# SKIN FAILURE OF ROOF AND RIB AND SUPPORT TECHNIQUES IN UNDERGROUND COAL MINES

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## ABSTRACT

Skin failures of roof and rib in underground coal mines continue to be a significant safety hazard for mine workers. Skin failures do not usually involve failure of the support systems, but result from rock or coal spalling from between the support elements. For instance, in 1997 more than 800 miners were injured by roof and rib falls, of which 98% were the result of skin failures [Bauer et al. 1999]. Also, nearly 80% of the roof and rib failure injuries occurred at or near the working faces in development sections. The face area is a zone where the potential for skin failure accidents and injuries and for roof and rib failures is high because of mining activity, ground readjustment due to changing stress conditions, and the higher exposure of mine workers. In addition, failures occur where the roof and rib are unsupported. This paper reviews the roof and rib accident statistics resulting from skin failure, and highlights the incidences by type, numbers and percentage, in-mine location, supported and unsupported roof, and worker activity at the time of injury. Also discussed are the causes of roof and rib skin failures, current and improved support methods and materials for skin surface control, and machine design modifications for improved roof bolter operator protection. It also reviews the historical literature on skin failures and control methods.

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## INTRODUCTION

Falls of roof and rib traditionally have been one of the leading causes of mine worker injuries and fatalities in underground coal mines. From 1993 to 1998, nearly 35% of all reported underground incidents resulted from falls of roof and rib. These falls of roof and rib resulted in more than 4,600 injuries, or 12% of the total reported underground injuries. Also, skin failures, which are the failure of small blocks or slabs of roof and rib, have been recognized as a problem in the coal mining industry for many years. Detailed analyses showed that in 1997 alone, approximately 98% of the roof and rib injuries were from skin failures. This suggests that as many as 4,500 injuries may have resulted from skin failures of the roof and rib during this 5-year period.

Reference to skin failures is found in the literature as far back as the late 1920s. Most of the early references discussed the effect of moisture and humidity on roof failures [Paul 1928; Hartman and Greenwald 1941]. Other authors addressed ways to condition mine air, such as water sprays and tempering entries, to prevent roof deterioration [Fletcher and Cassidy 1931; Herbert 1940]. Considerable work was presented on the effectiveness of various sealants to coat mine strata, including coal tar [Brown 1941], Ebonol [Robbins 1937], asphalt-based paints [Shacikaski 1951], sulfur-based coating materials [Dale and Ludwig 1972], cement and cement mixtures [Artler 1974], shotcrete [Cecil 1968], and polymeric sealants [Franklin et al. 1977]. More recently, researchers have investigated the mechanisms of shale roof rock deterioration due to atmospheric moisture, which seems to be a result of stresses from moisture-induced weakening and swelling strain, rather than slaking [Cummings et al. 1983; Pappas and Vallejo 1997]. Finally, although much attention has been given to the effects of moisture and humidity on the mine roof and the resultant roof slaking, moisture-induced skin failure is probably not the most prevalent cause of roof skin injuries. This moisture-induced slaking is primarily a nuisance from the standpoint of cleanup and perception. Skin failure of the roof due to geology and stress, in combination with mining, creates a more substantial hazard to the miners at the face and not the long-term deterioration of the roof due to moisture. Supporting evidence is that nearly 80% of all roof skin injuries occur inby the feeder breaker in development sections. To date, the problem of skin failure at or near the working face has not been adequately addressed. This type of skin failure will have to be addressed by surface control systems other than sealants and by the use of alternative methods, such as removal of a lower roof member during mining.

Although the above literature dealt mostly with roof skin failure, rib skin failure has also received attention by the coal mining industry. The theory and practices regarding rib failure, especially in thick coal seams, were addressed by Smith [1989], who suggested that fracturing begins at a stress level equivalent to one-third to two-thirds of the ultimate strength of the material. Peng [1986], Dolinar and Tadolini [1991], and Dolinar [1993] discussed general coal rib stabilization and the effectiveness of wood dowels, resin bolts, and straps to provide pillar reinforcement. Martin et al. [1988] provided information that demonstrated the superior performance of yieldable rib bolts to stabilize ribs when twin-seam mining at Jim Walters Resources. Wykoff [1950] and Horino et al. [1971] investigated the use of wire rope to wrap pillars. Their research indicated that wire rope can significantly affect the compressive strength and stability of pillars. In addition, many of the references on mine sealants mentioned the use of these for coating and sealing coal ribs.

