CDC
Workplace Safety and Health

Make It Safer With Roof Screen

National Institute for Occupational Safety and Health
NIOSH

Instructional Materials

A Brief History of Roof Screen

Roof screening for ground control originated with metal miners in the western United States. At first chain-link fence was used, but because it was so difficult to handle, the miners started installing a more rigid welded wire screen used in the concrete industry. Eventually coal mines in the west began to use screen, and now more and more coal operations, especially longwall mines, are installing roof screen on a regular basis. Screen use has recently increased in the Illinois basin and is now making its way to underground coal mines in the eastern U.S.

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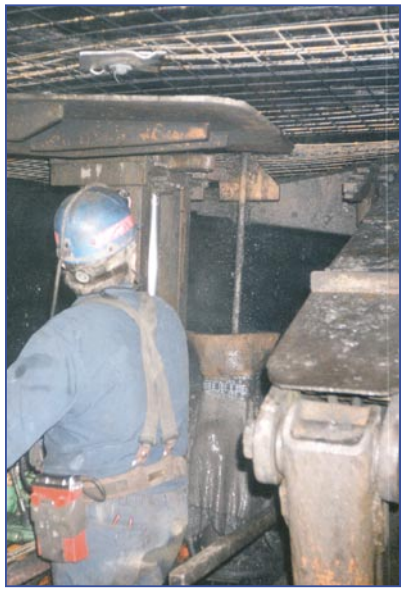
Introduction

Coal miners, especially roof bolter operators, work in a hazardous environment where they are frequently exposed to poor roof conditions, putting them at risk of a rock fall injury. Over 450 reported injuries each year result from rock falls; 99 percent of those reported are not caused by a major roof collapse, but from falls of smaller rocks from the mine roof (Robertson et al., 2004). Roof bolts are not failing; rather, the rocks are falling from the uncontrolled area in between the bolts. The loose rocks that cause injuries are usually just a few inches thick but weigh on average 280 lbs. (Molinda et al., 2003).

Loose rocks can fall from between roof bolts and injure miners.

The highest percentage (44%) of rock fall injuries happen to roof bolter operators, followed by continuous miner operators. Roof bolters must work in the most hazardous place in the mine: the freshly cut face. Their bolting activities, especially the drilling process, can disturb the mine roof and cause pieces of rock to fall. A particular concern is the unprotected space between the Automated Temporary Roof Support (ATRS) and the bolter canopy. Even after the roof is bolted, continuous miner (CM) operators and other miners can be injured by falls of loose rock.

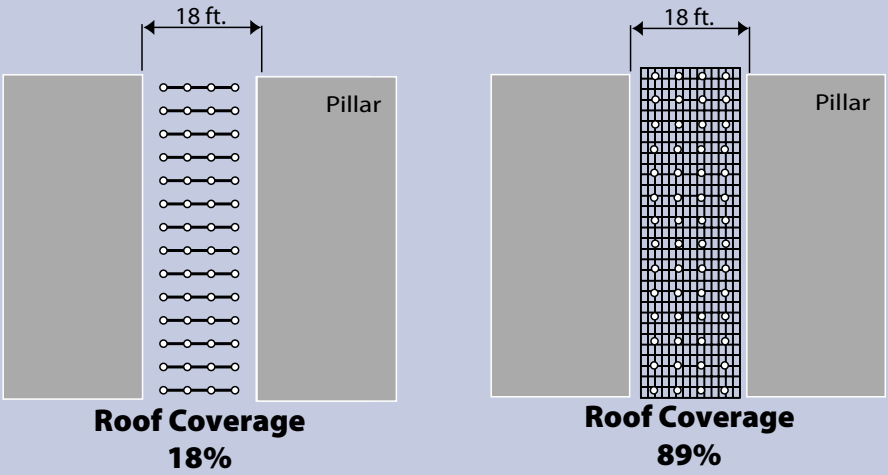


Roof screen provides overhead protection to the bolter operator during the entire bolting installation process.

*"Our top isn't heavy necessarily, it doesn't load up, but we have **small pieces of roof rock that fall out between roof bolts**. We tightened up our roof bolt pattern, but yet that didn't help. But the **screening has solved that problem**."*

~ Mine Safety Director, West Virginia

The Roof Screen Advantage



Compare the coverage provided by roof mats (a widely used surface support sometimes called straps or "bacon strips") versus roof screen.
A mine with 18-ft. entries that installs 16-ft. x 10-in. steel straps every 4 ft. of advance achieves 18% roof coverage. By installing 16-ft. x 5-ft. sheets of screen instead, the coverage can increase five-fold to 89%.
The material cost for the screen is only about 25% higher.

