Novel stopping designs for large-opening metal/nonmetal mines

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ABSTRACT: Improving the air quality in metal/nonmetal mines is important in protecting the health of miners. Air quality can be improved in metal/nonmetal mines by developing proper ventilation techniques. Mine ventilation systems require stoppings to direct the airflow and establish pressure differentials throughout the mine. Due to their large size, stoppings in large-opening mines are cumbersome and costly to construct and maintain. As part of its mining health and safety program, the National Institute for Occupational Safety and Health (NIOSH) designed and tested two novel stoppings (Super Stopping and the EZ-Up Curtain Stopping) at its Lake Lynn Laboratory (LLL). The Super Stopping is designed as a long-term permanent stopping for use in the main entries of the mine, while the EZ-Up Curtain Stopping, although very durable, is designed more for portability and ease of installation. This paper describes the design, materials, and construction methods used for these stoppings as well as their performance and durability when subjected to tests simulating actual production face blast pressures.

1 INTRODUCTION

Stoppings play a significant role in underground mines by coursing and separating ventilation airflows. The utilization of stoppings, combined with proper mine designs, are essential components of a reliable ventilation system (Grau 2002, 2004a, b, Head 2001a, Krog 2004). In addition, supplying sufficient fresh air quantities to work areas to remove airborne contaminants will significantly improve air quality (Head 2001b, Robertson 2004, Haney 1998) thereby improving miners health. The design, construction, and maintenance of effective stoppings in large-opening mines are often challenging for mine operators. The choices for the design, materials, and construction techniques depend on a number of site-specific utilization factors, such as the intended life and required effectiveness of the stopping.

Stoppings have not always been widely used in large-opening stone mines. Capital expense, construction, and maintenance problems have impeded this segment of the mining industry from fully utilizing stoppings. Their use is particularly problematic in the larger, more established mines where stoppings have not previously been incorporated into the mining plan. In those mines, retrofitting the operation to include the use of stoppings to course the air requires building large numbers of stoppings requiring a significant investment in time and expense.

The Super Stopping and EZ-Up Curtain Stopping are designed for use as a practical and cost effective means to control and direct ventilation airflows throughout the mine. A reduction in worker exposure to diesel particulate matter (DPM), gases from production blasts and diesel equipment, and silica dust (Chekan 2002, 2004) can be accomplished by using an enhanced ventilation system that includes these stoppings.

2 SUPER STOPPING

The Super Stopping (Fig. 1) was constructed by NIOSH at the LLL in cooperation with several manufacturers. The stopping is designed for use as a permanent, long-term ventilation control, and is constructed from oversized Omega Blocks, which are low density, composite cement and fly ash blocks manufactured by Burrell Mining Products, Inc. The individual blocks are 1.22 m (48 in) long by 1.22 m (48 in) high by 0.81 m (32 in) wide and weigh approximately 544 kg (1200 lb) each. The Super Stopping constructed at LLL is 17.4 m (57 ft) wide by 9.1 m (30 ft) high. Construction of the Super Stopping is conducted in three phases: Phase I - Site Preparation and Foundation Building; Phase II - Block Stacking; and Phase III - Capping and Sealing.

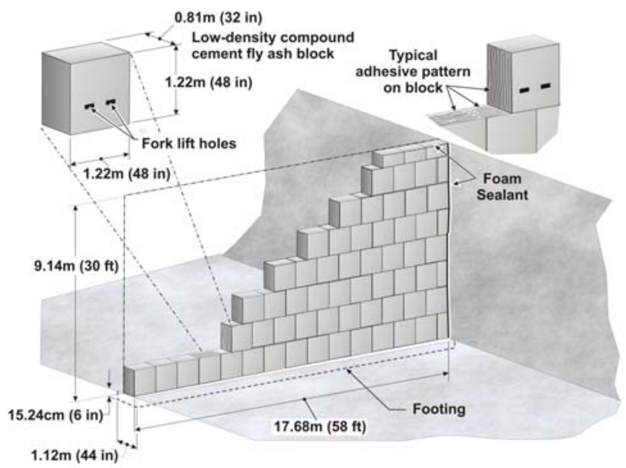

Figure 1. Schematic of Super Stopping.

2.1 *Phase I - Site Preparation and Foundation Building*

For a stable installation, the stopping should be built on a level surface which is best achieved using a concrete footing. The approximate footing dimensions are the distance across the mine opening width by 1.12 m (44 in) in depth, with a minimum 0.15-m (6-in) concrete thickness. A footing width of 1.12 m (44 in) provides an extra 0.15 m (6 in) on each side of the 0.97-m (32-in) wide stopping block. The footing should consist of 20,680-kPa (3,000-psi) standard mix concrete, embedded with standard 0.15-m (6-in) by 0.15-m (6-in) wire mesh reinforcement material, which is sufficient to withstand the weight of the wall.