Many advances have been made in dealing with roof and rib failures. Unfortunately, the problems have not been eliminated. Continued research by government, academia, labor, and the mining industry is needed to address roof and rib skin failures and minimize the associated injuries to underground mine workers. Research at the National Institute for Occupational Safety and Health (NIOSH) is continuing this effort by investigating the causes of skin failure and evaluating control techniques.

## DESCRIPTION OF SKIN FAILURE

For the purposes of this paper and analyses, skin failure does not involve the failure of the primary support, but the spalling of rock from between roof bolts and from around the automated temporary roof support (ATRS) system and canopies of roof bolting machines. Rib skin failure includes the spalling of coal from unsupported ribs. Skin failure involves smaller pieces of rock or coal, rather than massive roof failures (above anchorage) or coal pillar failures (bumps and bursts). Skin failures can occur in both supported and unsupported mine strata. Figure 1 shows skin failure of unsupported mine roof; figure 2 is an example of skin failure of supported (bolted) mine roof where the failure occurs between the supports. In general, skin failure of the roof inby permanent support must be controlled by the ATRS or canopies of the roof bolting machine. The skin failure under permanent support can usually be handled by removal or by surface control systems. Rib skin failures are shown in figure 3 (unsupported rib) and figure 4 (supported rib).

The mechanisms responsible for skin failures vary considerably. The most common factors are competence of the

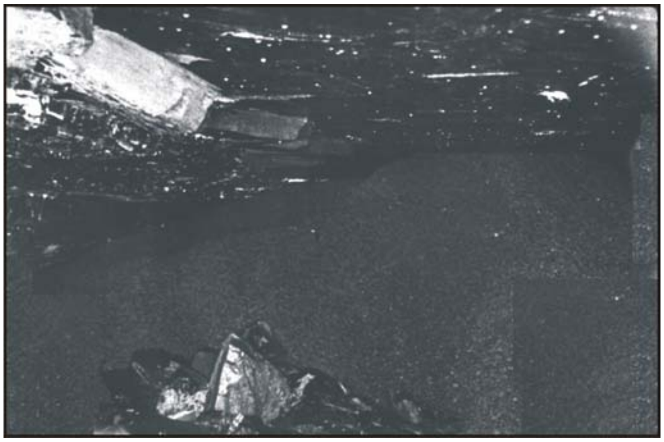

Figure 1.—Skin failure of unsupported roof.

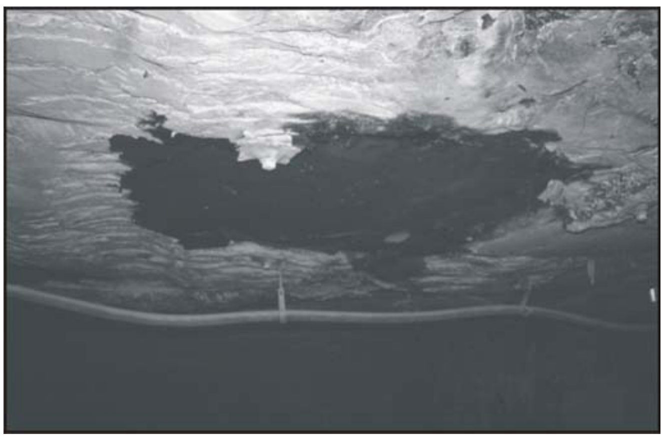

Figure 2.—Skin failure in supported roof.

strata and presence of geologic discontinuities. In many mines, the roof is composed of draw rock (soft slate, shale, or rock), coal, bony material, and other highly stratified, thinly laminated strata. These strata are susceptible to failing in thin layers because of bedding plane weaknesses. Some of the causes of bedding plane failures that result in skin failures include sag of the strata from gravity, overburden pressure as depth increases, horizontal stress, and moisture or temperature sensitivity. Mining-induced stresses and damage are also important in the development of skin failure in both the roof and rib. If geologic discontinuities are present, the likelihood of skin failure increases because the discontinuities weaken and compromise the structural integrity of the rock. It seems logical that the potential for the roof to experience skin failure can be estimated using the Coal Mine Roof Rating (CMRR). The CMRR estimates the structural competence of coal mine roof and considers bedding most important. It includes the factors that

Figure 3.—Skin failure of unsupported rib.

