Roof Screening for Underground Coal Mines: Recent Developments

BY CRAIG S. COMPTON, SEAN GALLAGHER, GREGORY M. MOLINDA, CHRISTOPHER MARK, AND GENE WILSON

Figure 1: Roof screen offers immediate protection for face equipment operators.

The failure of the immediate roof or "roof skin" between installed primary and secondary roof supports causes hundreds of injuries and, on average, one or two fatalities each year in U.S. underground coal mines. Conventional roof supports cannot cover enough roof area to adequately control these relatively small, but very dangerous rock falls. The 2006 Mine Safety and Health Administration (MSHA) accident database lists a total of 542 ground fall injuries, including 10 fatalities. An analysis of the database suggests that 434 of the injuries and three of the fatalities can be attributed to roof skin falls (See Figure 2).

The key to controlling falls of the immediate roof or roof skin is maximizing the area of roof coverage and confining these relatively small loose rocks. Roof screen offers maximum coverage of the immediate roof. Depending on the size and configuration of the screen panels, coverage of up to 100% of the roof area is possible. Screen also offers a first line of defense for machine operators working in the face area by confining or deflecting small rocks that can come loose during mining or roof bolt installation. Figure 1 shows an example of the protection screen provides during bolt installation.

Although the benefits of screen are well-known, mining companies in some areas of the U.S., mainly Northern Appalachia and the Illinois basin, are not convinced that roof screen is the best tool for dealing with roof skin control issues. The logistics of material handling, possible ergonomic injuries to workers, and the costs associated with installation are delaying the acceptance of screen as an on-cycle roof support tool. Other mines however, have concluded that installing roof screen can be cost-effective when compared to the cost of lost time accidents, training of replacement workers, or returning to already developed entries for the cleaning and rebolting process.

Installation Technique with Roof Screen Stored on the Bolting Machine

The majority of room-and-pillar coal mines in the U.S. use an outside-controlled dual-boom roof bolting machine, especially in seam heights of less than 8 ft. This type of roof bolting machine was not originally designed to store, transport, or assist with screen installation. Therefore, each coal mining company that uses these machines to install roof screen on a routine basis has developed its own procedures and machine adaptations to ease the installation of screen panels.

The National Institute of Occupational Safety and Health (NIOSH) has observed that good housekeeping practices and the organization of materials on the bolting machine ease the entire roof support process. At the most productive and efficient operations, supplies are arranged to give the scoop unobstructed access so that screen panels can be loaded quickly and safely. Supplies on the machines are positioned to minimize the amount of bending and lifting required by the operators to complete the bolting and screening procedure. Screen panels are carried on top of the scoop from the supply area to the bolting machine, instead of being dragged, to reduce damage to the panels and make them less difficult to install. The most efficient supply method observed was the use of racks or rails (See Figure 3) installed on the bolting machine.

This practice allows roof screen to be stored on the machine without hindering access to other consumables stored on the bolter. Screen panels can be loaded on these racks by supply personnel while the roof bolters are installing bolts, eliminating the need to stop the machine for re-supply while personnel change places. This installation technique has been observed to work seamlessly with an experienced crew. The operators also used the stored screen panels as a platform to help rotate and slide the roof screen into the installation position. Keeping the screen stored off of the floor significantly reduced the amount of bending and lifting usually associated with screen installation. Compared to other techniques observed, this system appeared to be the safest, fastest, and least strenuous for the machine operators.

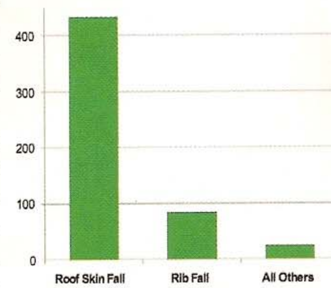

Figure 2: 2006 Ground Fall Injuries by Fall Type.


Figure 3: Roof bolter equipped with roof screen storage rack.

