Underground Space Technology
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Lecture – 52
Shotcrete

Hello everyone, In the previous class we learnt about the various methods of excavation and then we started our discussion on various support system, and, I mentioned to you about the shotcrete, rock bolts, and grouting through rocks and then, we started elaborate discussion on shotcrete and, we were discussing the mix design criteria for shotcrete. So, to continue with that discussion today we will learn about few aspects related to shotcrete, a special focus on admixtures and then we will see that, in what all applications this shotcrete can be sprayed or applied.

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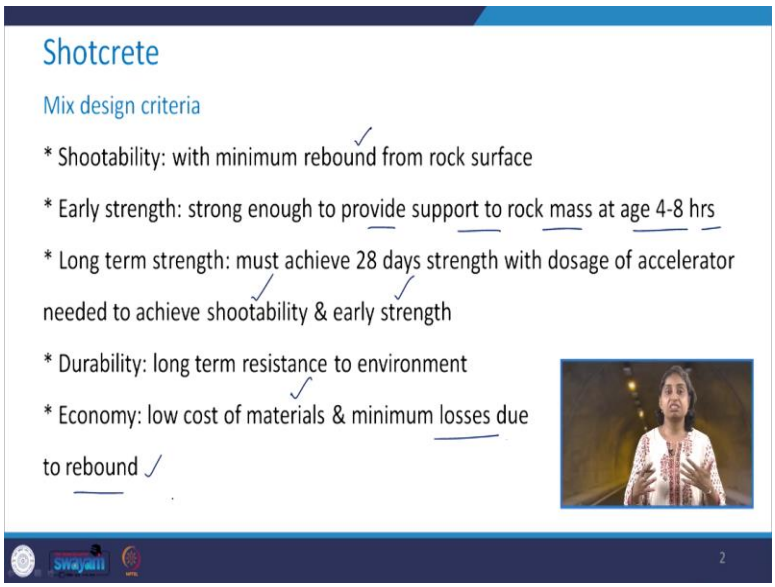

So, as far as the mix design criteria is concerned, the shoot ability is an important aspect with the minimum rebound from the rock surface. If the rebound is more, we will have more loss of the material and less effectiveness of the shotcrete layer. So, therefore the rebound should be minimum. The early strength is also needed, so it should be strong enough to provide the rock mass support at an age of 4 to 8 hours.

As far as the long-term strength is concerned, it should be achieved 28 days strength with the dosage of accelerator which are needed to achieve the shoot ability and the early strength. The durability, it deals with the long-term resistance to the environment, economy there

should be low cost of material, and, minimum losses due to rebound. So, all these factors such as shoot ability, early strength, long-term strength, durability, and economy, one should keep in mind when you go for the design of the mix for the shotcrete.

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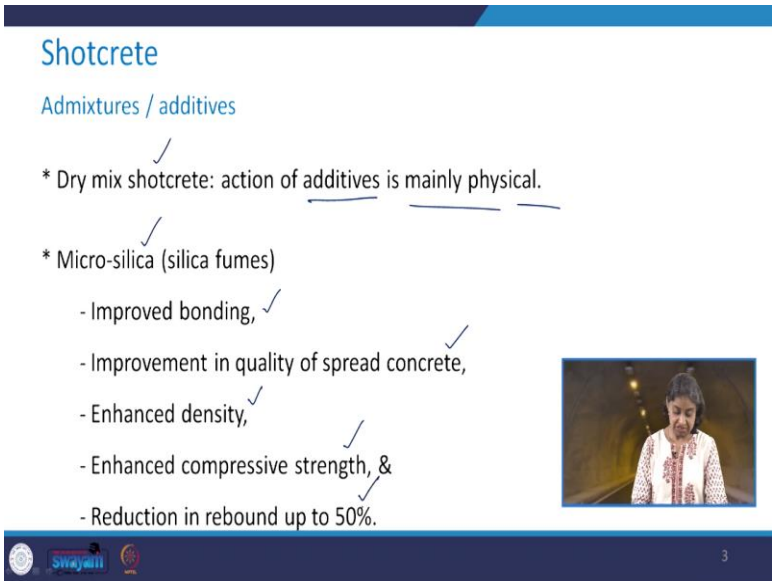

Coming to the admixtures or additives, let us try to learn these in detail that whether they are helpful or any particular type of admixture it has some advantage or disadvantages, let us take a look. So, as far as the dry mix shotcrete is concerned the action of additives is mainly the physical one. So, in case of the micro silica which we also call as silica fumes. If we use these help in improving the bonding and the quality of sprayed concrete.

