considered as reasonably water type and therefore, grouting is not needed in such type of situations.

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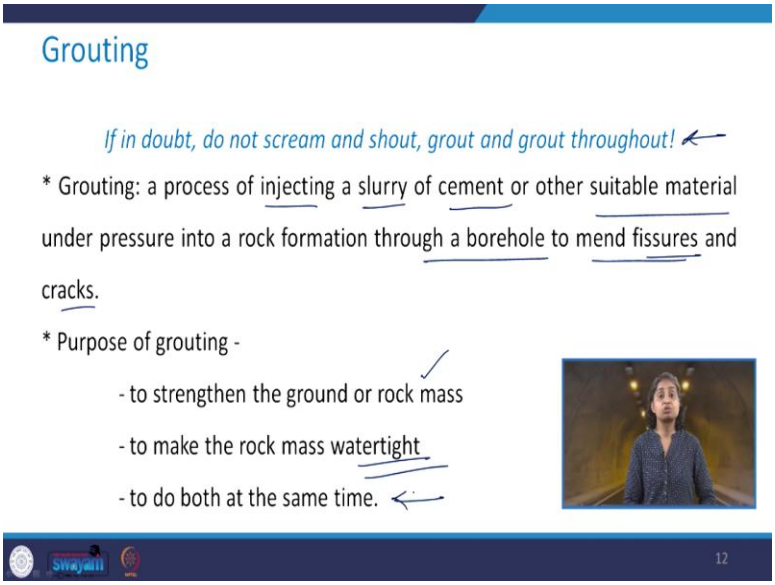

Now coming to grouting. So, we have a very nice saying here that if in doubt do not scream and shout just grout and grout throughout. So, this is used in a very funny manner, but then it has lot of fact in it. So, let us say in case, if you are in doubt whether should we grout this rock mass or not you should not worry, you should not scream or shout. Just go ahead with the grouting. So, what exactly do we mean by this term grouting?

This is a process of injecting a slurry of cement or the other suitable material under pressure into a rock formation through a borehole to mend the fissures and the crack. So, what we need to do is when we go for the grouting first, we need to have the borehole and then we inject this grouting slurry under pressure into that rock formation. Now, what will happen when we inject this slurry under pressure?

This will go in the fissures and the cracks depending upon that what is the permeability of that rock mass and then it is set in those fissures and cracks and thereby it strengthens the ground or the rock mass. So, this is one of the purpose of the grouting is to strengthen the ground or the rock mass. The second one is to make the rock mass watertight or sometimes, both these purpose are fulfilled in some of the applications. So, therefore the third point comes that is, to do both at the same time

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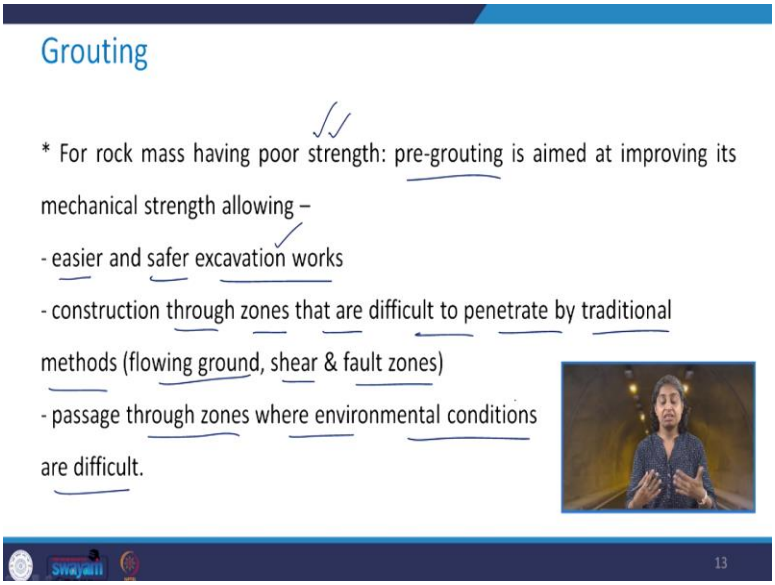

So, for the rock mass having poor strength pre-grouting is aimed at improving its mechanical strength? What do we mean by pre-grouting means is that before the excavation we first grout the rock mass which has the poor strength. So, what happens because of the pre-grouting. So, basically, this allows easier and safer excavation works because, what happens it was having the poor strength.