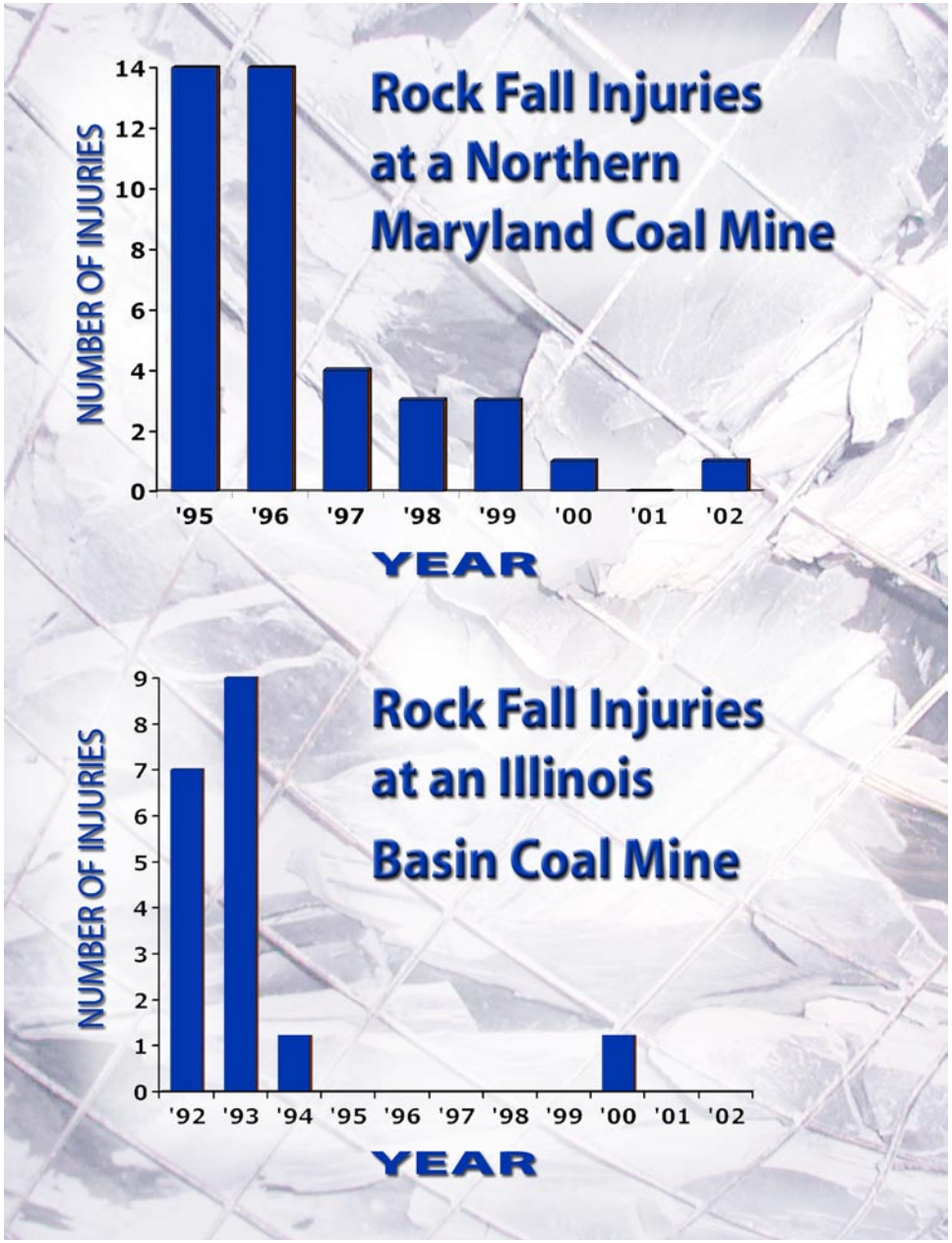
Surface controls, including steel straps, header boards, large surface plates, and steel screen or mesh help protect miners from loose rock. The effectiveness of a surface control depends on the amount of roof that it covers. Roof screen is by far the most effective surface control because it covers the most roof area.

Roof screen can cover a large area of the mine roof.