This results in the enhanced density and the compressive strength of the shotcrete layer and also reduces the rebound as high as up to 50%.

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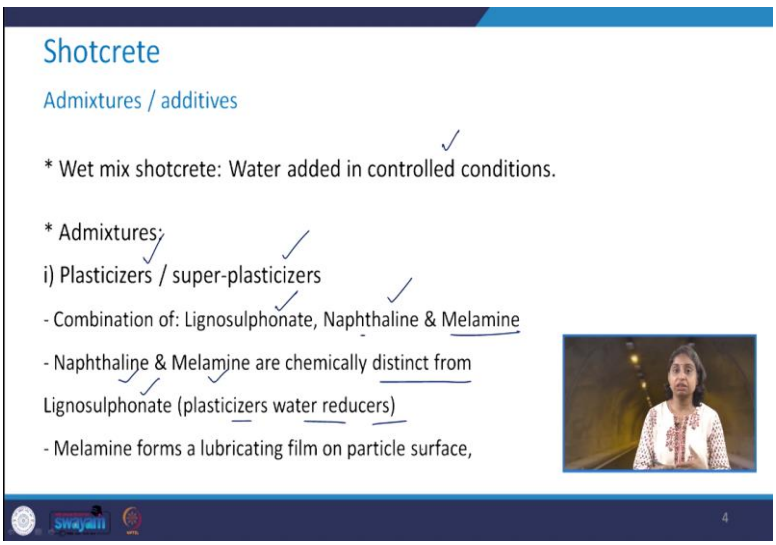

For wet mix shotcrete, the water is added in the controlled conditions. So, the admixtures which are used there are few in the list. So, the first one is the plasticizers or superplasticizers. These are the combination of Lignosulphonate, naphthalene, and melamine. Naphthalene and melamine, they are chemically distinct from the lignosulphonate, which is the plasticizer- water reducers. Melamine, what does is it forms a lubricating film on the particle surface.

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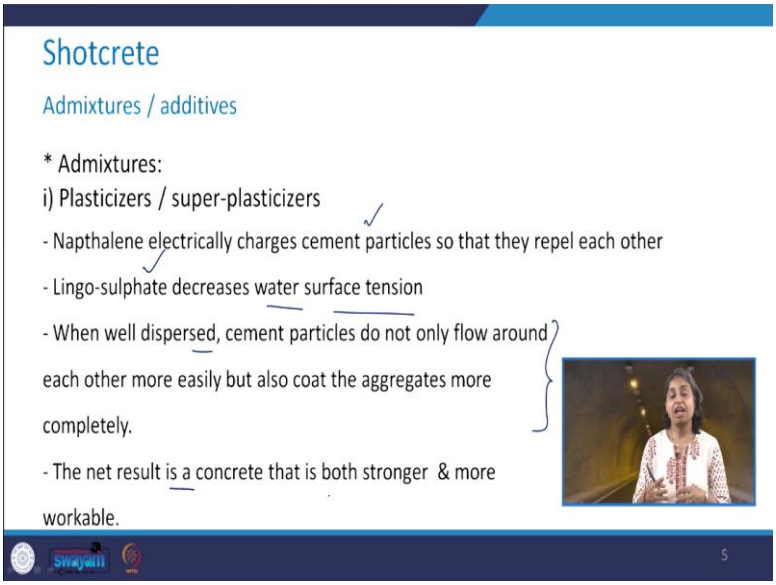

And, naphthalene electrically charges the cement particles so that they repel each other. So, what happens in that case maybe when these are well dispersed? These cement particles they do not only flow around each other more easily but, also coat the aggregates more completely. The presence of the lignosulphonate, it reduces the water surface tension and therefore this particular phenomenon happens.

