Accelerator Dosing Pump Calibration and Verification

By Lihe (John) Zhang

Accelerators are widely used for underground shotcrete applications. The most commonly used accelerator dosage ranges from 3 to 6% by mass of cementitious materials. The accelerator dosage added to the shotcrete is critical for shotcrete performance and quality. It is important to properly calibrate the accelerator dosing pump to provide a reliable accelerator supply at the designed dosage. This article compares the conventional way of accelerator dosing pump calibration with a more reliable way of accelerator dosing pump calibration.

For tunnels and mines that require overhead shotcrete application, it is essential to use an accelerator, primarily to reduce the incidence of shotcrete falloff. The dosage of accelerator added to the shotcrete is critical, as it directly affects the quality and strength development of the final shotcrete support. Too little accelerator will not be sufficient to enable the shotcrete to set within several minutes and therefore may not be effective in preventing shotcrete from falling off. Too high a dosage of accelerator will set the shotcrete within a few minutes, or even seconds, but will result in porous shotcrete with poor quality, including high permeability and low strength.

Fig. 1: An accelerator dosing pump with control valve

An accelerator is typically added using a dosing pump that pumps the accelerator to the nozzle at a preset dosage rate, but it can also be added as a dry powdered accelerator to prebagged dry-mix shotcrete. For wet-mix shotcrete applications, liquid non-alkali accelerators are generally used. The accelerator is supplied by a dosing pump at a design dosage rate. The accelerator hose is connected to the shotcrete nozzle and liquid accelerator is injected into the material stream at the nozzle. A control valve is connected to the accelerator hose and can be adjusted to control the accelerator dosage rate (Fig. 1). For dry-mix shotcrete application, powdered accelerators can be added to dry bagged material, or a liquid accelerator can be added to the materials at the nozzle through a dosing pump. For a non-alkali liquid accelerator, the typical dosage is about 3 to 6% by mass of cement or cementitious materials.[1]

Method A: Calibration of Dosing Pump by Setting Up Flow Rate

The most commonly used accelerator dosing pump calibration method is to measure the quantity of accelerator supplied by the dosing pump while the accelerator hose is not connected to the nozzle over a given period of time (for example, 1 minute). The quantity of shotcrete supplied by the shotcrete pump over the same period of time is determined by the pump production rate—that is, how many pump strokes per minute times the volume of the pump piston times the fill rate in the piston. The typical fill rate in the piston is about 90%, depending on the slump of the shotcrete mixture.

Generally, the accelerator supplier will provide a calibration flowchart for the accelerator being used based on the accelerator dosing pump flow rate and the shotcrete pump rate. The accelerator flow rate is controlled by the dial gauge or valve.

This can be simply calibrated by running the accelerator dosing pump for a fixed time (1 minute, for example) and determining the volume of accelerator being pumped out by collecting the accelerator in a graduated flask.

Method B: Calibration/Verification of Dosing Pump by Recording Actual Volume of Accelerator Added to the Shotcrete

During a number of trials, it was found that the setting time and early-age compressive strength development of the shotcrete varies from that expected from the accelerator dosages calibrated by the aforementioned Method A. The addition rate of the accelerator was carefully investigated and it was found that the dosing pump was not able to supply accelerator at a reliable feed rate, even when the dial was preset to be the designed accelerator dosage rate. The accelerator dosing pump was calibrated based on the supplier's flow rate chart method, but the actual quantity added to the shotcrete was different.

Further investigation found that with certain types of accelerator pumps, when the accelerator pump was connected to the shotcrete nozzle, the accelerator dosage rate was affected by the pressure from the compressed air added to the shotcrete at the nozzle. Thus, the actual quantity of accelerator added to the shotcrete mixture was not accurately known. For example, if the accelerator dosing pump is a peristaltic type of equipment, it can supply accelerator at a certain rate and at a certain accelerator pump pressure.[1] The supply volume might be reduced by the "back pressure" caused by compressed air during shooting.

The quantity of accelerator being added to the shotcrete has a greater potential to be excessive rather than below optimum because the shotcrete crew, including the pump operator and nozzlemen, may field-adjust the required quantity of accelerator in response to perceived conditions. It is not uncommon for the crew to increase the dosage of accelerator (sometimes excessively) when they:

- See shotcrete start to fall off or slough;
- See shining water at the surface of the shotcrete;
- Feel that the slump of shotcrete is too high; or
- Are not confident that shotcrete will stay on the wall or overhead.

Therefore, it is critical to properly calibrate the dosing pump at the very beginning of shotcrete production and verify the actual quantity of accelerator added to the shotcrete mixture. A procedure for shotcrete-dosing pump calibration and accelerator dosage verification is described in the following sections.