Roof screen has been proven to dramatically reduce the number of rock fall injuries at coal mines. One mine in northern Maryland began roof screening routinely and on-cycle in 1997 because of very poor roof conditions and a high occurrence of small rock falls. Before the mine started installing roof screen it averaged fourteen rock fall injuries per year; after 1997, rock fall injuries reduced dramatically. At another mine in the Illinois basin, similar geologic circumstances were encountered which also required roof screening. Rock fall injuries subsequently dropped from an average of eight per year to only two injuries over the next nine years (Robertson et al., 2004). These injury reductions were attributed to the overhead protection that screen provides to operators throughout the entire bolt installation process, including the area between the ATRS and the canopy. In addition to roof bolter operators, all others (CM operators, etc.) who work below the installed screen will have overhead protection from rock falls.

"Before the roof screening, it was hard to travel in on the track and back out without having to clear rock off the track. It was just a matter of time before someone was going to get some rock on them. Now you can go in and out of the mine everyday and travel the track entry freely and not have to worry about getting a piece of rock on you or someone else getting a piece of rock on them."

~ Mine Safety Director, West Virginia



Data collected from two years before and several years after the start of full-scale roof screening shows the dramatic reduction in rock fall injuries.

Specification / Custom Ordering

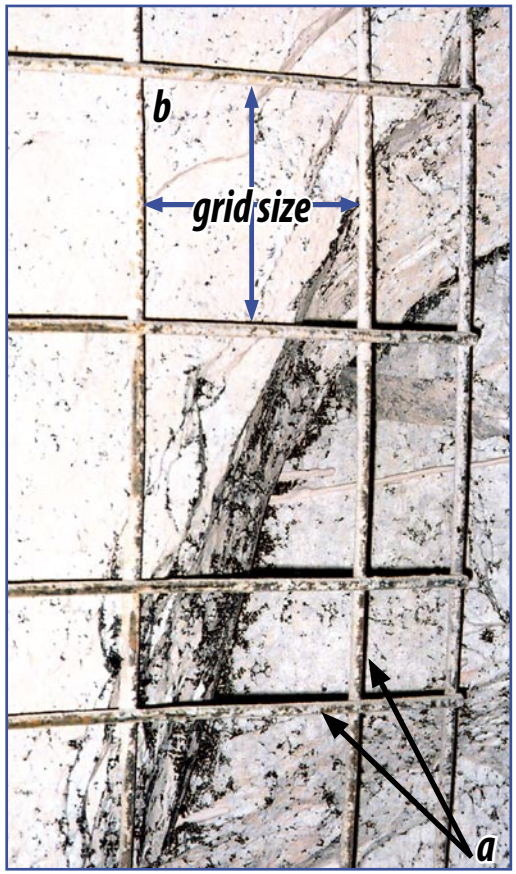
Roof screen can be ordered from the manufacturer or vendor with the following options:

Size of Roof Screen – Manufacturers can produce roof screen in various sizes and shapes (width and length) depending upon the needs of the mine operator.

- A full sheet of screen (commonly 16-ft. x 4-ft.) is generally wide enough to stretch across both ATRS rocker pads of the bolting machine.
- A smaller sheet of screen (e.g. 5-ft. x 5-ft.) called a Personal Bolter Screen (PBS) can be easily handled by one person.

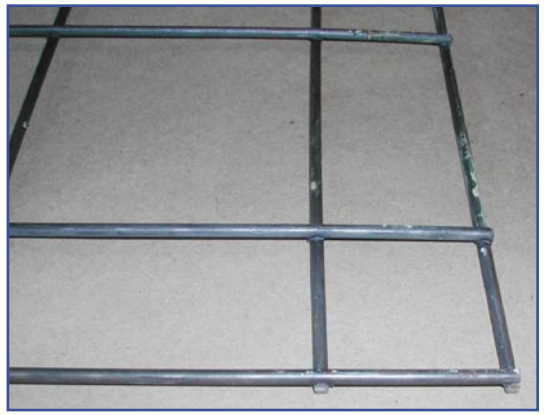
Grid Size – The grid size of roof screen is the size of the opening between the wires in both directions. A typical grid size is 4-in. x 4-in., but other sizes are currently being used.

Reinforcing Wire – Roof screen can be ordered with extra wires to reinforce the screen in selected areas. Some mines choose to add reinforcing wires around the perimeter of the screen, while others place them in the locations where bolts will be installed. Reinforcing wires are sometimes called "indicator wires" because they help show bolting machine operators where to install roof bolts.