The net result of adding these plasticizers or superplasticizers is the concrete, which is, more stronger and workable.

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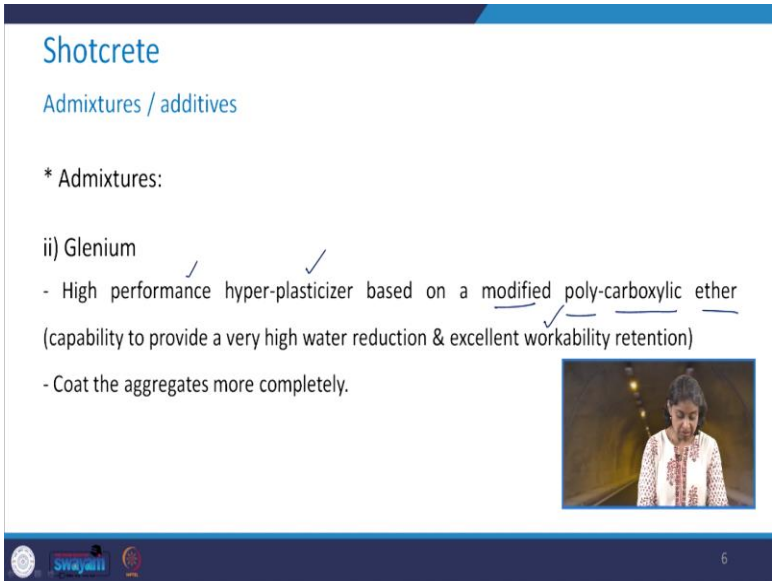

Second category is glenium. These are also called as, high-performance hyper-plasticizer, which are based on modified polycarboxylic ether which has the capability to provide a very high-water reduction and excellent workability retention. These coats the aggregates more completely as compared to the plasticizers or superplasticizers

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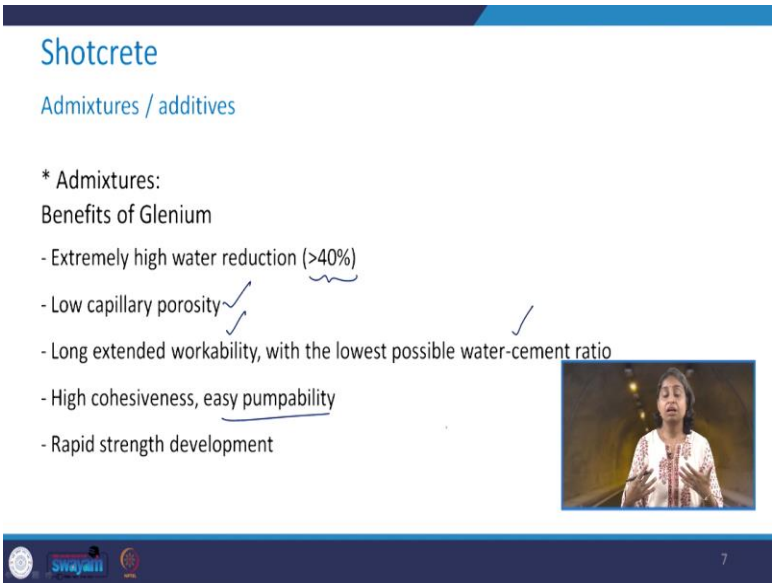

What are the benefits of glenium? some of these include that these are extremely high-water reduction, I mean it is to the tune of more than 40%, if you use these it results into low capillary porosity. They have long-extended workability with the lowest possible water-cement ratio. They are highly cohesive. So, the cohesiveness is very high and it results into, the easy pumpability and there is the rapid strength development with the use of glenium.

