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Field-Use Early-Strength Shotcrete Test System

Objective

To develop a practical method of measuring shotcrete early strength onsite in the first six hours after application using a partial beam test standard, ASTM C 116-90. Determining the early-strength development of as-sprayed shotcrete can improve mine safety by identifying appropriate reentry times and providing a convenient means of quality control during application (Figures 1–3). A more thorough understanding of shotcrete early strength will lead to improvements in ground support practices, thereby preventing groundfalls and reducing mine roof-fall accidents.

Background

When shotcrete is used as part of a multicomponent ground support system, it is important to know when the material has developed enough strength to be self-supporting and allow for reentry and emplacement of the remaining support elements that require drilling of the shotcrete layer without degradation. Typical reported values for this threshold strength for North American mines range from 1 to 1.6 MPa (145 to 233 psi) [O'Toole and Pope 2006], with a compressive strength equivalent to 1 MPa (145 psi) being the norm [Rispin et al. 2003; O'Toole and Pope 2006]. Typical ground control support includes a shotcrete flash coat 19- to 25-mm (3/4- to 1-in) thick, followed by screen, plates, bolts, and a second layer of shotcrete bringing the combined thickness to 75 to 100 mm (3 to 4 in). In areas requiring rehabilitation, the second layer of shotcrete is plated and bolted as well. While testing cored samples after 24 hours is standard, this is not practical for the one- to six-hour period following application when shotcrete unconfined compressive strengths are less than 10 MPa (1,450 psi). Indirect methods are typically used to determine shotcrete strength during the early stages of curing because the partially cured or green material is difficult to sample and test. While problems with inconsistent test results have been reported with the penetrometer-type devices, beam molds have been used successfully for creating shotcrete test specimens in the United States and Canada.

Operating the Partial Beam Test System

The test unit is a self-contained, servo-controlled, stiff- frame press (Figure 1). Partial beam test samples are obtained by spraying shotcrete into 102- x 102- x 152-mm (4- x 4- x 6-in)

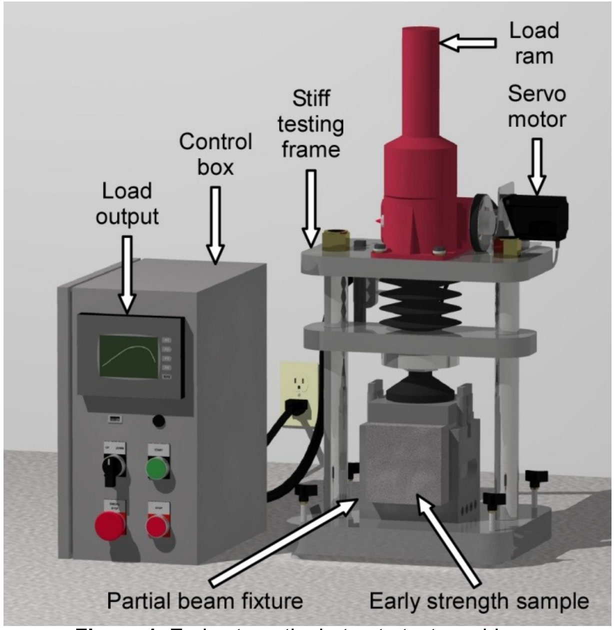

Figure 1. Early-strength shotcrete test machine.

mold boxes as shown in Figure 2. After the samples have been sprayed, tests are conducted at one-hour intervals over the next six hours (one- through six-hour tests). The shotcrete samples are carefully demolded by disassembling the mold fixtures and removing the enclosed sample. Next, a shotcrete sample is placed in a specialized testing fixture and centered under the loading head of the test machine (Figure 1). When the test sequence is initiated, a programmable-logic-controller- (PLC) driven press applies a fixed-rate load to the sample. The load profile is shown on a graphical output display, and the measured test parameters (time, displacement, and load) are stored on a thumb drive. Once the operator observes a well-defined peak in the load profile curve, the test is completed and the test machine's loading platen can be returned to its initial starting position. Peak load is typically reflected by the development of large vertically oriented cracks (Figure 3) along the platen-to-sample contact edges, which are indicative of the failure plane.

