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Geomechanics of Reinforced Cemented Backfill in an Underground Stope at the Lucky Friday Mine, Mullan, Idaho

Department of Health and Human Services
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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm	centimeter	ft	foot
hr	hour	in	inch
Hz	hertz	lb	pound
kg	kilogram	psi	pound per square inch
km	kilometer	°F	degree Fahrenheit
kN	kilonewton		
kPa	kilopascal	°	degree
MPa	megapascal	%	percent
m	meter		
N	newton		
°C	degree Celsius		

GEOMECHANICS OF REINFORCED CEMENTED BACKFILL IN AN UNDERHAND STOPE AT THE LUCKY FRIDAY MINE, MULLAN, IDAHO

By T.J. Williams,[1] D.K. Denton,[1] M.K. Larson,[1] R.L. Rains,[2] J.B. Seymour,[1] and D.R. Tesarik[3]

ABSTRACT

Because backfill has occasionally collapsed into an active working area, posing a hazard to miners, engineers from the Spokane Research Laboratory of the National Institute for Occupational Safety and Health and Hecla Mining Co. installed instruments in a cemented, backfilled, stope-ramp intersection at Hecla's Lucky Friday Mine, Mullan, ID. The purpose was to measure stress and strain changes in the backfill and reinforcing members during undercut mining. The instruments were monitored for 6 months while three successive cuts were mined below the intersection. Readings showed induced loads up to 3450 kPa (500 psi) in the backfill as stope walls converged 2.5 to 12 cm (1 to 5 in). The backfill then deformed against the top and bottom plates of the 2-m- (6-ft-) long vertical rock bolts installed as reinforcement, producing loads to 177 kN (40,000 lb) on the rock bolts.

We hypothesize that a compressive zone was created in the backfill that allowed the backfill to remain stable as long as the compressive zones from adjacent rock bolts overlapped. This hypothesis is presented in graphical form.

Of particular interest was the effect of loading on trusses installed to augment the vertical rock bolts and wire mesh typically installed in backfill. Data from the instruments indicate that wall closure perpendicular to the vein induced loads in truss legs parallel to the vein and in the rock bolt driven through the center of the truss, but, because they are designed to function under tension, truss legs perpendicular to the vein supplied insignificant support as a result of compressional forces from wall closure. Based on this study, use of trusses was discontinued, and an alternative support system of wood beams and posts was installed as needed to ensure the safety of miners working beneath the backfill in stope-ramp intersections.

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INTRODUCTION

Mining-induced wall closure in cemented, backfilled underhand stopes at Hecla Mining Co.'s Lucky Friday Mine in Mullan, ID, can cause the backfill to fracture. These fractures generally do not pose a hazard to miners working in the stopes beneath the backfill because any broken material is contained by wire mesh and Dywidag[4] rock bolts used for backfill reinforcement. Still, some collapses of backfill have occurred in stope-ramp intersections as the backfill was undercut.

Options for improving miner safety while miners are working under backfill include placement of a layer of low-modulus backfill above a reinforced cemented sill, installation of deformable plastic sheets along the centerline of the stope (Fredericksen et al. 1993; Krauland and Stille 1993), or placement of additional support to reinforce the backfill. The latter option was chosen by Hecla, and in addition to vertical rock bolts, trusses manufactured by Western Support Systems, Salt Lake City, UT, were installed in the four-way ramp-stope intersections.

To monitor the effectiveness of the trusses and to compare stresses in the truss-supported backfill with stresses previously recorded in stopes without truss systems, engineers from the Spokane Research Laboratory (SRL) of the National Institute for Occupational Safety and Health (NIOSH) and Hecla Mining Co. mounted instruments on both bolts and trusses. The instruments included vibrating-wire strain gauges and load cells on the rock bolts and the legs of the trusses, earth pressure cells in the cemented backfill, and string potentiometers across the stopes. Redundancy was designed into the instrumentation plan to overcome known instrument survival problems associated with deformation of the fill and to provide sufficient data to interpret the interaction of the individual support components.

In addition, cylinders of wet backfill material were collected during filling of the instrumented stope. The cylinders were cured in a room where humidity and temperature were controlled. They were then tested for 7- and 28-day unconfined compressive and splitting tensile strengths.