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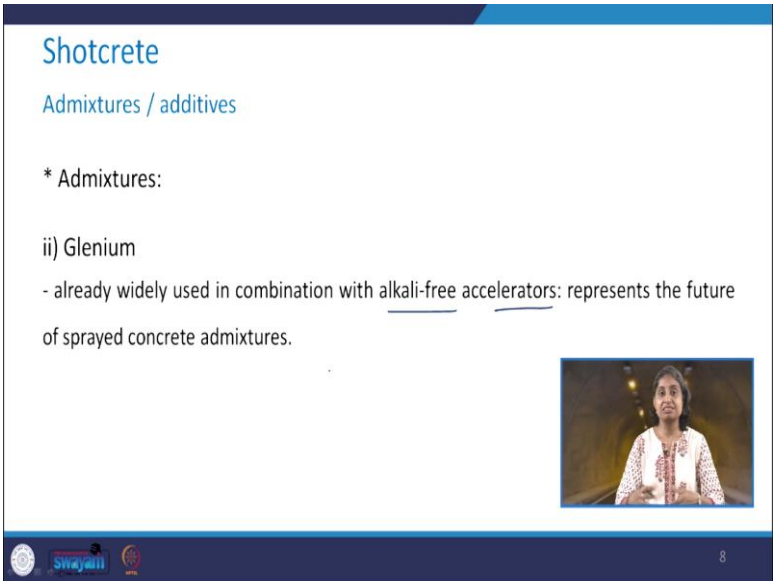

These are already widely used in combination with alkali-free accelerators. These represent the future of sprayed concrete admixtures. So, basically these days it is used quite often.

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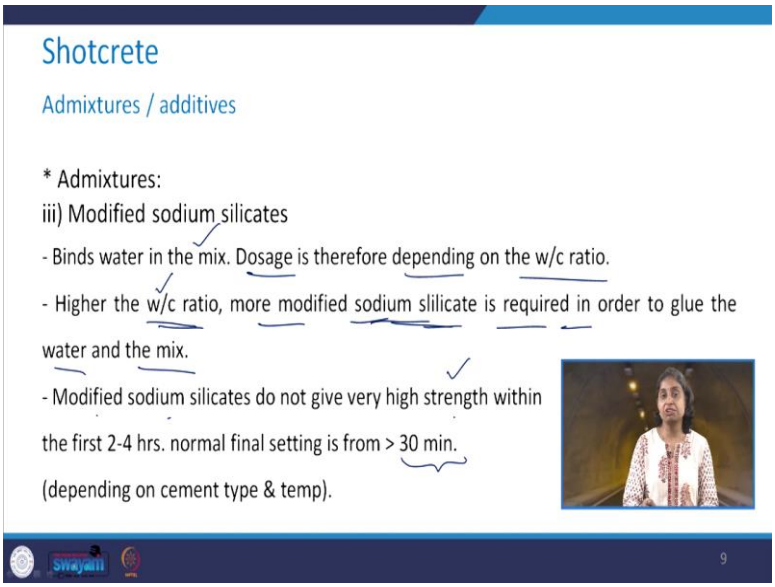

The third category is the modified sodium silicates. These binds the water in the mix. Therefore, the dosage depends on the water-cement ratio, higher the water-cement ratio more modified sodium silicate is required in order to glue the water and the mix. So, keep this in mind that if we have the higher water-cement ratio more modified sodium silicate would be required.

Now, modified sodium silicates, these do not give very high strength within the first two to four hours and their normal final setting time is like more than 30 minutes. Again, that also depends upon the type of the cement, which is being used and also the temperature.