And upon the pre-grouting it, strength typically enhances and therefore excavation work becomes easier and safer. Construction through zones that are difficult to penetrate by traditional methods such as flowing ground, shear and fault zone. So, there also pre-grouting helps a lot then passage through zones where the environmental conditions are difficult pre-grouting helps in the excavation work.

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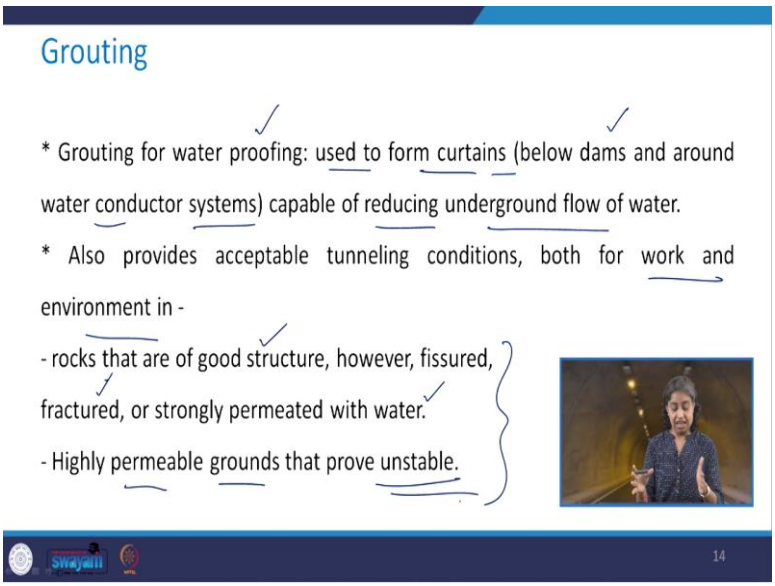

Grouting is done for the water proofing as well. Here it used to form curtains especially below the dams and, around the water conductor systems and these curtains, they are capable of reducing the underground flow of water. This also provides acceptable tunneling conditions both for work and the environment in the rocks which are of good structure, but they are fissured, fractured, or strongly permeated with water and, these are also helpful in highly permeable ground that prove to be unstable.

So, in both the situation it provides the acceptable tunneling condition, for working at the site as well as the environment.

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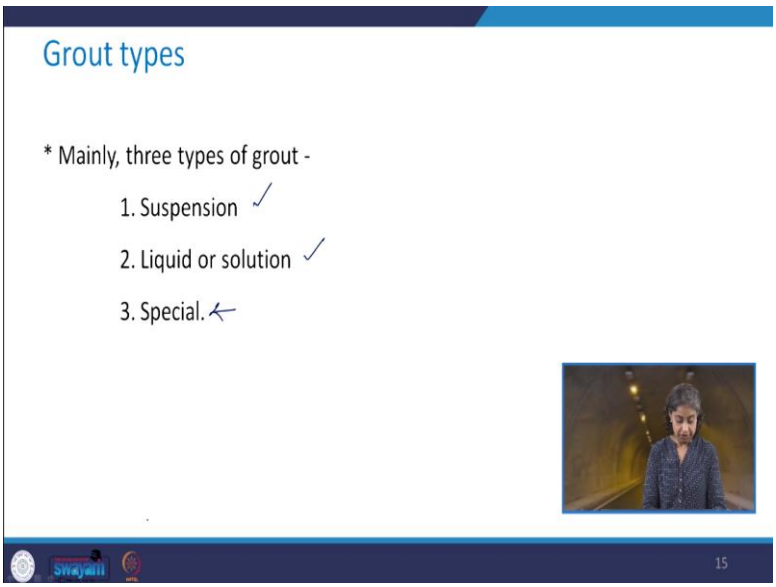

There are mainly three types of grout, which one can adopt depending upon what is the need. The first one is the suspension grout, the second one is liquid or solution, third one is some special type of grout.