As a best practice for installing roof screen using an automated temporary roof support (ATRS), when a new cut is entered, it is important that the operator position the machine with the ATRS outby the last row of bolts before positioning the screen panel. After the screen is secured to the ATRS, the machine can be trammed into position and the first row of bolts installed. When installation of the first row of bolts is complete, the following step by step procedure is used to install each screen panel:

1. The ATRS and personal canopies are lowered enough to allow screen panel to be carried over and positioned on top of the ATRS with minimal effort.
2. The roof bolter is backed up until the ATRS is outby the last row of bolts by at least 12 to 18 inches. Total maximum distance needed to back up the machine is approximately 3-1/2 to 4 ft. Backing up is necessary to ensure that the operators do not reach inby the last row of permanent support.
3. The forward end of the top screen stored on the rack is pushed toward the operator deck-side of the bolting machine, minimizing the distance the other operator has to reach to get ahold of the screen. The off-side operator then walks to the back of the screen, and together both the operators lift and carry or slide the screen panel over the personal canopies and onto the ATRS. Pre-measured marks are put on the ATRS to allow positioning of the screen correctly and quickly. The marks on the ATRS can be adjusted so that rib bolts are placed at the desired distance from the rib.
4. Once in position, the screen is secured by bending over a piece of 12-gauge wire secured to the ATRS. This holds the screen in position until the bolter is moved forward into position and the ATRS is set against the roof.
5. When the row of bolts is installed, the ATRS is lowered and the 12-gauge wire pulls away from the screen panel. The steps are then repeated for each row of roof bolts.

Improved Screen Handling Techniques and Equipment

Roof bolter operators are arguably the hardest working persons in the mine. They are constantly lifting, bending, pulling, and carrying materials they need to control the mine roof. Material handling injuries continue to sideline hundreds of underground workers each year. Lost time material handling accidents constituted 32.6% of all lost time accidents in underground mining between 2000 and 2005, according to the MSHA database.

Adding roof screen installation to the already labor-intensive job of the roof bolt operator obviously increases the risk of stress and strain injury to the operator. With this in mind, based on observations from various successful roof screen installation techniques in the field, NIOSH has developed several combinations of rails or bars that can be easily retrofitted to existing bolting machines. NIOSH ergonomists also designed tests that would evaluate different techniques of lifting and carrying roof screen based on the relative risk of back injury. The initial design was tested on a Roof Ranger II dual-boom roof bolter loaned to NIOSH by J.H. Fletcher and Co., and later on a full-scale wooden mock-up of an outside-controlled bolting machine built by NIOSH at the Pittsburgh Research Lab (See Figure 4).

The tests involved lifting and transporting eight full sheets of roof screen up to the ATRS to simulate the requirements for screening a typical cut. Several conclusions were drawn from these laboratory investigations. First, the data show that muscular demands are reduced when sliding roof screen on rails rather than manually carrying them. This reduced muscle activity indicates lower loading of the joints and muscles and a lower risk of repetitive trauma injury. Secondly, sliding screens on the rails was faster on average than manual carrying. Both of these findings strongly support the use of rails and/or racks to assist with screen installation. However, lifting screens from the ground when they are dragged behind the bolter requires a significant degree of forward bending, which puts the spine at risk. This risk can be reduced if screens are stacked/stored on the rails mounted on top of the machine.


Figure 4: Roof screen ergonomic studies at the Pittsburgh Research Lab's mine simulator.

In 2000, J.H. Fletcher introduced the walk-through CHDDR roof bolter with a complete material handling system (MHS). The system consists of removable pods for bolter consumables and a mesh tray that loads and holds roof screen. J.H. Fletcher has developed a slightly modified version of the MHS for the Roof Ranger II roof bolter (Figure 5). The Roof Ranger II is designed to be used in seam heights between 96 and 48 inches, so instead of a mesh tray, a "goal post" type of storage rack is

Figure 5: Roof Ranger II with material handling system.

used for roof screen storage, located along the centerline of the machine. The operator deck has been replaced by remote control operation on both machines. This allows the operator much greater visibility while tramming the machine and provides additional room on the deck for the material handling system. All of these modifications are meant to reduce some of the repetitive motions and awkward positions that roof bolter operators encounter routinely while performing their jobs. Reducing the number of lost time injuries and transferring difficult tasks from the worker to the machine can also lead to higher job satisfaction and improved workforce morale.

