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Technology News

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Field-Expedient Shotcrete Adhesion Test System

Objective

To develop a practical method of measuring shotcrete adhesion strength in underground mines. A more thorough understanding of the in-situ strength properties of shotcrete, particularly the bond strength of shotcrete to the rock, will lead to improvements in ground support practices, thereby preventing groundfalls and reducing mine roof-fall incidents.

Background

When shotcrete is used as an integral part of a mine's ground support system, it is important to know the strength properties of the in-place shotcrete. To quantify the bond strength of the shotcrete to the rock, a shotcrete adhesion test system has been developed for use in underground mines. As shown in Figure 1, the test system consists of readily available components, primarily a small stand-mounted core drill and a pulling unit equipped with a precision pressure gauge. All of these components are rugged and portable, and they can reliably be used to measure the adhesion strength of shotcrete applied to the surface of an underground mine opening (Figure 2).

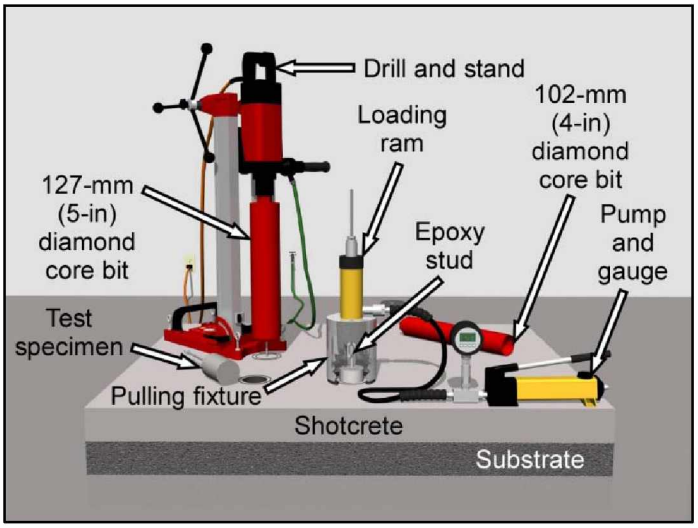

Figure 1. Schematic of direct tensile test system for measuring shotcrete adhesion strength.

With this test method, a direct tensile load is applied to a core drilled through the shotcrete into the underlying rock. As this load is gradually increased, the test core typically breaks or fails in tension. This tensile failure can occur in the shotcrete, at the bond surface (interface), in the rock, or at some combination of these locations. As a result, the tensile-strength values derived from these tests provide important information about the quality of the applied shotcrete and the competency of the underlying rock, as well as the bond strength of the shotcrete to the rock.

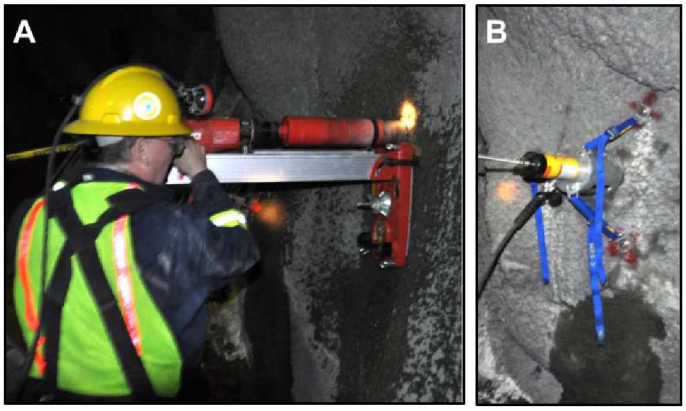

Figure 2. Shotcrete adhesion test system for underground mines: (A) drilling 4-in-diameter hole for the test core and (B) pulling unit mounted to mine rib using a three-point safety restraint.

Conducting the Shotcrete Adhesion Test

Once a desired test site has been selected, a hand-operated rotary percussive drill is used to drill a 16-mm x 51-mm (0.625-in x 2-in) hole for anchoring the drill stand. After installing a 13-mm- (0.5-in-) diameter threaded stud and expansion anchor in this hole, the drill stand is leveled and secured in position. Three holes are then drilled from this drill setup ensuring that all of the holes are parallel and concentric (Figure 3). First, an 11.1-mm- (0.4375-in-) diameter hole is drilled dry into the shotcrete using a rotary percussive bit, to a depth of 60 mm (2.375 in), assuming a shotcrete thickness of 75 mm (3 in). Next, the hole is cleaned, filled with a quick-setting, two-part epoxy adhesive, and a 9.5-mm- (0.375-in-) diameter pull anchor is inserted. After the epoxy has initially set or gelled (about 15 min), a 102-mm- (4-in-) diameter diamond core bit is used to wet drill a second hole through the shotcrete to a depth of about 25 to 50 mm (1 to 2 in) into the underlying rock. Finally, a 127-mm- (5-in-) diameter diamond core bit is used to wet drill a shallow kerf for seating the base of the pulling fixture (Figure 3).