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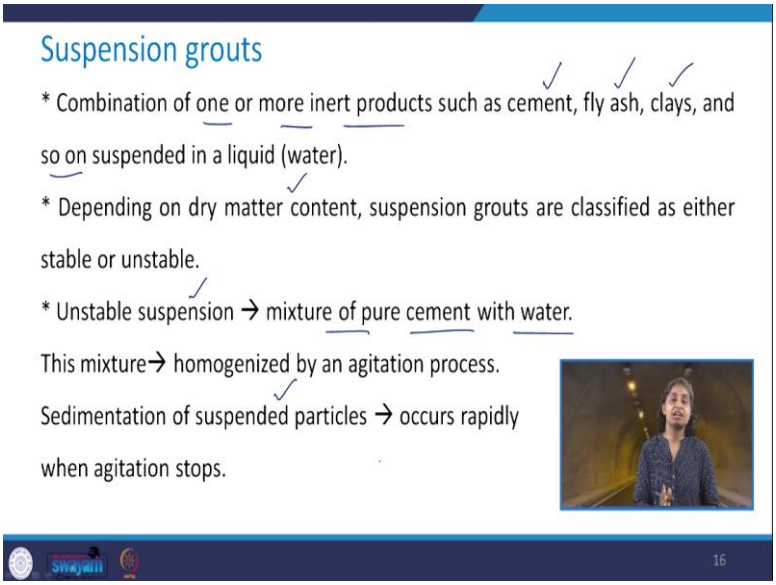

So, let us take a look on the suspension type of grouts. So, it is the combination of one or more inert products such as cement, fly ash, clays and so on which are suspended in the liquid which is water. Now, depending upon the dry matter content suspension grouts are classified as either, stable or unstable. So, when we talk about the unstable suspension this means that, it is the mixture of pure cement with water.

So, what happens that this mixture is homogenized by an agitation process. So, the continuous agitation keeps on happening. The sedimentation of the suspended particles it takes place rapidly as soon as the agitation stops.

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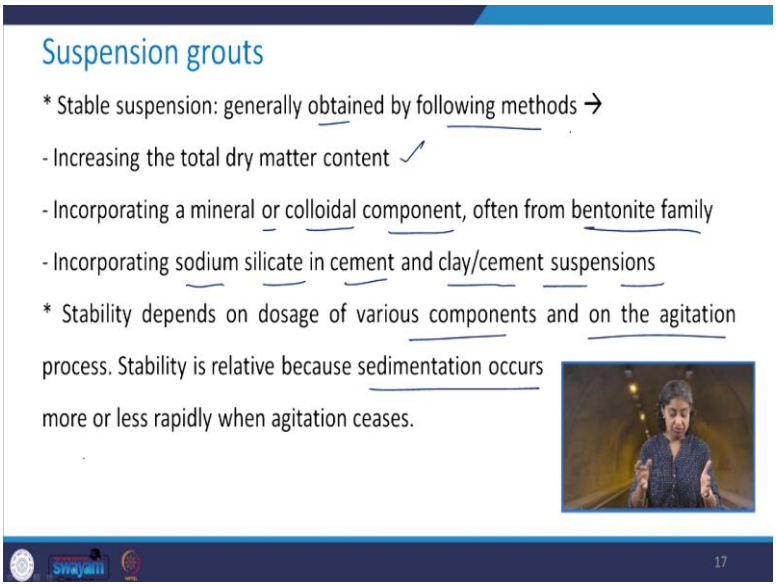

As far as stable suspensions are concerned, these are generally obtained by the following methods. The first one is, by increase in the total dry matter content, by incorporating a

mineral or colloidal component, which is often from the bentonite family, then, we can also achieve these, stable suspension by incorporating sodium silicate in cement and clay or cement suspensions.

This stability will depend upon the dosage of various components and, also on the agitation process. The stability is relative because the sedimentation occurs more or less rapidly when the agitation is stopped. So, again here one needs to be careful that, when we talk about the term stable or unstable and, if we say that it is stable suspension again this term is very relative term.

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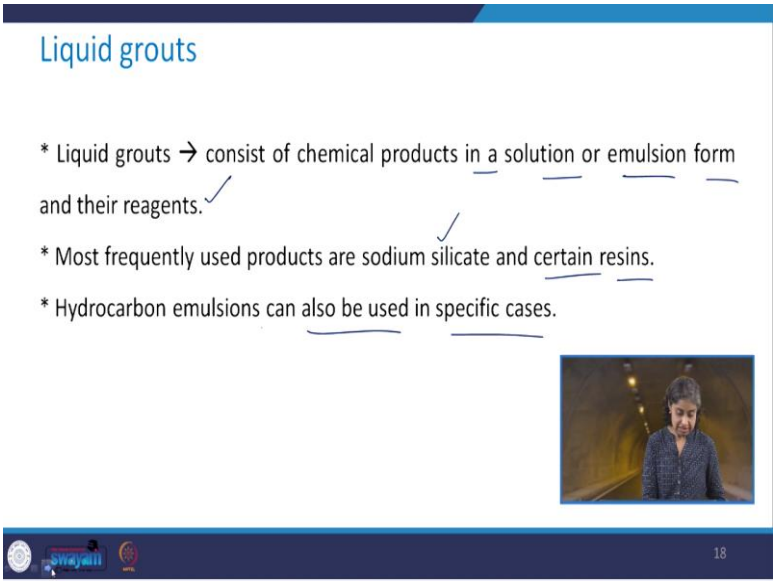

Coming to the liquid grouts. These consist of chemical products in a solution or emulsion form and their reagents. Most frequently used products are sodium silicate, and some resins, hydrocarbon emulsions can also be used in some of the cases as the part of the liquid grout.