Economic Benefits of Roof Screening

When the best available practices for screen installation are employed, together with simple modifications to the roof bolting machine detailed above, the impacts of screen installation on the overall mining cycle can be minimized. For example, NIOSH visited a mine near Evansville, Ind., that has routinely installed screen in about 50% of its drivage since it was opened in 2004. This mine is also one of the most productive underground mines in the U.S. According to MSHA data, the 67 underground employees at this mine produced nearly 1.2 million tons of clean coal in 2006, achieving a productivity of 6.6 tons per employee hour.

Moreover, there are substantial potential economic benefits to the use of screen. The most valuable is the opportunity to reduce the cost associated with rock fall injuries. NIOSH studies have found that a "struck by rock" injury can easily cost in excess of $100,000, and a permanent disability could cost $1 million. Because injuries are so expensive, workman's compensation costs for underground coal mines typically average 20% to 40% of payroll in the eastern U.S. Industry-wide, rock falls account for about 10% of these costs, and at many mines the percentage is considerably higher.

A simple example shows how a program of screen installation can actually save a mining operation money. A key assumption is that roof bolting is not the bottleneck in the production process—in other words, screen installation can be added without decreasing the footage of advance per shift. This situation is not unusual when two dual-boom roof bolters are used on a supersection (as at the Indiana mine described above). Other assumptions include:

- The section advances 400 ft/shift in a 5-ft-thick coal seam.
- Roof bolts are installed on 4-ft centers in 20-ft-wide entries.
- Straps, costing $8 per piece, are currently installed in all headings and crosscuts.
- Screen installation requires an additional 10 minutes per 40 ft of advance.
- Screen, costing $16 per piece, will replace the straps in 50% of the drivage.
- Labor cost (fully loaded) is $40/hr.

The incremental costs associated with the roof screening program can be estimated as:

- Cost of screen = $2/ft.
- Cost of labor to install screen = 0.25 minutes/ft times two roof bolt operators = $0.33/ft.
- Cost of supplying screen to the section is approximately $0.10/ft.

The total cost for installing screen is therefore approximately $2.43/ft or $0.58/ton. If screen is installed in 50% of the drivage, the cost per ton for the mine drops to $0.29/ton. If this one-section mine produces 1 million tons annually, the yearly cost for the screen installation is $240,000. A single rock fall injury could cost more than that amount in workman's compensation. Indeed, if the screen program succeeds in reducing workman's compensation premiums by just 25% at this mine, the savings could be sufficient to pay for the entire program.

The economic benefits of roof screening go well beyond a reduction in direct injury costs. An effective screening program that brings down the rate of rock fall injuries can indirectly save money by:

- Reducing the costs associated with replacing injured workers,
- Reducing labor turnover and improving workforce morale,
- Reducing requirements for extra spot bolts to support loose roof, and,
- Reducing the costs associated with long-term clean-up and re-support.

Roof screen has the potential to prevent hundreds of injuries caused by the fall of small rocks between permanent roof supports. The ability of screen to cover all of the gaps between permanent supports makes it the most effective method for stopping the fall of these relatively small rocks. Simple modifications and installation procedures can substantially increase the efficiency of outside controlled dual-boom roof bolting machines used to install roof screen. Supplying roof screen to racks/rails fitted on bolters can significantly reduce the risk of a back or strain injury to roof bolter operators. Material handling systems currently available on J.H. Fletcher roof bolters can reduce the stress and strains associated with roof screen installation as well as reduce the time necessary to complete screen installation. Basic machine modifications, well-planned supply methods, and using best practice installation techniques can minimize the economic effects of roof screen installation on a mine's overall mining cycle. Reducing the number of rock fall injuries at a mine will also have a positive effect on the economics of a mine and improve the morale of the entire workforce.

Compton is an engineering technician; Gallagher is senior research scientist; Molinda is lead research scientist; and Mark is principal research engineer for NIOSH-Pittsburgh Research Laboratory, located in Pittsburgh, Pa. Wilson is the manager of product development for J.H. Fletcher & Co., located in Huntington, W.Va. This article was adapted from a paper presented last year at the International Conference on Ground Control.