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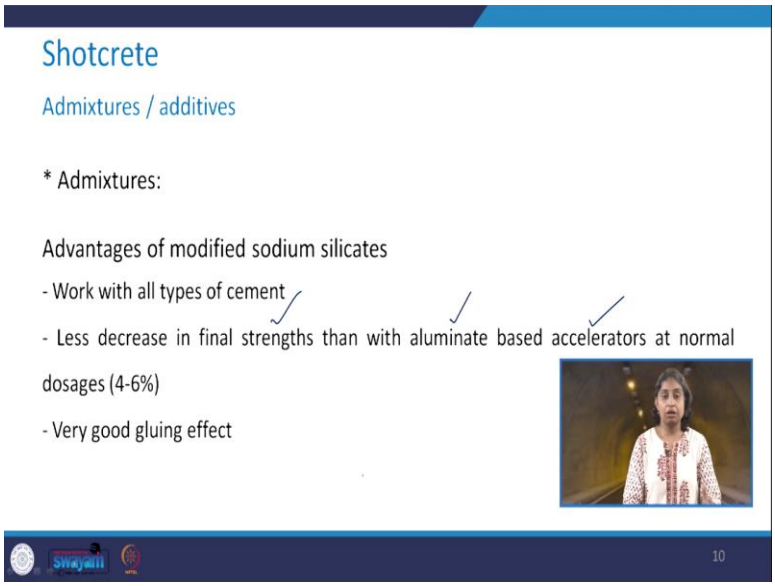

Advantages of modified sodium silicates, these include that it works well with almost all types of cement. There is less reduction in the final strength than with respect to aluminate-based accelerators at normal dosage, which are 4% to 6% by weight. So, the next one that we will take is the aluminate-based accelerators. So, I am just right now comparing the aluminate-based accelerators with those of the sodium silicates.

So, here there is a less decrease in the final strength as compared to aluminate-based accelerators at normal dosage. These have very good gluing effect.

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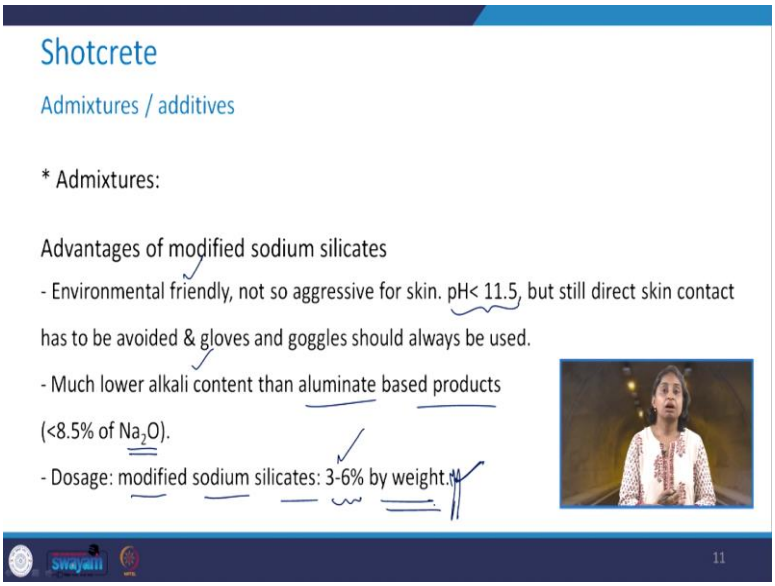

Further, these are environmental friendly and they are not very aggressive for human skin, their pH is less than 11.5, but still, the direct skin contact should be avoided and the use of

gloves and goggles is always recommended, when such type of admixtures, they are used in the shotcrete. So, they have much lower alkali content as compared to the aluminate-based products that it is having less than 8.5% of Na_2O.

The dosage for the modified sodium silicate, it is 3% to 6% by weight. Please remember these things because it is extremely important 3% to 6% by weight of the modified sodium silicates is recommended to be added to the shotcrete to arrive at or to derive the maximum advantage of the modified sodium silicates.

