Changing the Traditional Shotcrete Mixture to Suit Underground Applications

By Dan Millette

Concrete mixtures used in the shotcreting process have traditionally been low-slump mixtures. Low-slump mixtures are fine when transport distances are short, but in the current tunneling industry, longer pumping distances are often a requirement. The mining industry also often requires long vertical drops to get the mixture where it needs to be. In these situations, low-slump mixtures can cause plugging and higher pump and hose wear and cost the contractor or owner a lot of time and expense in dealing with these issues.

Over the last few years, it has become more common to use a highly flowable mixture in shotcreting applications. Self-consolidating concrete (SCC) has been developed to enhance pumping applications and better encase the heavy reinforcing steel often found in many of today's modern structures. With its high flowability, SCC is being adapted for use in shotcreting applications. When testing the flowability of SCC, a slump-flow test, as defined in ASTM C1611/C1611M, "Standard Test Method for Slump Flow of Self-Consolidating Concrete," is the appropriate test rather than slump.

The first consideration when designing an SCC concrete mixture is to increase the fines content of the mixture, which in turn requires a higher paste content. With most shotcrete mixtures, we are already there because we generally have a fairly high paste content. Two important properties for SCC in the plastic state are flowability and stability. In the hardened state, we need to see the required strength. Simply adding water will increase the flowability but negatively affect the stability and strength.

Mining technician measuring the slump flow of a shotcrete mixture

Although they are more costly than water, chemical admixtures can help to ensure the correct properties for an SCC mixture. A high-range water-reducing admixture (HRWRA) is the main component in allowing the SCC mixture to flow without the addition of water. Modern HRWRAs are made with polycarboxylic ethers, providing cement dispersion by steric stabilization, and these molecules can be tailored to provide various initial slumps and slump retention times. They can also be tailored to work with various types of cements.

One other addition to a mixture that can help with flow is air. With a simple air-entraining admixture, you can add up to 12% air to a mixture, which can significantly increase flowability; however, you must make sure that the air is knocked out during shooting or by a sudden stop at the end of a vertical drop, as air in hardened concrete will also reduce the compressive strength.

When a mixture becomes very flowable, it can tend to segregate during a fall or when pumping, but you guessed it: there is also a chemical to prevent that from happening. A viscosity-modifying admixture (VMA) can be added at a very low dosage to help keep the mixture together during transport.

So, the next time you need to pump your mixture a long distance into that dark tunnel or drop it 5000 ft (1500 m) straight down a pipe into a mine, work with your ready mix supplier to design the right mixture for the job. The mixture may be more expensive, but this can save a great deal of money in labor costs and plugged equipment.

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