MINING METHOD

The Lucky Friday Mine (figure 1) uses a mechanized underhand cut-and-fill mining method to mine lead-silver ore from a steeply dipping, 2.4-m- (8-ft-) wide vein at a depth exceeding 1.6 km (1 mile) (Scott 1990). In the underhand mining method, the mined-out stope is backfilled with reinforced, cemented mill tailings following each cut, which provides a safe stope back or roof for the following cut. Approximately 10% cement by weight is added to the mill tailings to strengthen the backfill rapidly so that mining of the following cut can resume under the backfill without a long wait. This amount of cement has been selected after years of experience in balancing miner safety, cost of the cement, and the need to start mining the following cut soon after backfill placement.

Approximately 70% of the stope height is backfilled, leaving a 1-m (3-ft) gap between the bottom of the previous fill and the top of the new fill. The backfill is delivered from the surface in a pastelike consistency, which lowers water content, thereby increasing the final strength of the backfill (Brackebusch 1994). Backfill reinforcement consists of 2- or 2.4-m- (6- or 8-ft-) long Dywidag rock bolts driven vertically on 1.2-m (4-ft) centers into loose muck on the floor. When the end of the rock bolt driven into the loose muck is exposed during mining of the following cut, chain link fencing, a bearing plate, and a nut are installed for ground support.[5] The high horizontal in situ stresses at the Lucky Friday Mine (Whyatt and Beus 1995; Whyatt et al. 1995) result in rapid closure of the wall rock in the mined-out portion of the vein, and this wall closure is the main factor affecting the stability of the backfill.

Each mining cut is 3.3 m (11 ft) high and 2 to 3 m (6 to 10 ft) wide and extends approximately 75 m (250 ft) along the vein to each side of an access ramp (slot). The broken ore is stored in a muck bay on the opposite side of the vein from the access slot. This creates a four-way intersection. Thus the backfill may span a distance of up to 9 m (30 ft) diagonally.

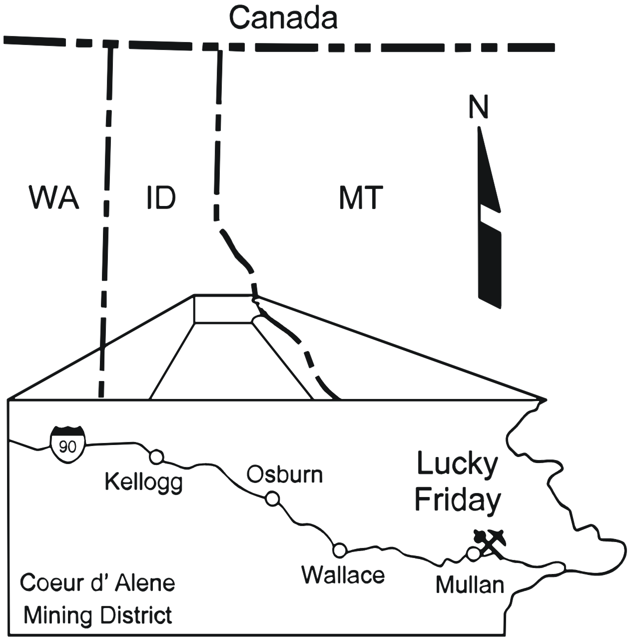

Figure 1.—Location of Lucky Friday Mine, Coeur d' Alene Mining District, Idaho.

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[4] Mention of specific products and manufacturers does not imply endorsement by the National Institute for Occupational Safety and Health.

[5] The Garpenberg Mine in Sweden (Krauland and Stille 1993) and the Henty Mine in Western Tasmania, Australia (Henderson et al. 1998), use similar reinforcement with their undercut-and-fill mining methods.

DESCRIPTION AND PLACEMENT OF INSTRUMENTS

Although stope wall closure and fill pressure had been monitored previously at the mine (Williams et al. 1992; Hedley 1993), loads on backfill reinforcement had not been. Thus, the instrumentation plan was designed to determine closure of the backfilled mine openings, pressure in the backfill, strength of the backfill, and induced loads on the truss and rock bolts placed in the backfill. Because support is provided by mechanical interaction among these elements, a complete evaluation of the engineering parameters of each element was needed to determine how the whole system functioned. Failures of the instruments from deformation and breakup of the backfill were anticipated; therefore, redundant systems were used.