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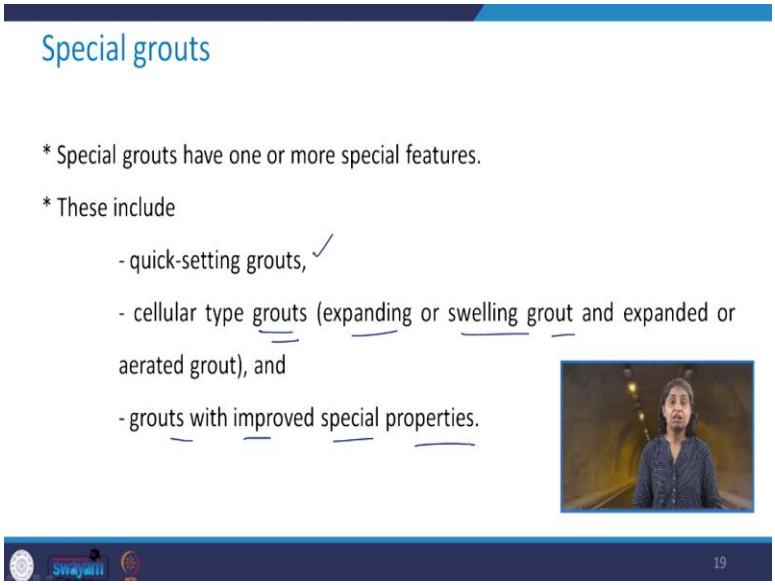

Now, coming to some of the special grouts. So, here these have one or more special features such as quick setting grouts then we have the cellular type grouts. So, what happens in this case these are expanding, or swelling grout, and expanded or aerated grout, and the third one is the grouts with improved special properties.

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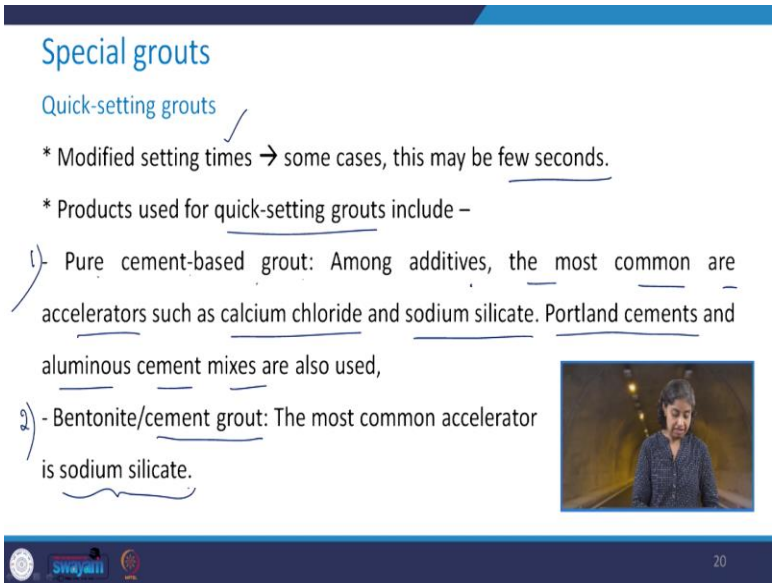

So, let us take a look about the quick setting grouts. So, here these have the modified setting times. In some cases, these maybe few seconds. The products which are used for quick setting grouts these include the number one is pure cement-based grout. So, among additives the most common are accelerators such as calcium chloride and sodium silicate. In this cases, portland cements and aluminous cement mixes are also used.

The second one is the bentonite or cement grout. In this category the most common accelerator is the sodium silicate.