Figure 2. Partial beam box mold and test specimen.

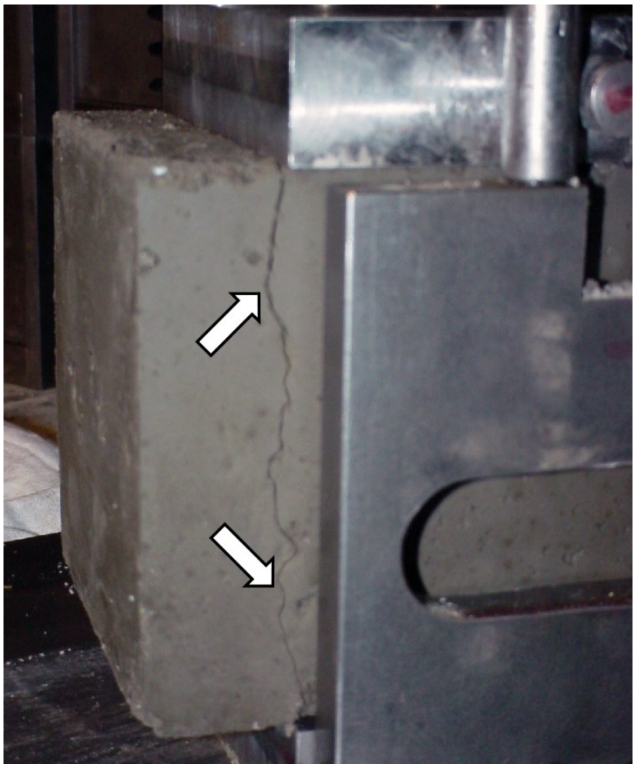

Figure 3. Vertical crack in shotcrete test specimen.

Shotcrete early-strength values obtained from cast and shot samples using the test system are shown in Figure 4. There is a marked difference in early-strength gain between sprayed and cast shotcrete. The cast shotcrete samples have a similar strength gain profile to that of cast concrete samples.

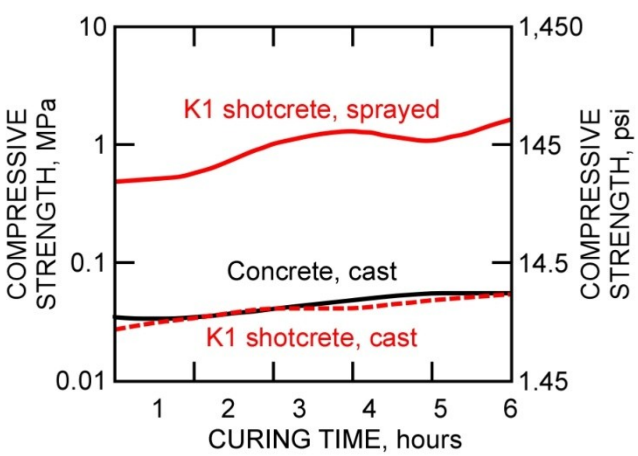

Figure 4. Typical early-strength partial-beam test values for dry-mix shotcrete and concrete, n=54 samples.

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Design Features

- Mobile stiff-frame press
- Compact size for transport and storage
- Graphical user interface with PLC-servo control
- Visual load display of test status
- USB thumb drive for data collection and storage
- Power choices: 110-V AC through UPS

Specifications		
Press		
Capacity	22 kN	5,000 lbf
Height	71 cm	28 in
Width	31 cm	12 in
Depth	26 cm	10 in
Test speed	1.27 mm/min	0.05 in/min
Positioning speed	91.4 mm/min	3.6 in/min
Drive system	ball screw	
Control	PLC servo	
Load display, collection, and storage system	graphical user interface with USB thumb drive	
Control Box		
Height	38 cm	15 in
Width	18 cm	7 in
Depth	36 cm	14 in
Power	110-V AC through UPS	
Operating system	Eaton Controls	

For More Information

For more information on the early-strength test machine, contact Lewis Martin, LMartin@cdc.gov, (509) 354-8077, or the Health Communications Coordinator (OMSHR@cdc.gov), NIOSH Office of Mine Safety and Health Research, P.O. Box 18070, Pittsburgh, PA 15236-0070.

References

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