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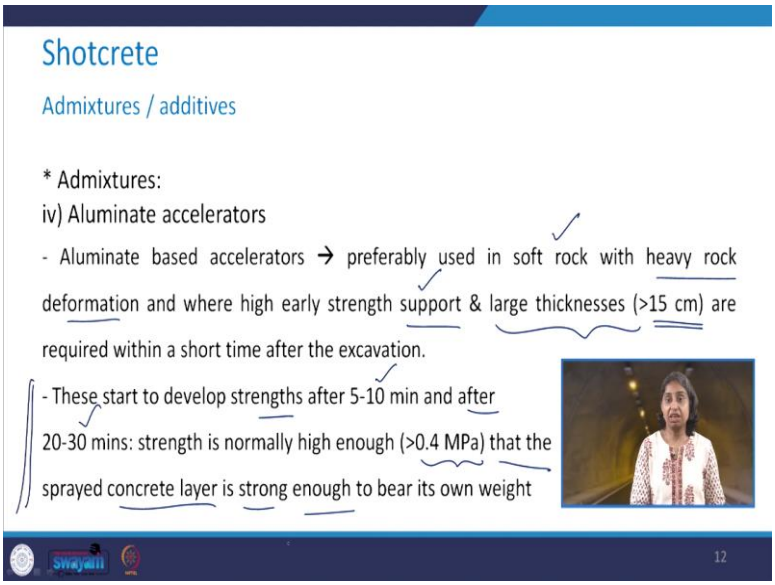

Then, coming to the next category which is the aluminate accelerators. So, the aluminate-based accelerators, these are preferably used in the soft rock with heavy rock deformations and, where high early strength support is needed and the large thicknesses which is more than 150 millimeter or 15 centimeters is required within the short span of time after the excavation. So, these start to develop strength after 5 to 10 minutes of their application on the rock mass surface.

And, after about 20 minutes to 30 minutes, the strength is reasonably high enough to the tune of maybe more than 0.4 megapascals, that the sprayed concrete layer is strong enough to bear its own weight. So, these are some of the significant features of aluminate accelerators.

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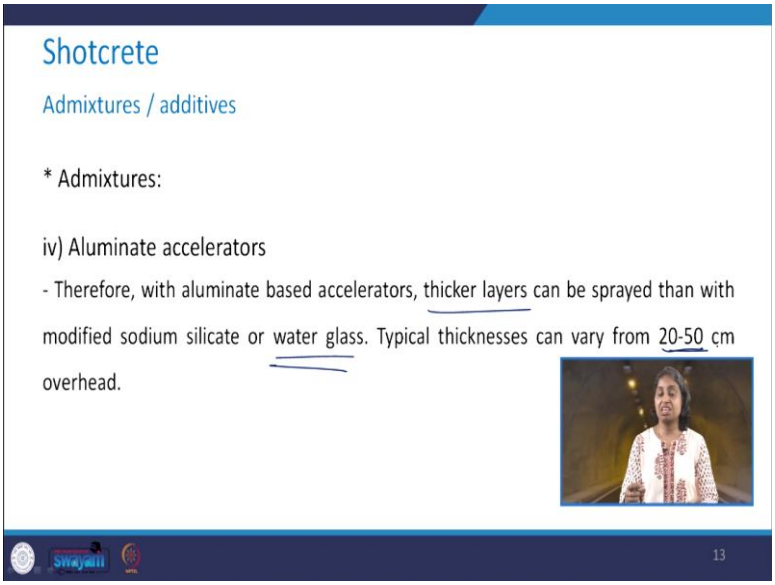

And, because these have these special properties and, therefore one can go for the spray of thicker layers as compared to the case of modified sodium silicate or the water glass. So, here in this case the typical thickness can vary from 20 to 50 centimeters or 200 to 500 millimeter overhead. So, here in case, if the requirement of the support system, that you need larger thickness of the shotcrete then rather than going for the modified sodium silicate one should go for aluminate-based accelerators.