2.2 *Phase II – Block Stacking*

An extended reach forklift is used to lift and position the blocks (Fig. 2-3) during the stacking phase. The blocks have two factory cast holes on one side to receive the forklift tines. Articulation of the blocks is necessary for their proper alignment in the structure to maintain stability and vertical trueness. It is critical to establish a stable structure as the stopping height increases. The first course of blocks is aligned along a chalk line struck on the concrete footing.

Each block is secured in place with a high grade polyurethane construction adhesive. The adhesive used on the Super Stopping at LLL was the Touch ‘N Seal Mine Mortar Adhesive manufactured by Convenience Products. The adhesive is applied in a zigzag pattern with each line spaced approximately 5.08 cm (2 in) apart and distributed on all contacting sides of each block (Fig. 3). The blocks must be positioned tightly to ensure proper adhesive distribution between blocks. The standard masonry technique of staggering blocks on successive layers is recommended to maximize the strength of the stopping (Fig. 1). The fly ash blocks can be scribed and readily cut to fit with a simple hand saw or axe. Successive layers of blocks are laid until the remaining gap between the top of the blocks on the highest row and the roof is less than the 1.22-m (48-in) height of a full block.

Figure 2. Setting blocks for construction of a Super Stopping using extended reach fork lift and precast lifting holes.

Figure 3. Placing Supper Stopping block in place after applying adhesive.

2.3 *Phase III – Capping and Sealing*

To complete the structure, smaller fly ash blocks, 0.61 m (24 in) by 0.41 m (16 in) by 20.32 cm (8 in) or 15.24 cm (6 in), are used to cap the top of the stopping. As with Phase II construction methods, the smaller cap blocks are staggered and cut to conform to the roof as well as the ribs, and secured in place with an adhesive. The final row of cap blocks should be placed within approximately 7.62 cm (3 in) of the roof and walls of the mine opening.

The remaining gaps at the top and sides of the stopping are sealed using an expansion foam product. Since the foam is applied using a handheld apparatus, access to areas beyond reach is achieved using a man-basket. The stopping constructed at the LLL was sealed using Touch ‘N Seal Mine Foam manufactured by Convenience Products. The foam is applied to approximately half the depth of the blocks, or until expansion of the foam completely fills the voids. The expansion foam acts to conform to the shape of both the cut blocks and surfaces of the mine opening, thus increasing structure stability. Since the fork lift holes do not pass through the entire block, they do not require sealing.

3 THE EZ-UP CURTAIN STOPPING

The EZ-Up Curtain Stopping (Fig. 4) was also constructed by NIOSH at the LLL in cooperation with several manufacturers. This stopping is designed primarily for use as a temporary or portable stopping, although test results indicate it may remain useable for an extended time. The EZ-Up Curtain Stopping can be constructed from a variety of fabrics including mine brattice. Evaluations were performed on EZ-Up Curtain Stoppings composed of two separate curtain materials: (1) NOVA-Shield RU88XFR-6, a high density polyethylene woven fabric, manufactured by Intertape Polymer Group, Inc. and (2) Dura-Skrim D15CFB, which is composed of two layers of film laminated with polyethylene that sandwiches a scrim reinforcement, manufactured by Raven Industries, Inc. The EZ-Up Curtain Stopping is manufactured with a sewn-in loop so it can easily be laced onto tubing while laid out on the ground. It is then hoisted to the mine roof with a strap and ratchet mechanism system. Since the EZ-Up Curtain Stopping is constructed primarily on the ground, workers' exposure to accidents related to the typical 6.10-m (20-ft) to 12.20-m (40-ft) working heights associated with large-opening mines is reduced.

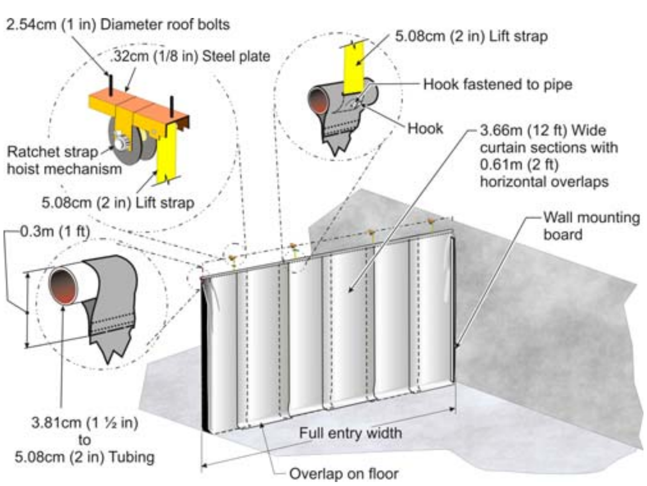

Figure 4. Schematic of EZ-Up Curtain Stopping that is constructed using fabric strips.