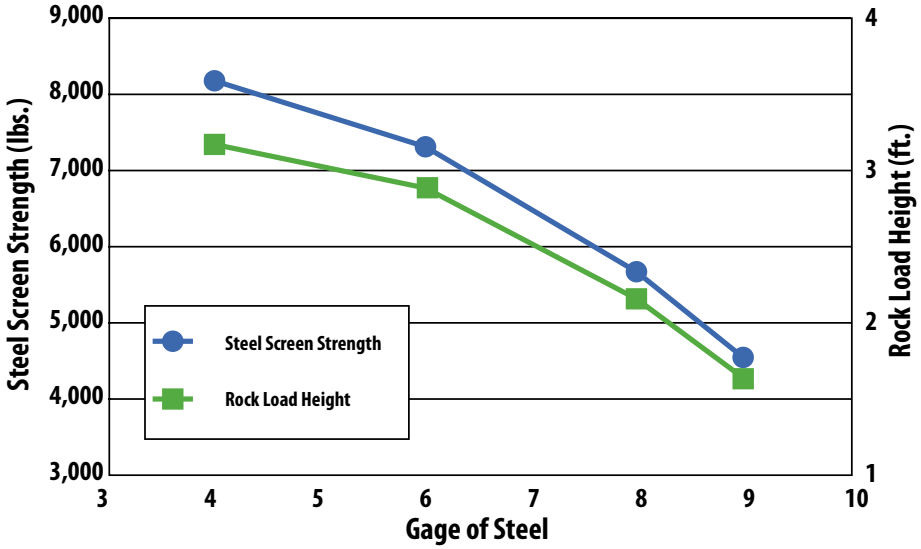
(a) Reinforcing wire can be fabricated into the screen at various locations. (b) Grid size is the space between the wires.

Edge Cuts – It is important to order roof screen with minimal, if any wires protruding from the edges of the screen. Protruding wire ends can catch materials causing tears and snags and are a potential cut/puncture hazard. Certain screen manufacturers are able to cut the edge wires down to an eighth of an inch, while others are able to "trim cut" the wires so that they do not protrude at all from the edge of the screen.



Screen that is "trim cut" has no wires protruding from the edge of the screen.

Strength – The strength of the screen depends on the gage (diameter) of the steel wires and the grid pattern of the screen. As the gage of the steel wire decreases, the diameter increases along with the strength and rock load heights that the screen can maintain (as seen in the graph below). A common choice of gage for coal mines is an 8-gage steel screen that can hold up to 2 feet of rock.



NIOSH studies showed the relationship between gage and strength/rock load heights for roof screen bolted on 4-ft. centers with a 4-in. grid size. (Robertson et al., 2003)

Installation

Machine manufacturers have been working with mine operators to design innovations that will make roof screening safer and easier. NIOSH has observed and performed production time studies of different roof screening procedures at numerous coal mines and found that the installation procedures and screen-handling times depend on the following:

* Number of persons – Aside from the two bolting machine operators, some mines utilize an additional person (often the utility person or scoop operator) to help retrieve, carry, and handle the roof screen.

* Operator experience with the installation of roof screen – As mine operators and bolting machine operators find better ways and gain experience installing roof screen, the installation time generally decreases.

* Size and Weight of the Roof Screen – The size and weight of the roof screen can affect how easily and quickly the roof screen is handled and installed. In general, two operators are needed to handle a full sheet of screen whereas a single operator may be able to easily handle a personal bolter screen.

* Type of twin-boom roof bolting machine – Roof screen is being installed using three types of bolting machines. Each can include various devices (clamps or wires) that can be used to help make sure that the roof screen does not slide across the ATRS when it is being raised against the roof. Once the


a


b


c

screen is secure against the roof, roof bolts are installed using normal procedures.

a. Outside-controlled - With most outside-controlled bolting machines, the screen can be stored either on top of the rear of the machine or behind it on the ground. It may also be pulled behind the machine by a rope or chain. To install the screen, both bolting machine operators retrieve a sheet, carry it to the front of the machine, and then place it on top of the ATRS.

b. Walk-thru - With a walk-thru bolter, the screen is also stored on top of the machine, on the ground, or pulled behind the machine. Operators carry the roof screen up the center of the machine before placing the screen across the ATRS.

c. Walk-thru with a Materials Handling System (MHS) - A Materials Handling System retrofitted onto a walk-thru bolting machine has numerous machine innovations, including a mechanized screen tray that makes materials handling of screen and bolting supplies much easier and safer.