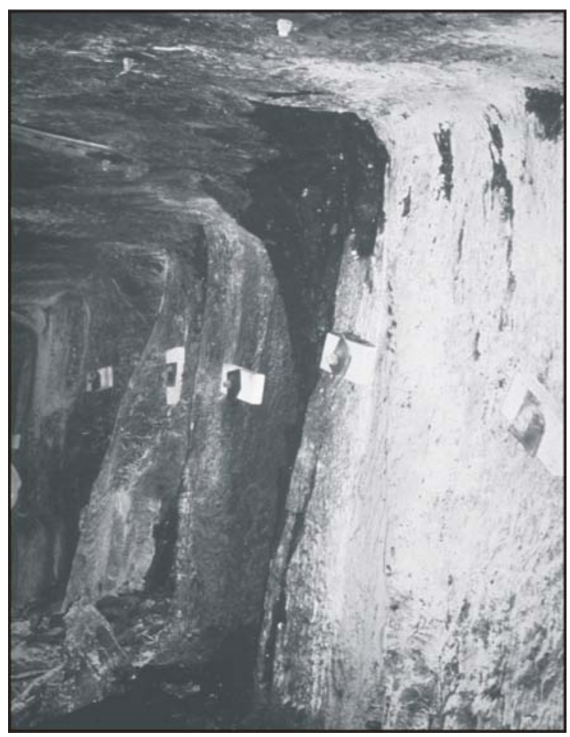

Figure 4.—Skin failure of supported rib.

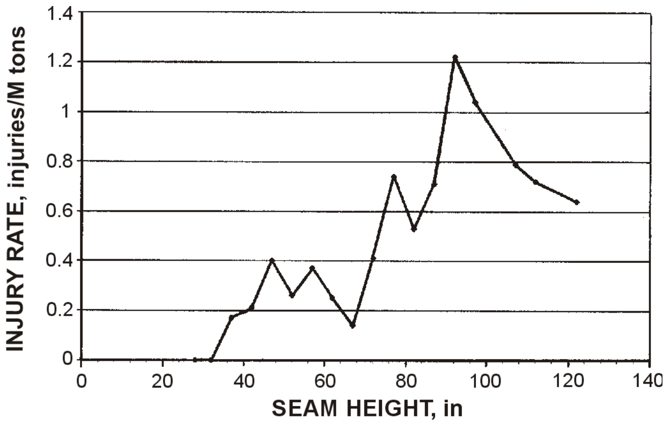


**Figure 5.—Seam height versus injury rate for rib skin failures, 1997 (after Bauer et al. [1999]).**

**Figure 6.—Example of differential movement along a parting in a coal rib.**

weaken bedded coal-measure rocks, such as discontinuities, moisture, and rock strength [Molinda and Mark 1994]. The lower the CMRR, the less competent the roof and the more susceptible it is to skin failure.

Coal ribs can experience skin failure for many of the same reasons. Primarily, rib skin failure is associated with effects of depth or, at times, with the early stages of the failure of insufficiently sized pillars. A general observation about rib skin failures is that rib spalling tends to increase as mining height increases. A plot of rib skin failure injuries and seam height for 1997 indicates that the injury rate increased as the seam height increased, up to 8 ft thick (figure 5). For seam heights >8 ft, a decreasing trend occurs, probably because more rib support is used in the thicker seams. Rib spalling may also increase with depth and is affected by mining-induced stresses. Rib skin failure is also frequently associated with rock partings within the coal pillar or with draw rock located at the roof-rib interface. Rock partings or bands within the pillar create planes of weakness where differential movement (figure 6) and failure can occur, leading to spalling (skin failure). When weak draw rock that is subject to failure during coal extraction is present and is mined with the coal, the draw rock exposed in the coal pillars creates a zone of potential rib skin failure. This inherent weakness makes the draw rock susceptible to spalling from the rib as the coal pillars experience load.

## SKIN FAILURE INCIDENT ANALYSIS

Two separate incident analyses were conducted. One addressed roof and rib fall fatalities during 1996-98; the other addressed all reported roof and rib fall incidents during 1995-97. These analyses were designed to identify the fatalities and injuries resulting from skin failures, both roof and rib, and massive failures, then draw some statistically based conclusions.