The EZ-Up Curtain Stopping is constructed in four phases: Phase I - Preparation and Ratchet Assembly Installation; Phase II - Curtain Preparation; Phase III - Curtain Hoisting; and Phase IV - Securing the Perimeter and Floor.

3.1 *Phase I - Preparation and Ratchet Assembly Installation*

The walls and roof of the stopping installation area should be fully scaled to prevent injuries from falling rock during construction, and to provide a solid foundation to secure the stopping to these surfaces. The stopping is attached to the mine roof with four ratchet assemblies anchored by roof bolts (Figs. 4-5). For the LLL stopping, a 30.0-cm (12-in) long by 2.5-cm (1-in) diameter roof bolt that was anchored in competent roof material provided substantial support to suspend the curtain.

The ratchet assembly (Fig. 5) was constructed by welding the ratchets to U-angle steel stock, drilling two holes into the stock for the roof bolts, and welding a nut on the ratchet for easier winching. The ratchets used for these assemblies are standard off-the-shelf ratchets used for equipment tie-downs on trucks. The four ratchet assemblies are positioned in a straight line across the roof of the entry. One ratchet assembly should be mounted near each entry wall, with the two additional assemblies spaced evenly across the entry. After mounting, the ratchet mechanisms are ready to accept the straps for lifting the curtain.

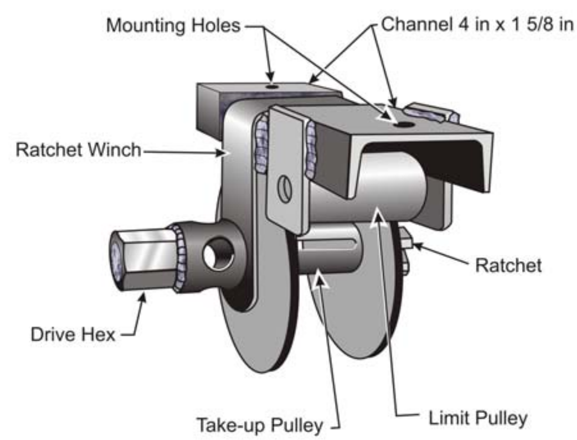

Figure 5. Ratchet assembly for hoisting EZ-Up Curtain Stopping.

3.2 *Phase II - Curtain Preparation*

The fabric size used for the EZ-Up Curtain Stopping should be full entry width and height, plus several feet excess in both dimensions to allow for attachment to the rib and for sealing on the mine floor. A stopping composed of material strips that can also be used as a drive through stopping can be constructed by hanging strips of fabric as shown in figure 4. A similar designed, but one-piece fabric stopping, can be made by having the fabric distributor sew the strips together or, if available, ordering from the manufacturer a custom designed one piece fabric to fit the entry. Both a hanging strip stopping and a one piece stopping were constructed and tested for blast pressures at LLL. In either case, the fabric along the top edge of the fabric material is folded over and sewn at the factory to form a loop, through which 5-cm (2-in) diameter tubing or conduit is threaded (Fig. 4). The individual lengths of tubing can be joined together with either threaded or tapered connections to span the entire length of the entry. For the hanging strip curtain stopping, to limit air leakage, each curtain panel is overlapped horizontally approximately 0.6 m (2 ft) onto the adjoining panel. The loop at the top of each panel must be cut away on one side to allow for the 0.6-m (2-ft) overlap.

3.3 *Phase III - Curtain Hoisting*

The lift straps are suspended from the ratchet mechanisms and attached to the tubing through a narrow slot cut with a small handheld electrical grinder (Fig. 4). The flat plate hook is fitted into the slot, and bolted if necessary, to secure attachment to the tubing. After attaching all lift straps, the EZ-Up Curtain Stopping is lifted using the ratcheting mechanism.

Lifts should be made approximately 1.5 m (5 ft) at a time by alternately ratcheting each mechanism. This will ensure the curtain tubing is kept as level as practical (Fig. 6). The curtain is hoisted until the tubing is flush with the pulley, which will place the top of the curtain near the roof of the mine entry.

