2011 Outstanding Underground Project

Incline Tunnel—S&S Quarries, Inc.

By Edwin Brady

The Incline Tunnel, S&S Quarries, Inc., is the access to an underground rock mine in Knoxville, IA, owned by Bruening Rock Products. This access tunnel is 1950 ft (594 m) in length on a 12% grade with a depth at the bottom of the incline of 210 ft (64 m). A section approximately 250 ft (76 m) long and 1300 ft (400 m) down the incline passes through a fault zone. Earth pressure had caused extensive distortion of the tunnel cross section, with the base of the horseshoe-shaped arch moving approximately 2 ft (0.6 m) inward on both sides. Distortion of the section profile had created longitudinal and transverse cracking in the original shotcrete lining, along with movements of several feet. Inspection by Roberto Guardia, PE, Vice President of Shannon & Wilson, Inc., Geotechnical and Environmental Consultants in Jacksonville, FL, detailed the condition of the tunnel and made recommendations to reinforce this 250 ft (76 m) section by adding steel lattice trusses encapsulated with a new lining of steel fiber-reinforced, microsilica-enhanced shotcrete. A joint effort by the owner and Richie Benninghoven of USC Technologies, LLC as general contractor undertook the task of performing repairs. Edwin Brady Construction Co., Inc. was employed as the shotcrete contractor.

Prequalification and Startup

It was critical that operations at the mine remain fully operational during the repairs. Work was scheduled to start in early March 2009. Preconstruction testing revealed problems with the shotcrete mixture. Local aggregates were not very well-graded, pea gravel was not available, and 80 lb/yd^3 (47 kg/m^3) of steel fibers produced a very difficult-to-pump concrete mixture. This problem was solved by adding fly ash to the mixture, along with water reducers, plasticizers, and strict quality control to regulate slump. An Allentown RP20 Refractory Pump with an integral peristaltic accelerator pump was obtained from Gary Carlson Equipment, and a successful preconstruction qualification test/mockup was accomplished with authorization to commence the work with Edwin Brady, an ACI-Certified nozzleman and ACI examiner, of Edwin Brady Construction Co., Inc., as the approved nozzleman. With shotcrete thicknesses of as much as 6 ft (1.8 m) in vertical sections and 2 ft (0.6 m) in overhead portions, a set accelerator was required. Eucon Sureshot AF, a high-performance alkali-free shotcrete accelerator

Fig. 1: (a) and (b) Steel lattice trusses in place and ready for shotcrete

Fig. 2: Surface preparation by high-pressure water blasting

Fig. 3: Shotcrete placement

manufactured by The Euclid Chemical Company was the perfect solution. With this accelerator, we were able to place approximately 4 in. (100 mm) of shotcrete overhead, allow it to set for approximately 1 hour, and then place another 4 in. (100 mm). This allowed us to place upward of 12 in. (300 mm) of shotcrete thickness in an overhead application in a single shift.

Project Schedule

We quickly settled into a routine of mobilizing equipment to the work area, shooting a 24 x 24 x 4 in. (600 x 600 x 100 mm) test panel, shooting 4 to 7 yd^3 (3 to 5 m^3) loads of shotcrete, flushing hoses and cleaning up the pump, taking a lunch break, shooting three additional 7 yd^3 (5 m^3) loads of shotcrete, flushing hoses and cleaning up the shotcrete pump, and demobilizing equipment to allow trucks to carry ore from the mine to the surface through the repair area during the night shift. This routine resulted in the placement of a total of 49 yd^3 (37 m^3) of shotcrete in a 10-hour shift. This all required very precise coordination with the ready mix concrete supplier (Bruening Rock Products, project owner) and a quick turnaround between trucks because they had to back down a 12% slope (1300 ft [400 m]) in an unlit, dark tunnel to get to our Allentown shotcrete pump. Our four-man crew consisted of a pump operator, man-lift operator, nozzleman, and general laborer. A typical week consisted of 2 to 3 days of placing shotcrete, 1 to 2 days for surface preparation with high-pressure water blasting, and 1 day for equipment cleaning and maintenance. With this schedule, we placed about 1050 yd^3 (800 m^3) of shotcrete to complete the work in the tunnel in approximately 8 weeks.

Additional Work

Upon completion of work in the tunnel, the owner directed us to perform the additional work

Fig. 4: Completed section

Fig. 5: The light at the end of the tunnel

Fig. 6: Scaling loose rock from high wall

Fig. 7: High-pressure water blasting to prepare high wall for shotcrete

Fig. 8: High wall and portal completed

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Incline Tunnel—S&S Quarries, Inc.

Project Location
Knoxville, IA

Shotcrete Contractor
Edwin Brady Construction Co., Inc.

General Contractor
USC Technologies, LLC

Architect/Engineer
Shannon & Wilson, Inc.

Material Supplier/Manufacturer
The Euclid Chemical Company*

Project Owner
Bruening Rock Products, S&S Quarries, Inc.

*Corporate Member of the American Shotcrete Association

of applying new shotcrete to the tunnel portal and high wall to provide stabilization to the friable and unstable exposed rock faces. After scaling these surfaces and cleaning them with high-pressure washing, we placed about 150 yd^3 (115 m^3) of shotcrete in 1 week to complete the extra work.

Project Summary

Total shotcrete placed: 1200 yd^3 (920 m^3)
Total Eucon Sureshot AF accelerator used: 275 gal. totes × 18 = 4950 gal. (18.7 m^3)

Total Time on Project

Mobilization and preconstruction: 1 week
Shotcrete placement: 9 weeks
Cleanup and demobilization: 3 days

Conclusions

This project demonstrated how effective shotcrete is as a repair method for ground support. Through the use of admixtures, you can produce a very high-performance concrete and control its setting characteristics to allow high-build applications, even in overhead conditions. A properly designed mixture, along with a good nozzling technique, allowed for full encapsulation of the steel lattice trusses equal to the quality of a form-and-pour repair. Highly mobile equipment allowed for efficient setup and knockdown each day. This, coupled with high production rates, allowed for a very tight completion schedule with few or no interruptions to normal mining operations for the owner. Nearly 2 years after completion of this work, the owner reports no problems with the work and reiterates satisfaction with the overall success of the project.

***Edwin Brady**, PE, President of Edwin Brady Construction Co., Inc, has over 20 years of experience in wet- and dry-process shotcrete, including over 3000 hours of nozzleman experience, concrete repair, and specialty grouting projects on four continents and throughout the U.S. Brady received his BSCE from the University of Kentucky, Lexington, KY, in 1980 and has done extensive graduate work toward his MSCE from the University of Houston, Houston, TX. He is an ACI Certified Nozzleman (wet- and dry-process, vertical and overhead); an ACI Certified Examiner (wet- and dry-Process); and a licensed professional engineer in Kentucky and Colorado.*