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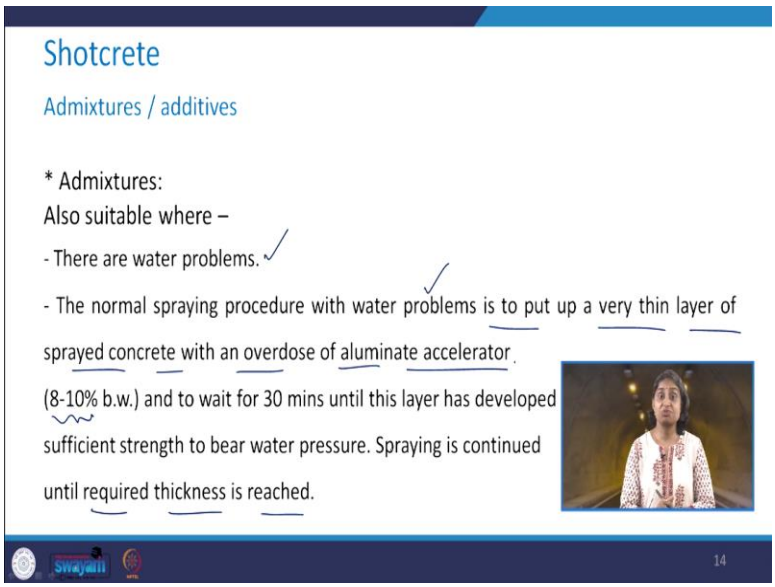

These are also suitable where there are water problems. The normal spraying procedure with water problems is to put up a very thin layer of sprayed concrete with an overdose of aluminate accelerator which can be, 8% to 10% by weight, and then to wait for about 30 minutes until this thin layer has developed sufficient strength to bear the water pressure and then, maybe the spraying can be continued until the required thickness is achieved.

So, basically, wherever you have the water problem so first, you apply a very thin layer of sprayed concrete with an overdose of aluminate accelerator because it sets quickly, so then you can wait for 30 minutes so that, this layer develops sufficient strength and then maybe the spraying can be continued until the required thickness which has been designed earlier is arrived at.

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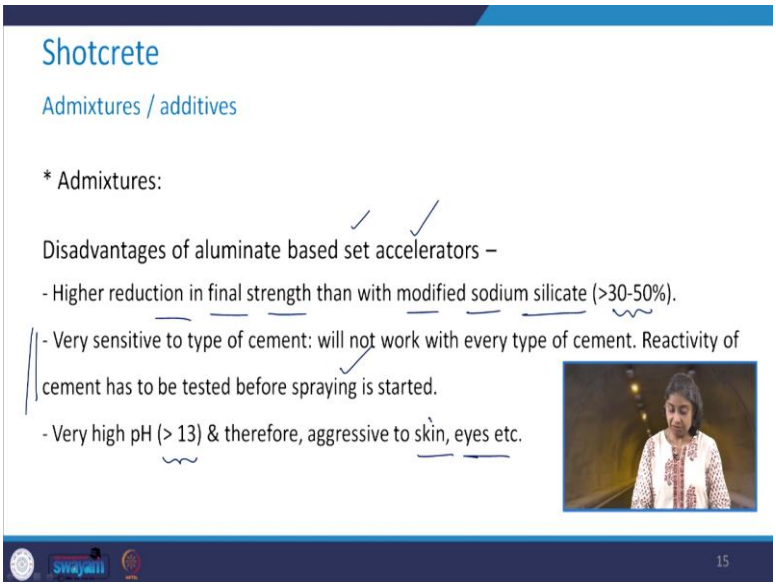

So, basically, wherever you have the water problem so first, you apply a very thin layer of sprayed concrete with an overdose of aluminate accelerator because it sets quickly, so then you can wait for 30 minutes so that, this layer develops sufficient strength and then maybe the spraying can be continued until the required thickness which has been designed earlier is arrived at.

As these will not work with every type of cement, which was not the case for the modified sodium silicates. The reactivity of the cement should be tested before the spraying is started. So, we have to be careful while we use the aluminate-based set accelerator in view of this aspect. These have very high pH maybe to the tune of more than 13 and hence these may be aggressive to skin and eyes.

So, as against the modified sodium silicates where pH was of the order of 11 or so, here it is much larger more than 13. So, one needs to be careful, as these are aggressive to skin and eyes.