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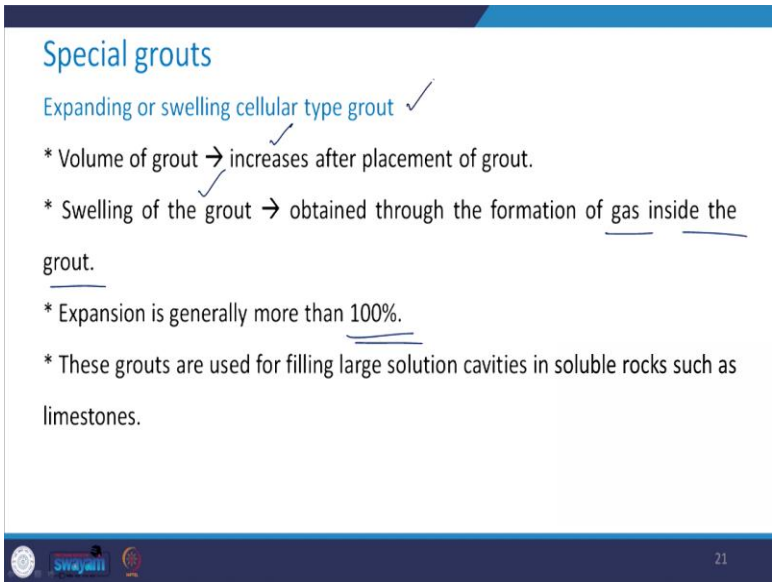

So, coming to the expanding or swelling cellular type grout, the property of such grout is that the volume of the grout increases, when it is placed in the rock mass or when you complete the grouting there is increase in the volume of the grout. So, the swelling of the grout is obtained through the formation of gas inside the grout. Generally, this expansion can be more than 100%.

So, these grouts, are used for filling large solution cavities in soluble rocks such as limestone. So, because after the placement of the grout there is the swelling of the grout or increase in the volume of the grout by the formation of the gas inside the grout and therefore wherever you have the large solution cavities it is helpful to use such type of grouts.

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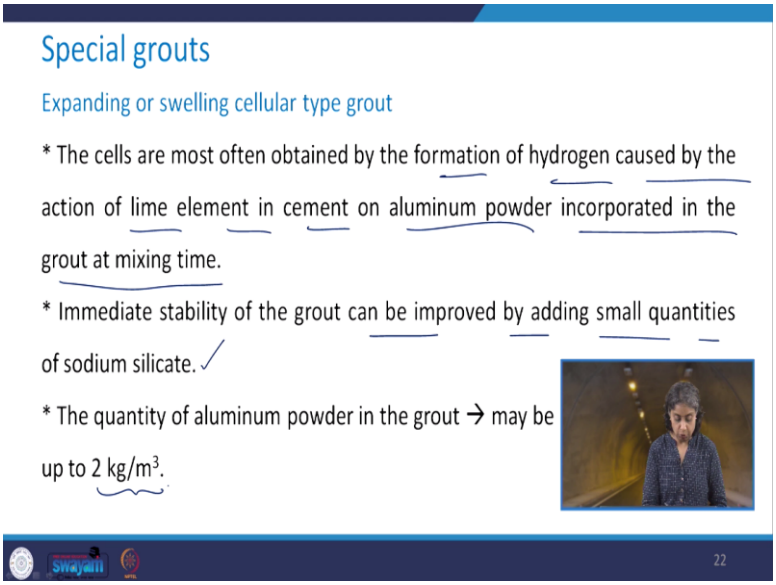

The cells are most often obtained by the formation of hydrogen, which is caused by the action of lime element in cement on aluminum powder incorporated in the grout at the mixing time. The immediate stability of the grout can be improved by adding some small quantities of sodium silicate and the quantity of the aluminum powder in the grout it can be maybe up to 2 kg per meter cube.

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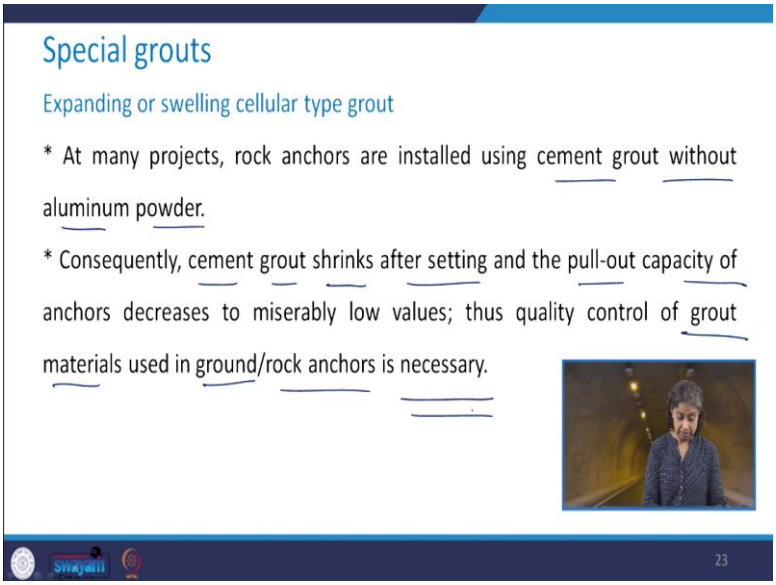