The results of recent roof screening time studies and observations conducted by NIOSH (Robertson et al., 2004) were the following:

* Roof screening added between 5 and 25 percent to normal bolt installation times.

* The addition of the third operator reduced load and installation times by 40 percent.

* Installation times were reduced by 50 percent as operators gained more experience handling and installing roof screen.
* Roof screen installations were 30 percent quicker using a walk-thru bolter when compared to the outside-controlled machine.
* Operator maneuverability while installing roof screen was easier using a walk-thru compared to the outside-controlled bolting machine.
* The total screen handling times were 40 percent lower using the MHS compared to the regular walk-thru bolting machine with the majority of the time saved during screen loading onto the bolting machine.

The procedures and handling times for installing roof screen on-cycle will vary from mine to mine. Mine operators should work to find the best way to install screen, keeping the health and safety of their workforce in mind at all times.

Manual Materials Handling Tips

While the best way to reduce injuries associated with manual materials handling is to automate or mechanize the process, it is not always feasible or cost-effective. Manual materials handling can be done effectively and efficiently if careful consideration is given to the methods and principles used. Musculoskeletal injuries may result from task design that requires physical effort in excess of workers' capabilities and limitations. In the mining industry, over 40% of the injuries are musculoskeletal (MSDs) and cumulative in nature, with bolting machine operators experiencing the highest percentage. The highly repetitive job of roof bolting coupled with an increased workload due to screen installation is cause to give attention to preventing MSDs.

Because roof screen has been determined to save many acute injuries such as cuts, contusions, and/or fractures, screening should be considered a necessary practice to ensure the safety of our mining workforce. Nevertheless, the installation process should not be so laborious as to deter operators from using this method to reduce the risk of rock fall injury. With that said, procedures to reduce the risk of cumulative injury to the worker when handling and installing roof screening materials follow:

* Closely estimate the number of sheets needed near a face area, then try to deliver only that specific amount. Contact the roof screen vendors or manufacturers to customize the number of sheets per bundle. The goal is to avoid rehandling the excess sheets.
* Keep lifting tasks between the elbow and knee levels. Lifting from below the knees or above the elbow levels increases the risk of injury.
* Minimize twisting and bending at the waist when picking up roof screen. Keep your back straight and turn slowly before proceeding to walk with the screen.
* Always use two workers to carry a full sheet of screen. Keep your back straight and keep the screen as close to your waist as possible.
* Using various mechanical devices, keep the roof screen from sliding off of the ATRS to avoid re-handling.
* Working overhead is difficult but a major task for roof bolter operators. Although it is difficult to eliminate this component, reducing the time spent in this posture is essential.
* Keep the bolting machine organized making sure that operators can easily retrieve bolting supplies. A screen tray and material pod system (as shown on p. 11) are machine innovations that keep the bolting machine orderly and more efficient.
* Keep the walkway areas on or around the bolting machines clear of clutter and debris to reduce tripping hazards.

More scientific research is still needed to minimize the effort required to handle and install roof screen. NIOSH researchers are planning a study on ways to reduce and eliminate the physical effort involved in the roof screen installation process as well as increasing efficiency. Included in this study will be the testing of new machine designs and materials handling innovations.

Materials Handling System (MHS)

The Materials Handling System (MHS), currently being used by several mines, can greatly simplify the screening process. Its most notable feature is a mechanized screen tray for storing the roof screen on the bolting machine. An entire bundle of screen can be pulled onto this tray at one time by a remote-controlled winch system (as seen in the video) which practically eliminates the hand-loading of roof screen onto the bolting machine. Front and rear lift cylinders decline the tray towards the mine floor, and the tray can be placed at a ramped angle so that the bundle can be pulled onto the tray easier. NIOSH studies have shown that by using the screen tray system, roof screen can be loaded on the bolting machine five times faster than when hand-loading each piece of screen (Robertson et al., 2003).

The screen tray of the MHS is tilted back toward the ground for the loading of a bundle of screen (a) by a remote-controlled winch (b,c).

During roof screen installation, the screen tray is raised to an elevation and angle which allows the bolting machine operators to pull a sheet of screen off of the screen tray easily. The screen is then placed across the ATRS and installed with roof bolts. This tray can also be lowered and

"And since we went to this MHS system, our injuries, as far as bending, back injuries, and the twisting turning type have really dropped dramatically."

