

Rapid-Setting Cement in Shotcrete

By Mike Ballou

Evolving technology in the shotcrete industry using a rapid-setting mixture with calcium sulfoaluminate (CSA) cement in lieu of a more common portland cement mixture is helping to meet the challenges for shotcrete repairs and underground projects throughout the world.

Repairs performed with ordinary portland cement (OPC) concrete mixtures can take up to 28 days before they reach design strength. This can slow down projects and cycle time for mining and tunneling. Shotcrete using rapid-setting CSA cement can reach full design strength in only a few hours. In about 15 minutes—without any accelerator—dry-mix shotcrete commonly reaches strengths of 2200 psi (15 MPa); in an hour, the strengths can be close to 3600 psi (25 MPa).

What Makes It Different and How Does It Work?

First of all, CSA cement is not a new product—it has been around for years and is manufactured in a way similar to OPC. Most of the same raw materials or ingredients are used to make rapid-setting cement, such as limestone, clay, gypsum, silica, and alumina. The materials are mixed, the clinker is made, and the clinker is ground to fine powder—much like OPC. The hydration or chemical reaction is similar, but the reaction time with the CSA cement is much quicker.



Fig. 1: Shotcrete repair on bridge abutment using low-permeability, rapid-setting cement

Where Do You Use It and Why? Time Savings

I won't get into the "time is money" clichés, but we all know that the more effective we are with our work force, the better. Time spent watching over concrete/shotcrete while it cures is a thing we've grown accustomed to but have never accepted—we've just dealt with it.

So, if we have a cement that cures in about an eighth of the time that OPC cures—and if we don't need to stand over it for hours, days, or weeks keeping it wet so that it won't develop shrinkage cracks—well, perhaps that's something we ought to consider for some applications. Oh, sure, you still need to cure it, and water curing is good for that, but it doesn't take nearly as long. Rapid-setting shotcrete, if care is used in placing, needs only a few hours of water curing. You can do it longer than that, but the hydration process or the chemical reaction is completed. The water helps to cool the hydrating CSA cement but is not a critical factor like it is for OPC shotcrete.¹

Strength and Durability

There's been a lot of very intensive testing done to show how well rapid-setting shotcrete gains strength and holds it in compressive tests. The results are incredible—3600 psi (25 MPa) in an hour, easily—without any accelerator. Shotcrete accelerators can promote cracking due to early-age plastic shrinkage and should be avoided if possible unless used with care.¹ Rapid-setting cement is not only strong in compression but also very durable. It has been used with steel fibers and several types of



Fig. 2: Screeding new rapid-setting, low-permeability shotcrete

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macrosynthetic fibers in shotcrete; the result is a shotcrete that is really tough and durable that provides great abrasion resistance in areas where a lot of scraping and gnashing of shotcrete surfaces occur, such as in the grizzly screener, vertical shafts, and horizontal transport drifts in mines.

Is It Easy on the Environment? Green Technology

Rapid-setting cement is considered a sustainable (green) product, as it is manufactured at a fraction of the temperature that is used in kilns to make OPC. The result? Fewer hot gases and CO₂ into the atmosphere. We can do our part to help save the planet for future generations—pretty simple.

Will It Work in Dry-Mix Shotcrete?

It works **really** well in dry-mix shotcrete and is being used to line hundreds of sewer pipes and drainage culverts throughout the United States. It's been used in underground mines for years and continues to gain favor in the mining industry.

How About Wet-Mix Shotcrete?

Whoa—hang on a minute. This stuff sets up really fast, my friend. Don't think that you are going to mix it and pump it and 10 minutes later pump it through a typical wet-mix machine. That is not advisable. You could get rapid-setting concrete into your shotcrete hoses that will set up in that length of time and cause major problems. The only practical method for placing wet-mix shotcrete is if a mobile mixer or a "dry-to-wet" system is used. These work great and are standard in some mines in Australia. If the wet-mix shotcrete goes straight from the mixer to the pump, things work out well; however, use too much hose with a longer transport time to the nozzle and problems ensue.

Mixture Design

Apart from not needing any shotcrete accelerators, rapid-setting shotcrete is much the same as OPC-based shotcrete. The main difference is the pot life. Even with retarders, rapid-setting shotcrete starts to harden quickly. If extra time is needed to finish or screed off rapid-setting shotcrete, it must be done soon after it is shot.

Winter Work

Because rapid-setting shotcrete reacts so quickly, the chemical reaction of hydration gives off a lot of heat in the **beginning** of the curing cycle.

This heat helps the shotcrete sustain a high enough temperature to cure without the need for hot water. Although the hydration process does not take place if it is too cold—say, below 40°F (5°C) as per ACI 306R-10²—work can be done in cool weather without worrying about protecting the top layer of shotcrete from freezing during the hydration process. Spray in the day and it's cured out before night, when the colder temperatures freeze OPC-based shotcrete because of the high water content.

Conclusions

CSA shotcrete is a very good choice for many types and applications for shotcrete, including areas that need special attention where abrasion is an issue and shaft liners, grizzlies, hoppers, chutes, open drifts, and stopes where there is a lot of equipment traffic. Only operators and nozzlemen who have been trained and are experienced with rapid-setting shotcrete should be permitted to place it, especially in underground conditions. Once the hydration reaction starts, there is not much time to get it through the equipment. Equipment does not need to be modified to use the rapid-setting shotcrete, but it needs to be cleaned and maintained properly before and after the use of rapid-setting shotcrete—and straight away. Rapid-setting shotcrete will gain a good deal of its final strength in the first 8 hours. Postponing the cleaning of equipment and tools can result in a great deal of extra effort if the shotcrete is allowed to harden; however, it's fine if it is cleaned within a few hours. As with any product that is new to us, it's best to find out how it works on the surface before using it underground in mines and tunnels.

References

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2. ACI Committee 306, "Guide to Cold Weather Concreting (ACI 306R-10)," American Concrete Institute, Farmington Hills, MI, 2010, 26 pp.



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