### ROOF AND RIB FALL FATALITIES

The underground coal mine fatalities caused by falls of roof and rib for the period 1996-98 were separated by skin and massive failures. Skin failure of the roof and rib has been previously defined. A massive roof fall involves the failure of the primary support system and usually has an areal extent in at least one dimension approaching the width of the opening. For the fatalities, the average thickness of the massive failures was 8.55 ft. For rib failures, nearly all were classified as skin failures, except those listed in Mine Safety and Health Administration (MSHA) fatality reports as an outburst or bump. Table 1 summarizes the classification by failure types. Essentially, 50% of the fatal injuries that occurred under supported roof were caused by skin failure of the roof or rib. Rib failures resulted in over twice as many fatalities as roof skin failures and were caused by the lack of rib support, which allows large slabs to spall from the ribs. Only three fatalities occurred from roof skin failure; however, these occurred under the supposedly safe conditions of supported roof. During this 3-year period, 11 fatalities occurred under unsupported roof. This is a human behavior issue rather than a ground control problem; thus, these fatalities are not included in this analysis.

**Table 1.—Roof and rib fatalities by failure type, 1996-98**

| Year | Rib skin fatalities | Supported roof skin | Massive failures |
|---|---|---|---|
| 1996 . . . . . | 3 | 1 | 1 |
| 1997 . . . . . | 3 | 0 | 6 |
| 1998 . . . . . | 1 | 2 | 3 |
| Total . . . . | 7 | 3 | 10 |

## REPORTED ROOF AND RIB FALL INJURIES

To delineate the extent of worker injuries resulting from skin failures, the MSHA accident database was examined for the period 1995-98. All injuries occurring in underground coal mines that resulted from roof and rib failures were extracted and analyzed. This included degree-of-injury classes from 1 to 6, which were injuries ranging from no lost time or restricted activity to those that resulted in a fatality. They did not include reportable roof falls that occurred when no workers were present. In addition, the accident injury illness types extracted were fall of face, rib (or side), and fall of roof. Some of the roof and rib fall injuries are classified under machinery incidents. These misclassified incidents were sorted out by using the source-of-injury code with a criterion of caving of rock, coal, ore, and waste. Table 2 summarizes the roof and rib injuries for 1995-98. The table reveals that most of the injuries resulted from roof skin failures (82%), followed by rib skin failures (16%), and massive failures (2%).

**Table 2.—Number of injuries from roof and rib failures, 1995-98**

| Failure type | No. of injuries | Percent of injuries |
|---|---|---|
| Roof skin . . . . . | 2,716 | 82 |
| Rib skin . . . . . . | 524 | 16 |
| Massive . . . . . . | 58 | 2 |
| Total . . . . . . | 3,298 | 100 |

Next, another analysis determined the mining situations in which roof and rib skin injuries occurred (for 1997 data only). Table 3 indicates that 84% of the skin failure injuries occurred during development or retreat mining, with the remaining 16% divided among longwall and other. An attempt was made to determine the location of skin failure injuries with respect to the state of roof support. The best estimate is that 383 of the 669 roof skin injuries (57%) occurred under permanent support. It is possible that many of the roof skin failure injuries occurring where the roof was permanently supported could have been prevented through modified support designs. Another 233 (35%) roof skin injuries occurred under temporarily supported or unsupported roof. Increasing the skin coverage of the ATRS or coverage area of the drill station canopies could help reduce the roof skin failure injuries occurring under temporarily supported roof. For the remaining 53 roof skin injuries, the state of support was uncertain, but was provided by either the ATRS or permanent support. Approximately 85 of the 128 (66%) rib skin injuries occurred where the roof was permanently supported. The rib skin failure injuries occurring under permanently supported roof may be minimized by securing the ribs, if necessary, or through scaling and increased awareness of rib conditions. Another 19 (15%) rib skin injuries occurred under temporarily supported or unsupported roof. The remaining 24 (19%) occurred where the state of the support was unknown.

**Table 3.—Roof and rib skin failure injuries classified by mining situation, 1997**

| Mining situation | Roof skin failures | | Rib skin failures | |
|---|---|---|---|---|
| | Injuries | % | Injuries | % |
| Development[1] . . . . . . . | 560 | 84 | 108 | 84 |
| Longwall[2] . . . . . . . . . . . | 38 | 6 | 11 | 9 |
| Other[3] . . . . . . . . . . . . . | 71 | 10 | 9 | 7 |
| Total . . . . . . . . . . . . | 669 | 100 | 128 | 100 |

[1]Includes advance and retreat mining.
[2]Includes injuries in the headgate and tailgate during panel mining.
[3]Includes injuries outby face and of unknown origin.