~ Shift Foreman, Illinois

"In the old days when we had to load the bolter, everything was done by hand. We had to load plates, all the glue, the bolts – tops and bottoms, everything. We had quite a few accidents – back injuries, shoulder injuries. With the material pods, we don't have to do that. Everything is pre-loaded so it has reduced our accidents immensely."

~ Section Mechanic, Illinois

moved to the center of the machine to protect the screen from damage, especially when tramming around corners.

The MHS also reduces the amount of materials handling required for the entire bolting process through the use of material pods that are loaded outside the mine. A larger left pod and smaller right pod contain supplies such as bolts, plates, cap boards, and resin boxes – enough for a full shift. Both the left and right pods are loaded into the scoop bucket and then delivered to the rear of the bolting machine. The pods are then pulled directly off the scoop in the same manner as the roof screen, by a remote-controlled winch system. The risk of sprain/strain, slip/trip, crush, or cut types of injuries is greatly reduced with the pod system. NIOSH studies have also found that two miners can supply the bolting machine as much as three times faster with the pod system than three workers can when hand-loading bolting supplies on a machine without the pod system (Robertson et al. 2003).


Scoop bucket loaded with pods of bolting supplies for the MHS.

Personal Bolter Screen (PBS)

In thin coal seams, handling a full sheet of screen can be awkward. In other cases it may not be necessary to install a full screen. For these situations, NIOSH has developed a smaller screen that can be installed by a single bolting machine operator. Called the Personal Bolter Screen (PBS), this screen can vary in size but is typically around 5-ft. wide x 5-ft. long. The PBS with a reinforced perimeter wire weighs just 11 lbs.

As seen in the video, the PBS can be installed with pattern bolting and has a 6-inch overlap of each screen. Trial installations have shown that the PBS is easy to handle and can be stored easily on the bolting machine. Material costs are comparable to roof straps and it affords three times the roof coverage. Single sheets of PBS can also be used for occasional supplemental support where roof conditions call for it or where specific tasks are being performed.

The Personal Bolter Screen is easily handled by one person.

Conclusion / Best Practices

Roof screening has been found to be an effective method for controlling poor roof conditions. Compared to other supports used to control loose roof rock, roof screening provides the most mine roof coverage. The experience of mines that use roof screen shows that injuries from falls of loose rock have been reduced dramatically. Increased use of regular, on-cycle roof screening in adverse conditions will help the mining industry reduce the annual number of rock fall injuries.

To help mines develop simpler and safer roof screening systems, the following best practices have been compiled:

1. Perform a biomechanical analysis of installation procedures to determine physical and time requirements (e.g., determine postures and handling methods which reduce physical workload).

2. Consult with roof bolting machine manufacturers about innovative ways to make roof screening easier and safer. These could include:

   - Rounded edges on bolter canopy tops to reduce material snagging and decrease the physical effort required to move the screen into place.

   - Retractable clamps or a wire assembly on the ATRS that can hold the screen in place while it is being raised against the mine roof.

   - The use of a separate tray to make roof screening easier to handle and provide for better storage of roof screen on the bolting machine.

(a) Bolter canopy with rounded edge. (b) Clamps hold the screen in place while the ATRS is raised against the roof, then retracts automatically.

- Remote-control operations, winches and material pods may eliminate or reduce material handling difficulties.

3. Ensure that no body parts extend past the last row of bolts when placing a sheet of roof screen across the ATRS by backing up the bolting machine a foot or two after each sheet of screen is installed.

4. Try to order roof screen that does not have wires protruding from the edges of the screen (trim cut) to reduce materials handling difficulties and lessen injury potential.

5. Consider roof screen fabricated with reinforcing wires to help sustain the integrity of the screen and aid in proper bolt spacing.

6. Try using small sheets of plywood or matting between the roof bolt plate and screen to prevent the roof bolt plates from cutting the screen wires.

Plywood installed between roof bolt plate and roof screen.

7. Fit anti-fatigue mats on top of the bolting machine walkway to provide a more cushioned standing surface, reducing fatigue on the feet, knees, and lower back.