In most projects, rock anchors are installed using cement grout without the aluminum powder. So, consequently what happens is cement grout shrinks after the setting and the pull-out capacity of the anchor it reduces to extremely low values. So, what will happen because of that, the quality control of the grout material therefore, becomes extremely important because if the pull-out capacity of the anchor they reduces to miserably low values then it will not serve the purpose for which it was designed for.

And, hence the quality control of the grout material which are used in ground or rock anchors it becomes necessary.

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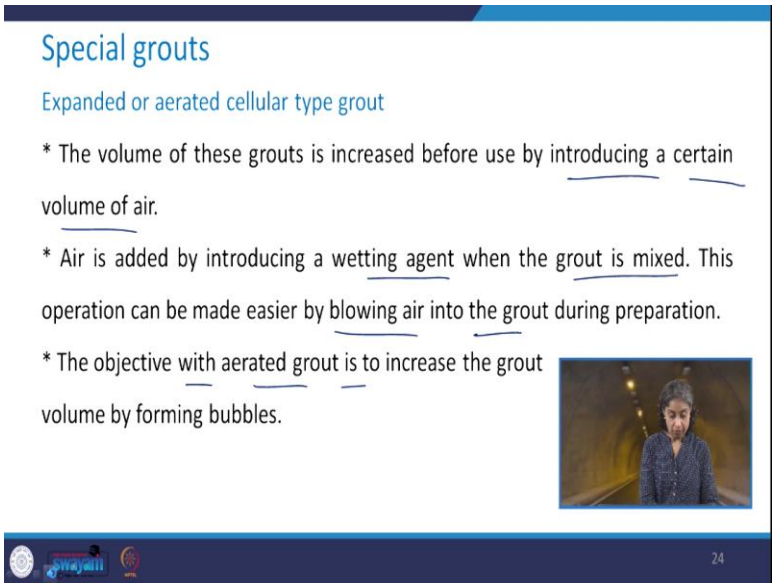

The volume of these grouts is increased before the use by introducing a certain amount of air, certain volume of air. The air is added by introducing a wetting agent when the grout is mixed. So, this operation can be made easier by blowing air into the grout during its preparation itself. So, the objective with the aerated grout is to increase the grout volume by forming the bubbles into it.

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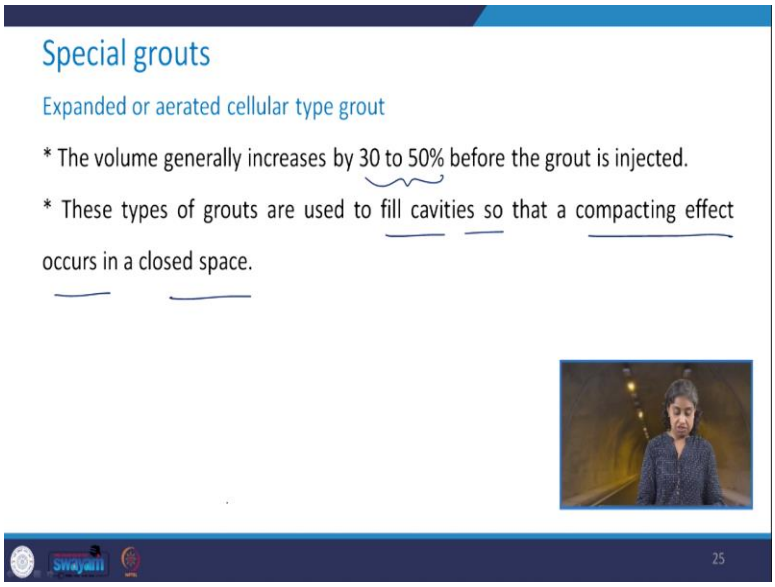

The volume generally increases by 30% to 50% before the grout is injected. These types of grouts are used to fill the cavities, such that the compacting effect occurs in a closed space. So, this was all about some aspects related to different type of grout. So, in the next class we

will continue with this discussion and, we will learn few more aspects related to some special type of grouts and their applications, in case of the rocks and rock masses. Thank you very much.