Table 4 shows the distribution of skin injuries by location and support type. Temporary support is provided by the ATRS and canopy of the roof bolter, while permanent support is provided by the primary support system. About 78% of all roof

**Table 4.—Location of roof and rib skin failures, 1997**

| Type and location | Injuries | Face[1] | Working section[2] | Face area total[3] | Face area, % | Other/ unknown[4] | Other, % |
|---|---|---|---|---|---|---|---|
| Roof: | | | | | | | |
| Permanent support . . . . | 383 | 150 | 111 | 261 | 68 | 122 | 32 |
| Temporary support . . . . | 233 | 215 | 4 | 219 | 94 | 17 | 4 |
| Rib: | | | | | | | |
| Permanent support . . . . | 85 | 38 | 25 | 63 | 74 | 22 | 26 |
| Temporary support . . . . | 19 | 16 | 1 | 17 | 90 | 2 | 10 |

[1]Injuries occurring at the active face or inby the last open crosscut.
[2]All other injuries occurring inby the feeder on working sections.
[3]Total injuries occurring in the face and working section.
[4]Injuries occurring inby the working section, or location unknown.

skin injuries occurred inby the feeder, while 58% of the injuries occurred at the active face. This is a strong indicator that roof slaking due to moisture was not the primary concern in causing these types of injuries. Again, with the coal ribs, nearly 77% of the injuries were inby the feeder.

Finally, the mine worker activities during roof and rib skin injuries were extracted from the MSHA database for 1995-98. The most common activities of workers injured by roof skin failures were drilling or bolting of the roof (39%), operating the continuous mining machine (11%), and general inside labor (9%) (figure 7). These three activities accounted for 59% of the injuries. No other worker activity was involved in more than 7% of the injuries. For injuries resulting from rib skin failures, the most common worker activities were operating the continuous mining machine (18%), drilling or bolting the roof (16%), general inside labor (12%), walking (9%), and maintenance and repair (8%). The total of these accounted for 63% of the injuries (figure 8). All other activities were involved in 5% or less of the rib skin injuries. Surprisingly, scaling of the roof or rib, which deals directly with skin failure and is thought to be a dangerous activity, comprised only 1% of the roof and rib skin failure injuries. This low level of scaling injuries compared with the high number of skin failure injuries may indicate that not enough scaling is done. In addition, cable handling was involved in 3% of the total roof and rib skin failures (figure 9).

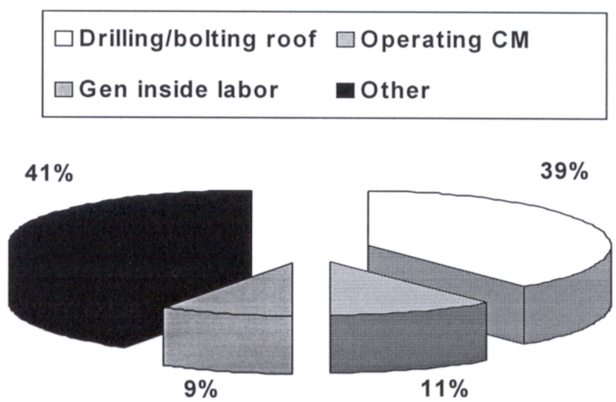


Figure 7.—Mine worker activities during roof skin injuries, 1995-98.

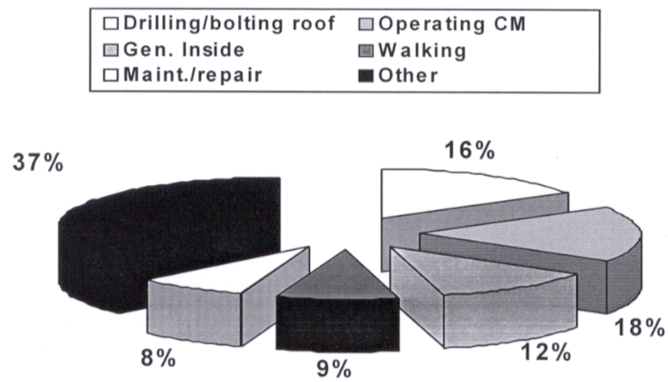


Figure 8.—Mine worker activities during rib skin injuries, 1995-98.