*"Since we've gone to the screening **we've definitely improved safety**. It's hard to tell how many accidents that we've prevented by installing the roof screen. I like it. The men like it. It makes us **a much safer coal operation** to work at. Had we started this from day one – I wish we would have – we may have prevented several other accidents as well."*

~ Mine Safety Director, West Virginia

Other sources of information

- Personal Bolter Screen Poster (http://www.cdc.gov/niosh/mining/topics/groundcontrol/PBSposter2_GroundControl_2003.pdf)

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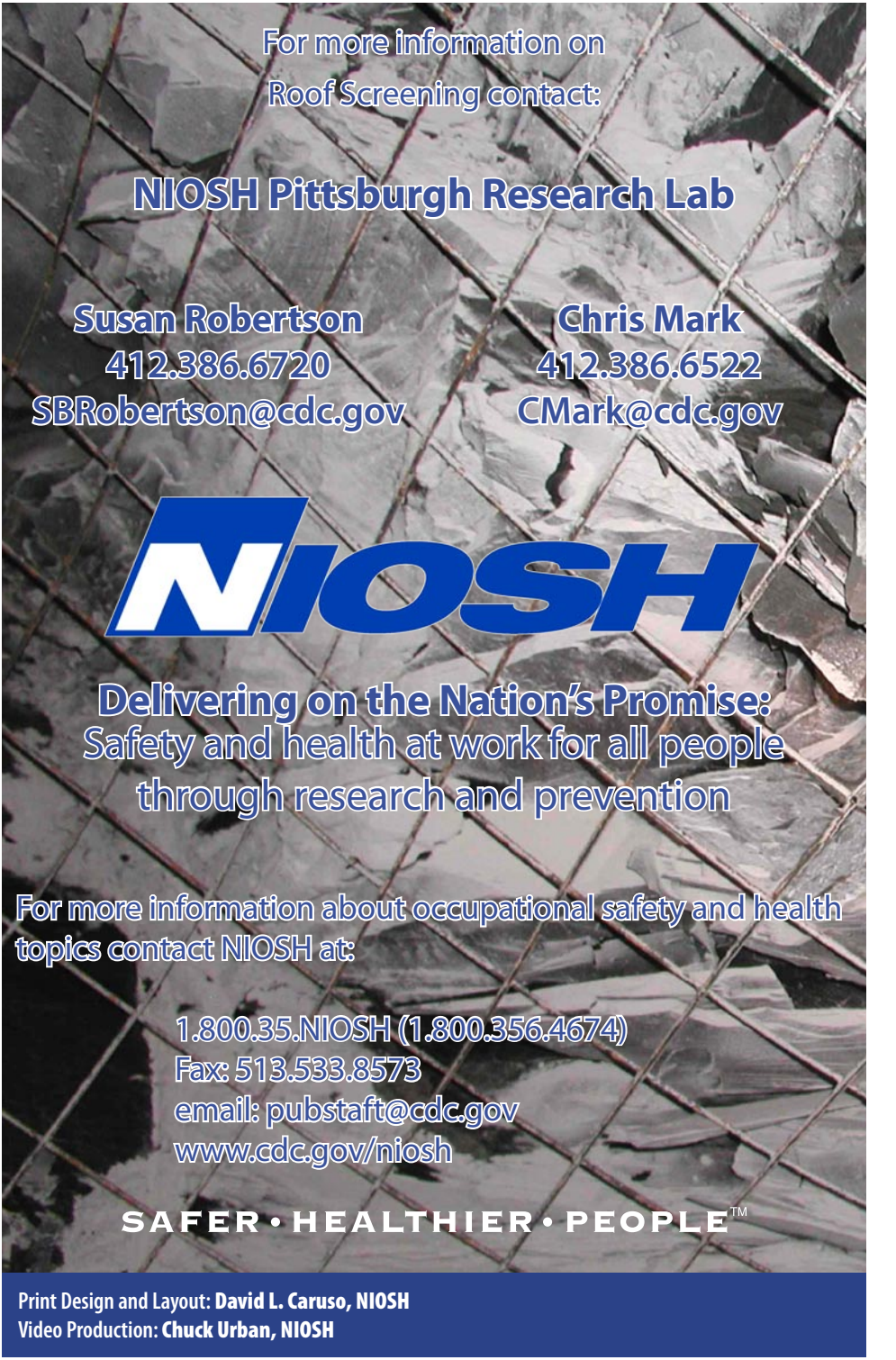

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Print Design and Layout: **David L. Caruso, NIOSH**
Video Production: **Chuck Urban, NIOSH**