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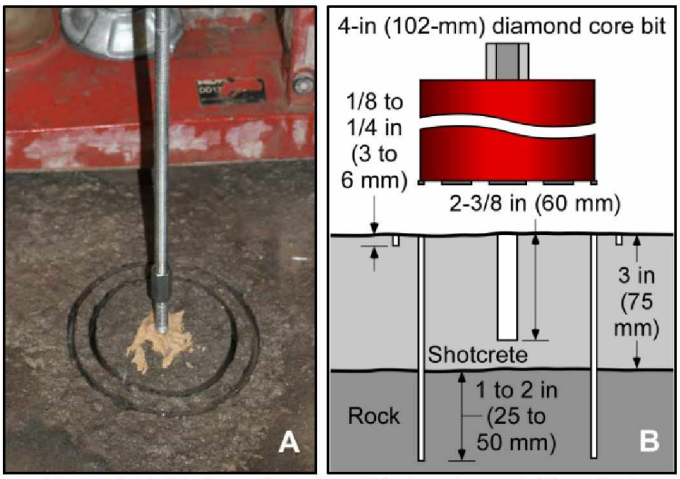

Figure 3. Drill hole configuration: (A) plan view and (B) vertical cross section.

After the epoxy has fully set (30–60 min), a threaded extension rod is connected to the pull anchor with a coupling nut; the pulling fixture is then carefully placed over the core sample with the base of its reaction ring positioned in the kerf of the outer drill hole. Next, a collet and a slip-on, quick-threading locknut are connected to the threaded extension rod to serve as a mechanical stop for the pulling fixture's ram. The hydraulic hose from the hand pump is then connected to the loading ram, and the pressure gauge is zeroed. To conduct a test, an increasing tensile load is applied to the core sample through a slow and steady movement of the pump handle until the core breaks. The adhesion strength of the test core is determined by converting the maximum hydraulic pressure value, saved on the pressure gauge's digital display, to the maximum tensile stress acting normal to the core's failure surface. Typical adhesion test results comparing tensile strength with shotcrete curing age are shown in Figure 4.

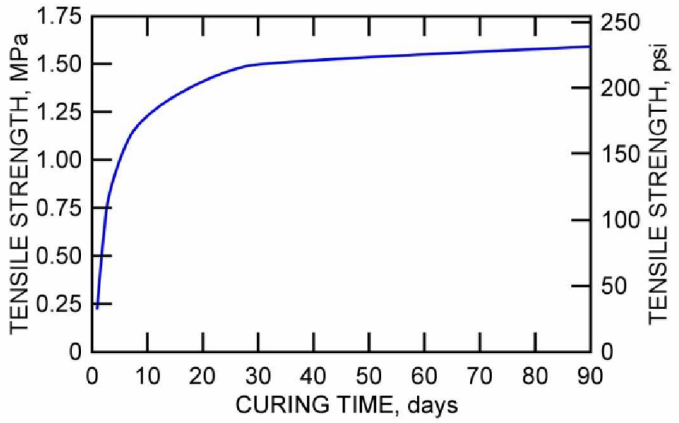

Figure 4. Typical shotcrete adhesion test results.

Design Features

- Test equipment is portable and easily stored.
- Test system components are easy to set up and operate.
- Test procedures are easily understood and require minimal training.
- Test results provide in-situ strength values.
- Power choices: 110-V AC or DC→AC inverter.

Test System Component Specifications		
Drilling unit		
Drill	Hilti DD-130 core drill (wet/dry)	
Drive system	Three-speed forward/reverse	
Drill stand	Hilti DD-ST-130 drill stand 11-in width x 22-in depth x 43-in height	
Diamond core bit	Test core	Hilti DD-BI, 4 in x 17 in
	Kerf	Hilti DD-BI, 5 in x 17 in
Drill bit	Pulling stud	Hilti TE-C3X, 7/16 in x 6 in
Custom drill chuck	Hilti DD-BI drill bit chuck welded to Bosch spline to SDS adaptor	
Pulling unit		
Extension rod	⅜-in threaded rod (⅜–16 NC x 30 in) ⅜-in coupling nut (⅜–16 NC x 1 in) ⅜-in hex head locknut (⅜–16 NC) ⅜–16 slip-on quick-threading locknut ⅜-in collet (1¼ & ¾-in OD x 1-in height)	
Pulling fixture	Aluminum weldament 6-in OD x 6½-in height x ⅜-in wall Steel-base insert 5¾-in OD x 2-in height x ½-in wall Kerf flange 5⅛-in OD x 5-in ID x 1-in height	
Hydraulic pump	Enerpac P-142 two-speed 1st stage 200 psi, 2nd stage 10,000 psi	
Hydraulic ram	Enerpac RCH-123, Holl-O-Ram 10,000 psi, 12 ton	
Digital pressure gauge	Parker SCJR 8700-2 PD with min/max display, 0–8,700 psi	
Safety restraint		
Safety strap (3)	NRS HD 1-in tie-down strap, 3-ft length heavy-duty 1-in cam buckle	
Strap bracket	Shotcrete L-shaped (3)	Aluminum 2 in x 2 in x ¼ in
	Pull fixture eyelet (3)	Aluminum 1½ in x 2 in x ¼ in
Anchors		
Drill stand	½-in Hilti Kwik-LOK nut and spindle ½–13 NC and ⅝ rope thread x 7½ in	
L-bracket (3)	½-in hex head bolt (½–13 NC x 1½ in)	
Shotcrete (3)	½-in Hilti HDI drop-in (⅝ in x 2 in)	
Eyelet bracket (3)	¼-in hex head bolt (¼–20 NC x 1 in)	
Pulling stud	⅜-in Hilti HIT-TZ (⅜ in x 4½ in)	
Epoxy	Hilti HIT-HY 150 MAX	

For More Information

For more information on the shotcrete adhesion test system, contact Brad Seymour at JSeymour@cdc.gov (509) 354-8019 or the Health Communications Coordinator (OMSHR@cdc.gov), NIOSH Office of Mine Safety and Health Research, P.O. Box 18070, Pittsburgh, PA 15236-0070.

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