Figure 9.—Mine worker moving mining machine power cables.

# SKIN CONTROL METHODS

This review of skin control methods both examines what has been done in the past and describes current control techniques. Our investigation reveals that many of the same methods used in the past are used today.

## EARLY SKIN CONTROL EFFORTS

Past control methods were directed primarily at preventing skin failures resulting from changes in temperature and humidity. These included various coating materials designed simply to seal the surface without providing additional strength or reinforcement and attempts to condition the mine air before it was introduced into the mine workings. The air conditioning involved regulating the temperature and humidity to near ambient mine conditions to prevent failures due to expansion and contraction and to prevent moisture variations. In the face area, past attempts at controlling roof and rib skin failure using artificial means reflected the support materials available. Mechanical bolts in combination with wood headers and planks, oversized plates, wire mesh, old hoist rope, wood dowels, and other simple support methods were commonly used.

## CURRENT SKIN CONTROL METHODS

Current control methods have built on the successes of past techniques, using the more sophisticated support materials now available. In addition, more thought has been given to matching the type of control to the failure mode. For instance, because the mining industry has an improved understanding of the mechanism of strata failure, cement coatings using steel or glass fibers are available not only to seal the strata, but also to add strength to resist failure. For control of roof skin failure, wood planks, steel straps and channel, and various meshes such as welded wire, chain link, or synthetic grid material are being used.

Rib support methods have changed as well, primarily in the use, type, and location of bolts. The emphasis is to match the deformability of the rib supports to that of the rib. Yieldable bolts, such as those used at Jim Walters Resources [Martin et al. 1988], can stabilize the coal seam and ribs effectively by controlling displacements to reduce stress buildup.

A recent information request from MSHA District 3 revealed the following examples of roof skin control methods: (1) one mine uses screens in one intake, one return, and the track entry, and uses a lot of gunite; (2) another mine uses 8-gauge steel, 5- by 16-ft panels of "welded wire" installed on cycle; (3) one longwall mine is required to use screening or gunite where it has trouble holding up head coal in its gate roads; and (4) one mine that has a history of falls due to deteriorating top has miles of gunited track entry. Information obtained from MSHA District 4 revealed additional skin control methods. These included using oversized bearing plates on pattern bolts, installing 2-ft-long "bacon skins" (straps) with 3-ft-long mechanical anchor bolts in between the pattern bolts or covering the roof with synthetic grid material when roof skin failure is a problem. For rib skin failures at the face, some mines install 4- to 6-ft-long planks with 18- or 36-in bolts. When sporadic rib failures occur outby the face area, mines mainly use timbers set close to the ribs to minimize the dangers to mine workers traveling nearby.

The following is taken from a roof control plan from a mine in Pennsylvania, which describes typical rib skin control methods: "Loose ribs are to be blocked, bolted, or taken down. Steel straps, planks, or header blocks with 4- to 6-ft-long bolts may be used. Bolts are not to exceed 8-ft intervals. In lieu of the above, such ribs may be supported by posts or cribs installed tightly near the rib."

## ADVANCES IN SKIN CONTROL

Improved skin control and elimination of skin failure injuries, especially those resulting from roof skin failures, are contingent on providing increased surface control. To this end, safer, faster, and more efficient installation of mesh is the surface control method receiving the most attention. For instance, the walk-through bolter allows sheets of mesh to be installed with minimal worker exposure to the unsupported roof. The mesh can be placed on top of the protective canopy, then slid forward into place without the workers ever leaving the supported roof area. The method of installing synthetic mesh material is also being improved. An automatic grid dispenser has been developed that mounts on the inby side of the ATRS and dispenses the mesh up and over the ATRS (figure 10). As the mesh leaves the dispenser, the folded edges fan out from 9 to 15 ft in width to provide almost complete rib-to-rib coverage. In addition, the mesh has been strengthened to >13,000 psf to provide a material with similar strength and protection as those of conventional mesh materials. Figure 11 shows the use of synthetic mesh to support roof and rib.