Equipment

1. Dosing pump: Identify maximum capacity; make marks for 4 and 6% accelerator addition by mass of cementitious materials.
2. Dosing pump hose: Ensure a 1 in. (25 mm) internal diameter; identify length of hose from accelerator container to nozzle.
3. Weigh scale.
4. Ensure dimensions of calibration box are 2 x 2 x 1 ft = 4 ft^3 (0.61 x 0.61 x 0.3 m = 0.11 m^3).

Methodology

1. Calculate the exact quantity of accelerator required. For example:
   - 4%: If 1 m^3 (35.31 ft^3) of concrete contains 410 kg (904 lb) cement, then the amount of accelerator required is 16.4 kg/m^3 (0.465 kg/ft^3) or 1.860 kg/4 ft^3 (4.1 lb/4 ft^3).
   - 6%: If 1 m^3 (35.31 ft^3) of concrete contains 410 kg (904 lb) cement, then the amount of accelerator required is 24.6 kg/m^3 (0.697 kg/ft^3) or 2.787 kg/4 ft^3 (6.1 lb/4 ft^3).
2. Have two buckets (25 gal. [95 L]) ready, with Bucket 1 half-full of accelerator and Bucket 2 full of accelerator. Weigh Bucket 2.
3. Submerge the accelerator hose in Bucket 1 (the half-full bucket). The nozzleman should then start shooting, but not into the box. This way, the accelerator hose will be filled with accelerator.
4. The engineer should give instructions to the nozzleman to shoot into one of the 4 ft^3 (0.11 m^3) boxes. At the same time, the accelerator hose must be removed from Bucket 1 and inserted into Bucket 2 (the full bucket).
5. Once the box is filled to the top with shotcrete, stop shooting and remove the accelerator hose from Bucket 2 at the same time.
6. Weigh Bucket 2 again. The difference in weight is the exact amount of accelerator added at the nozzle during shooting of the 4 ft^3 (0.11 m^3) of shotcrete.
7. Calculate the exact accelerator dosage rate as a percentage by mass of cement.

Note: The estimated time to complete calibration is about 10 minutes.

Once an accelerator pump is properly calibrated, a calibration table of the accelerator pump dial settings and shotcrete pump settings can be established. An example is shown in Table 1. With the table, it is very simple for the pump operator or nozzleman to accurately set the accelerator rate by checking the stroke rate and accelerator dial settings. This calibration table should be printed out, laminated, and attached to the accelerator dosing pump.

Table 1: An Example Field Chart of Accelerator Dosing Rate Setting

Shotcrete pump setting		Accelerator pump dial settings		
Number of strokes per minute	**Number of m^3 (yd^3) of shotcrete per hour**	**4% by mass of cement**	**6% by mass of cement**	**8% by mass of cement**
5	2.1 (2.8)	1.2	1.3	1.4
6	2.5 (3.3)	1.2	1.4	1.5
7	3.0 (3.9)	1.3	1.5	1.7
8	3.4 (4.4)	1.3	1.5	1.8
9	3.8 (5.0)	1.4	1.6	1.9
10	4.2 (5.5)	1.4	1.7	2
11	4.7 (6.1)	1.5	1.8	2.2
12	5.1 (6.7)	1.5	1.9	2.3
13	5.5 (7.2)	1.6	2	2.4
14	5.9 (7.7)	1.7	2.1	2.5
15	6.3 (8.2)	1.7	2.2	2.7
16	6.8 (8.9)	1.8	2.3	2.8
17	7.2 (9.4)	1.8	2.4	2.9
18	7.6 (9.9)	1.9	2.5	3.1
19	8.0 (10.5)	2	2.6	3.2
20	8.5 (11.1)	2	2.7	3.4

References

1. Millette, D., "Using Accelerators for Shotcreting," *Shotcrete*, V. 12, No. 2, Spring 2011, pp. 36-39.

***Lihe (John) Zhang**, PhD, PEng, LEED AP, recently opened his own firm, LZhang Consulting and Testing Ltd. Zhang has over 10 years of experience in concrete technology and the evaluation and rehabilitation of infrastructure. He received his PhD in civil engineering from the University of British Columbia, where he conducted research on fiber-reinforced concrete, and is also a LEED Accredited Professional. He is Chair of American Concrete Institute (ACI) Subcommittee 506-F, Shotcrete-Underground, and is a member of ACI Committees 130, Sustainability of Concrete; 506, Shotcreting; and 544, Fiber-Reinforced Concrete, and a member of ASTM Committee C09, Concrete and Concrete Aggregates. He is also Chair of the ASA Education Subcommittee: Graduate Scholarships, Co-Chair of the ASA Underground Committee, and an ASA Board member.*