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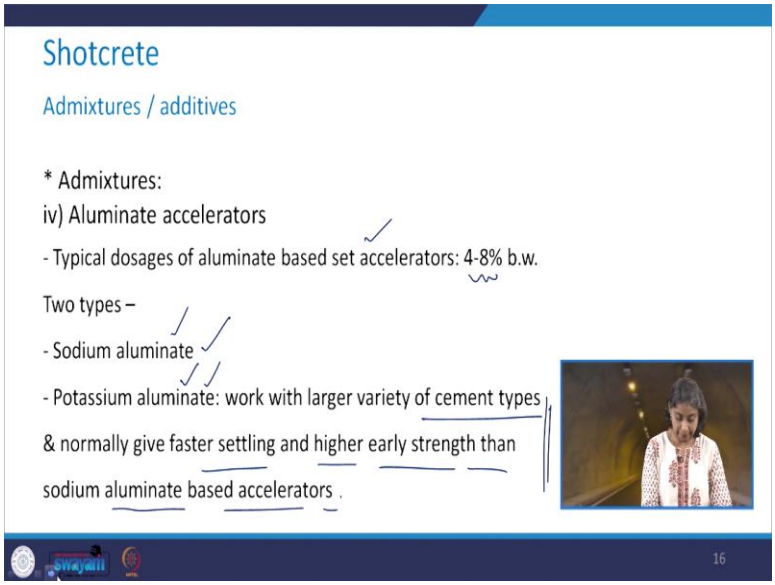

Typical dosage is 4% to 8% by weight for the aluminate-based set accelerators. There are two types of aluminate accelerators. One is sodium aluminate, another one is the, potassium aluminate. This potassium aluminate, it work with the larger variety of the cement types and normally gives faster settling and higher early strength as compared to sodium aluminate-based accelerators then we compare sodium aluminate and the potassium aluminate. A potassium aluminate has the advantage in view of these points.

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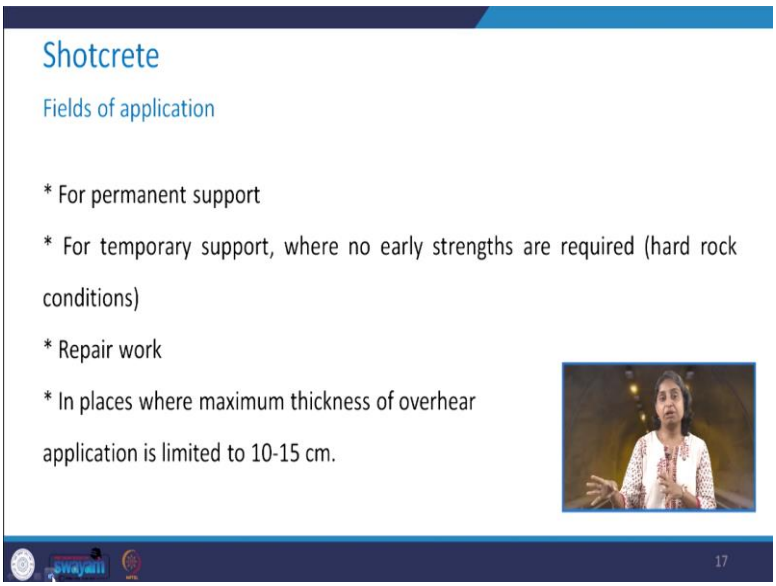

Now, as far as the fields of application of shotcrete is concerned these can be used for the permanent support and also for the temporary support, where you do not need to have the early strength, or maybe in the case of hard rock conditions. Sometimes, these are used for the repair work and the application of the shotcrete layer is limited to the places where the maximum thickness is limited to 10 to 15 centimeters, that means 100 to 150 millimeters.

So, in case, if the requirement is more than this then maybe you need to go for the combination of steel sets and the shotcrete or rock bolt and the shotcrete. So, this is all about the shotcrete support system. We have the other type of the support system such as rock bolts, plus the rock mass can also be improved with the help of grouting. So, we will take up the concepts related to rock bolts, such as, what all are their types.

What are their advantages, disadvantages, in what situation that these can be used, in the next class. Thank you very much.