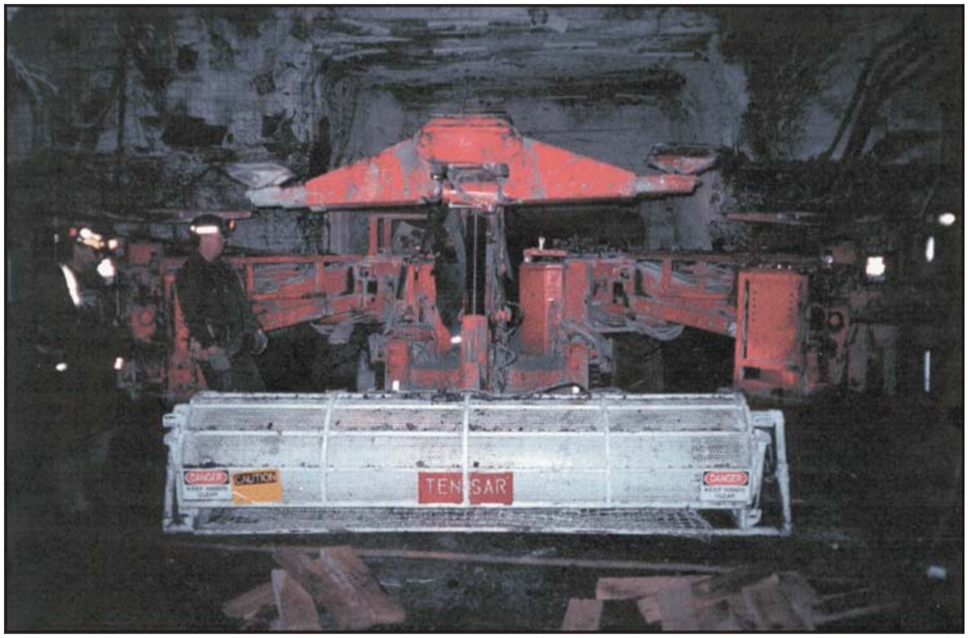


**Figure 10.—Automatic grid dispenser. (*Photo courtesy of Tensar Earth Technologies.)***

**Figure 11.—Synthetic mesh supporting roof and rib. (*Photo courtesy of Tensar Earth Technologies.*)**

# EQUIPMENT SAFETY IMPROVEMENTS

Visits to several roof bolting machine (RBM) manufacturers revealed that although they did not use the term "skin failure" to describe these types of roof and rib failures, they are aware of the problem and have been modifying the RBMs accordingly. Most of the safety modifications involved either removing the worker from the hazardous area or increasing the surface coverage of protective canopies, ATRS, etc., to prevent falling roof and rib from striking the RBM operator.

To remove the operator from the hazardous area, roof bolters with walk-through chassis, with or without automated drill functions, have been developed (figure 12). The major advantage of the walk-through chassis is to reduce mine worker exposure to rib hazards. Another manufacturer's RBM, currently available for higher coal seams only, uses four automated booms for drilling the bolt holes. The Multibolter is also a walk-through design (figure 13). It allows the operators to remain under a canopy equipped with side slide extensions that provide substantial work area coverage from roof hazards. This machine also uses side shields or chain curtain on the walkway platform to prevent rib failure injuries.

To provide additional protection to the operator during the bolting process, several machine modifications have been introduced. Many of the ATRS are equipped with hydraulic or manually extendable beams or roof contact pads to provide more coverage between the ATRS and the rib. At least one RBM manufacturer provides rock deflectors, called rocker pads, on the inby side of the ATRS that deflect rocks toward the face rather than allowing them to roll back onto the operator's legs and feet (figure 14). This was developed in response to injuries that occurred from dislodged rocks falling back onto the operator when the ATRS is lowered. The deflector forces the loose rocks to slide toward the face, falling flat against the mine floor, rather than landing on edge and falling over onto the operator's feet and legs. Rock deflector plates are also provided on the ATRS boom that can help deflect falling rocks away from the RBM operators. Another safety improvement is a sliding extension of the drilling canopy to provide additional surface coverage (figure 15).

Because the operator is subject to falling rocks any time that he or she is drilling or inserting bolts, one manufacturer developed a hydraulic resin inserter that keeps the operator from having to reach out from under the drilling canopy. Another improvement is to use reduced thrust, rotation, and feed when starting to drill a bolt hole. Accident statistics have shown that many injuries occur from falling pieces of roof rock when bolt holes are started. Some mines have even adopted the use of metatarsal gloves to protect the hands of RBM operators.

Ultimately, all RBM safety improvements are driven by the desire to provide the safest work environment for the roof bolting machine operators. Unfortunately, acceptance of these design changes can hinge on how they affect the bolting process. Changes that maintain the status quo or reduce bolting cycle times are more readily adopted by the mining industry than those that increase the time to perform any one function in the bolting process. This is because in most room-and-pillar operations the ability to mine the coal has outpaced the ability to support the roof. Thus, the speed and efficiency of the roof bolting operation is the critical production function.