Figure 6. Raising the EZ-Up Curtain Stopping into position.

3.4 *Phase IV- Securing the Perimeter and Floor*

The final step in the installation process is to secure the EZ-Up Curtain Stopping to the walls using vertical boards with dimensions of 3.8 cm (1.5 in) by 8.9 cm (3.5 in) by 3 m (10 ft) (Fig. 4). The first set of boards should be bolted to the walls from the roof to the floor in line with the edge of the curtain. Excess fabric on the sides of the curtain is then wrapped onto a second set of vertical boards. This wrapping prepares the curtain for attachment to the existing wall mounted boards to create a sandwich effect. Care should be taken to avoid wrapping the curtain too tight, or stretching the fabric, since the curtain should be able to yield slightly when subjected to variable pressures. The wrapped curtain boards on the prototype stopping at LLL were attached to the wall boards using 0.6-cm (0.25-in) diameter by 10-cm (4-in) long lag screws. Test results, described below, revealed that larger or different anchors would be better. When the curtain is anchored to the rib, excess curtain material along the bottom is trimmed to the desired length to complete the perimeter.

The curtain stopping can be further secured by laying sand bags on the excess curtain material draped on the floor. The bags serve two purposes: they seal the stopping from excessive leakage, and they provide for pressure relief to help reduce stopping damage in the case of a face blast that produces excessive pressures against the stopping. In an overpressure scenario, the curtain will be blown free from the sand bags preventing damage, but the sandbags will need to be replaced to reestablish the seal.

4 RESULTS OF BLAST TESTING

Stoppings in an underground metal/nonmetal mine must withstand air blasts associated with development and production blasting. Evaluation of the structural integrity of such stoppings can be investigated by subjecting them to unconfined blasts. Performance testing using consecutive charges of 1.4 kg (3 lb), 2.3 kg, (5 lb), 3.2 kg, (7 lb), and 4.5 kg (10 lb) of 50/50 Pentolite (50% TNT/50% PETN) unconfined explosive charges were conducted at LLL on the Super Stopping and the EZ-Up Stopping. The explosive charges were positioned at about 1.83 (6 ft) above the floor in the entry, approximately 18.29 m (60 ft) from the stoppings.

The unconfined blast tests confirmed the integrity the stopping construction and the materials used. The Super Stopping evaluation included observing how well the stopping held up to the blasts, i.e. the strength of the adhesive between the blocks, the effectiveness of the perimeter foam, and the overall stability of the stopping. Similarly, the integrity of the EZ-Up Curtain Stopping was tested for material strength, especially at the critical high-tension perimeter areas. From the multitude of blasts test performed, the stoppings were subjected to an incident maximum peak pressure of up to 17.2 kPa (2.5 psig) and up to an incident maximum pulse pressure of 0.14 kPa/s (0.02 psig-s). The incident maximum peak pressure for each test was: 1.4 kg (3 lb), 9.0 kPa (1.3 psig); 2.3 kg (5 lb), 11.7 kPa (1.7 psig); 3.2 kg (7 lb), 14.5 kPa (2.1 psig); and 4.5 kg (10 lb), 17.2 kPa (2.5 psig). Although the exact relationship between the pressures created and acting on stoppings from free standing blast charges and actual face production blasts is unknown, actual pressures from production blasts in operating stone mines have been measured at approximately 6.9 kPa (1 psig) (Mucho et al. (2001)). The Super Stopping showed no structural damage from the tests, although small amounts of superficial foam sealant was dislodged during the 2.3-kg (5-lb), 3.2-kg (7-lb), and 4.5-kg (10-lb) explosive charge blast tests. The EZ-Up Curtain Stopping had no rips or tears in either material tested due to blast pressures. However, during the 3.2-kg (7-lb) blast, several lag screws pulled out that were sandwiching the curtain material to the wood plank that was secured to the rib but damage was not increased during the blast using the 4.5-kg (10-lb) charge and the overall integrity of the stopping remained intact.

5 CONCLUSION

The Super Stopping and EZ-Up Curtain Stopping developed by NIOSH, in cooperation with several manufacturers, provide a practical and effective means to direct ventilation airflows within large-opening mines. The stoppings are durable and withstood test pressures that may be well above normal mine production blast pressures. The stoppings are constructed using economical, readily available materials. The stoppings are a practical and effective means to improve ventilation systems in large-opening mines, and thus reduce worker exposure to airborne contaminants

6 DISCLAIMERS

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health. Mention of any product or company does not constitute endorsement by NIOSH.

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