Shotcrete Accelerators for Wet-Mix

By Dan Millette and Marc Jolin

Unlike traditional concrete accelerators, shotcrete accelerators are not added to the mixture during batching, but rather introduced to the mixture at the nozzle in wet-mix shotcrete application. Dry-mix will sometimes have a powdered accelerator incorporated into the mixture that begins to react as soon as the water is added at the nozzle. These accelerators can provide fast setting or stiffening of the mixture, early-age strength development, the capability to attain increased layer thickness, improved overhead spraying performance, and reduced sagging, all resulting in a higher productivity.

Shotcrete accelerators work on the C_3A (tricalcium aluminate) fraction of the cement, influencing the rate of hydration, resulting in heat evolution and early-age formation of calcium silicate hydrate (C-S-H) gel (Fig. 1). There are two main types of accelerators used in wet-mix in North America. The first type of accelerator that we will look at is sodium silicate-based accelerator (water, glass, and modified silicates). These have been around a long time and are still being used in many applications. They work very quickly and allow the material to build well.

A sodium-silicate-type accelerator actually gels the water in the mixture to increase cohesion within the mixture as well as decrease the set time of the cement. Sodium silicate-based accelerators have a high alkali content and can be quite caustic, as the pH is above 11. Although these accelerators will display fast stiffening of the mixture, they can significantly decrease the final or 28-day strength of the mixture—up to a 50% reduction. Even a dosage of 5% by weight of cement has been known to decrease ultimate strength by as much as 25%. Durability can also be considerably reduced. Sodium silicate can also decrease waterproofing characteristics because of the leaching of lime when the concrete is subjected to continuous moisture. One other, potentially negative, effect is that these accelerators increase the risk of alkali-silica reaction (ASR) and leaching of water-soluble portions.

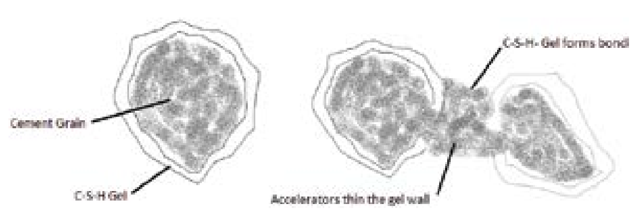

Fig. 1: C-S-H gel at work

Sodium silicates are relatively low in cost, so they are popular in instances where shotcrete is needed to attain a quick stiffening and then gain some early strength rather quickly. They are not recommended for permanent exposed shotcrete. Because of the high alkalinity of this type of accelerator and the high alkalinity of the shotcrete mixture, the mist that blows back from spraying the mixture can burn skin and eyes, so adequate protection must be used.

The second type of wet-mix accelerator is an aluminum-sulfate- or aluminum-hydroxide-based product that is commonly called alkali-free. These are often combined with various amines to boost their effectiveness. These accelerators are a little more sensitive than sodium silicates to several environmental and material conditions and do not always give as fast a stiffening effect, but they also do not have quite as severe a detrimental effect on 28-day strength when used at lower dosages. But even with these accelerators, a dosage of 10% by weight of cement can give up to a 25% reduction in 28-day strengths. Most modern-day specifications where accelerators are required insist on alkali-free accelerators only, as alkali-free accelerators do not have any effect on ASR.

Most alkali-free accelerators range from pH 2 to 3, which is fairly acidic. When spraying these, the acidity is tempered by the alkalinity of the concrete mixture so it is not as great a hazard to skin and eyes. But these accelerators are also very corrosive. Storage tanks for alkali-free accelerators must be either plastic or stainless steel—never store these accelerators in mild steel tanks or they can produce an explosive hydrogen gas.

Alkali-free accelerators are made by two different processes. The older, more common method is to dissolve solid flakes into a fluid using high-shear mixing. This produces a high-viscosity product much like the consistency of thick syrup. The solids tend to segregate out during storage so accelerators made from solids require fairly continuous agitation. This manufacturing method also uses a higher content of solids, making the accelerator slightly more reactive than the lower-viscosity materials.

The lower-viscosity alkali-free accelerators are made with liquid chemicals that do not require high-shear mixing and are usually closer to the consistency of water. Although these are slightly lower in solids contents, they do not segregate at all and are often said to better blend into the concrete mixture at the nozzle due to the lower viscosity, and often being as effective as the higher-viscosity products.

To get the optimum performance from any type of accelerator, it is very important to keep temperatures at a reasonable level. Ideally, concrete temperature should be between 70 and 80°F (21 and 27°C) to attain the optimum accelerator reaction. A 20°F (11°C) decrease in concrete temperature will roughly double the reaction time and conversely, a 20°F (11°C) increase will half it.

But you also need to keep the accelerator temperature at an appropriate level. It should be above 60°F (15°C) and preferably above 70°F (21°C). If the accelerator is too cold, it will not work nearly as well. Another problem with most accelerators is that when they are cold, they become more viscous, which makes it even more difficult to get it mix evenly into the stream of concrete at the nozzle.

When using accelerator in wet-mix shotcrete, make sure to use a proper dosing pump. Do not use a diaphragm pump. A diaphragm pump sends slugs of accelerator to the nozzle and if it is out of sync with the concrete pump you will get varying degrees of hard and soft shotcrete mixture on the sprayed surface.

Use a positive displacement pump such as a peristaltic or rotor-stator pump (Fig. 2 and 3). Make sure that the pump pressure is 10 to 15 psi (0.07 to 0.10 MPa) higher than the air pressure to the wet-mix nozzle or the air can keep the accelerator from getting into the air stream. Control the accelerator dosage with the pump. The pump should have a variable speed drive; and use that to control the flow. These pumps should all have stainless steel fittings due to the corrosivity of alkali-free accelerators.

Fig. 2: Peristaltic accelerator pump

Fig. 3: Rotor-stator accelerator pump

There are all sorts of wet-mix nozzles on the market and everyone has their preference. Some nozzles have a connection for the accelerator on one side of the nozzle and the air connection on the other side. Some have only one inlet to the nozzle that is split into two. The type of nozzle shown tends to mix the accelerator into the concrete better than the ones with separate inlets. Better yet is to pump the accelerator into the air stream a few feet back from the nozzle, don't use a regulating valve for the accelerator. Simply an on-off valve allows for control of the accelerator with the pump (Fig. 4).

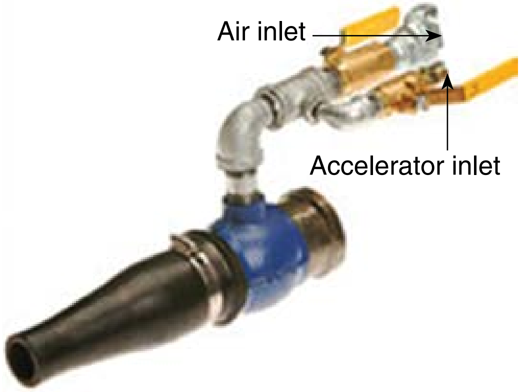

Fig. 4: Acme nozzle with accelerator port

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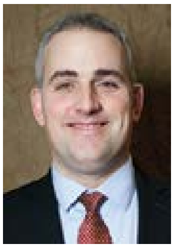

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