A four-way truss was installed at the center of the intersection in addition to the vertical rock bolts typically used as reinforcement. The truss was constructed using No. 7 Dywidag rock bolts having a minimum yield strength of 160 kN (36,000 lb). It consisted of one vertical rock bolt, four legs angled 15° to 20° from the horizontal, one four-way horn bracket, and four stirrup U-bolts bent upward at 25° from the horizontal. The horizontal legs consisted of two or three rock bolts joined together with couplings so that the ends of the legs lay outside the intersection into the east and west sides of the stope along the vein and into the slot and the muck bay (figure 2).

Instrumented No. 7 Dywidag rock bolts were obtained from Roctest, Plattsburgh, NY, to measure induced load on the rock bolts used for backfill reinforcement. Roctest installed a vibrating-wire strain gauge and thermister in one end of each rock bolt. These instrumented rock bolts were placed at the ends of all the truss legs. They were also used to replace some of the vertical rock bolts throughout the stope. All instrumented rock bolts were installed so that the instrumented end was in the backfill to protect the instruments from blasting as the next cut was mined.

ALC10 rock bolt load cells were also obtained from Roctest to provide redundant readings on the vertical rock bolts and the truss. Load cells were the only instruments that could be used to obtain load readings at the junction of the stirrup and the horizontal legs at the truss bracket because blasting at this location would have destroyed the instrumented rock bolt wires. The load cells were installed on the lower end of instrumented rock bolts (figure 3) and on the truss legs after mining had passed. The load cells survived better than the instrumented rock bolts because the wires were not subjected to backfill deformation.

At various locations, wall-to-wall closure was measured in three different vertical positions (figure 4). A closure plane in the 1-m (3-ft) gap above the backfill was measured with string potentiometers. Another closure plane across the backfill was measured with string potentiometers inside collapsible steel casings, and a closure plane in the new stope cut was measured with a tape extensometer. All closure readings were taken between 15- by 15-cm (6- by 6-in) bearing plates on 1.2-m- (4-ft-) long rock bolts to achieve as much accuracy as possible.

Compressional loads in the backfill were measured with 690 kPa, 23-cm- (1000 psi, 9-in-) diam Model 3500 earth pressure cells from Geokon, Inc., Lebanon, NH. Each earth pressure cell had a backfill wall closure instrument, a gap wall closure instrument, and an instrumented vertical rock bolt installed at the same location.

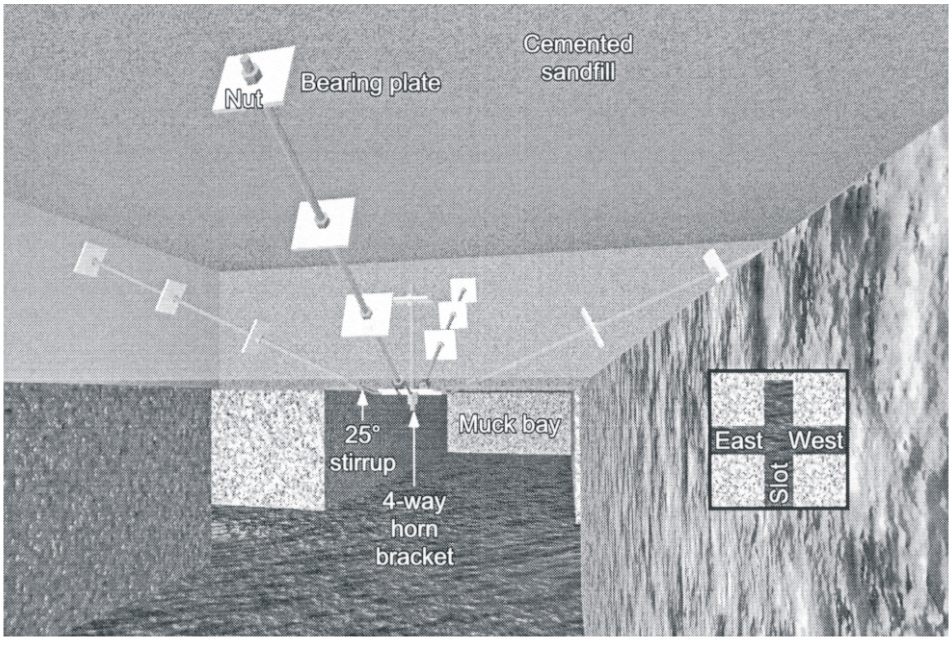

Figure 2.—Intersection truss system.