**Figure 12.—Walk-through chassis roof bolting machine. (*Photo courtesy of J. H. Fletcher and Co.*)**

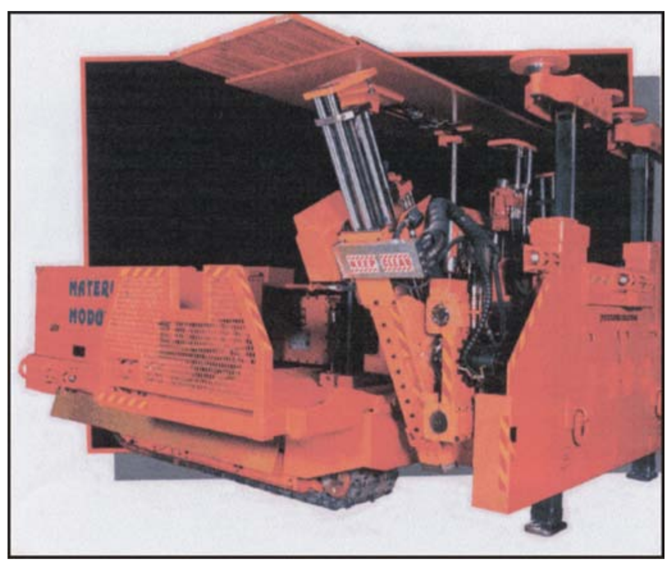

**Figure 13.—Joy Multibolter. (*Photo courtesy of Joy Mining Machinery.*)**

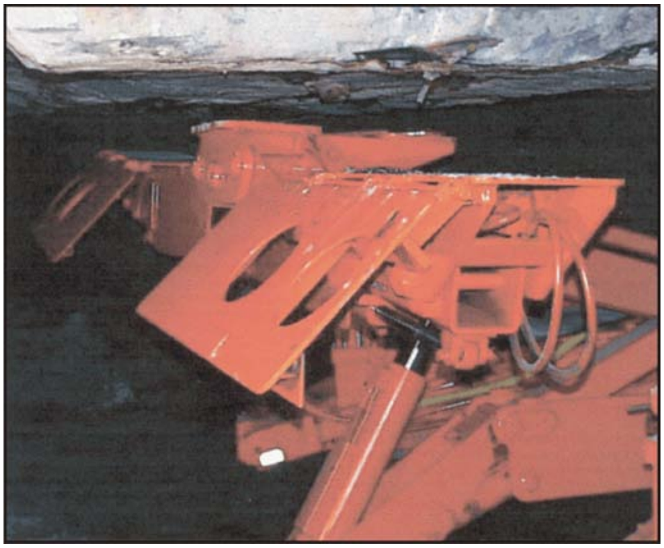

**Figure 14.—Inby rocker pads to deflect falling rocks. (*Photo courtesy of J. H. Fletcher and Co.*)**

**Figure 15.—Pullout canopy extension. (*Photo courtesy of J. H. Fletcher and Co.*)**

## SUMMARY AND CONCLUSIONS

Skin failure of roof and ribs injures many workers in underground coal mines. Statistics from 1997 indicate that 98% of the injuries from roof and rib falls are due to skin failures, resulting in more than 800 injuries, or approximately 12% of all underground coal mine injuries.

Skin failure is defined as the failure of small pieces of rock and coal from between the primary supports, rather than massive roof falls or coal pillar failures. Coal ribs may not be supported, but when the rib spalls, it is still considered skin failure.

An analysis of roof and rib skin failure injuries revealed that far more injuries resulted from roof skin failures, but that the rib skin failures caused more severe injuries. The analysis also revealed that roof and rib skin failures were three times more likely to occur on the working section than outby in other mine areas because of greater worker activity in the face area and because the face is an active stress zone. From a worker activity standpoint, the roof bolters have by far the most injuries from roof skin failure. By contrast, the risk of injury from coal rib falls seems to be approximately the same for all face workers.

The methods for support of roof and ribs to prevent skin failure are simply extensions of standard roof support methods. As dictated by the extent of skin failure problems, the on-cycle supporting methods are modified to provide additional surface coverage. Common skin control methods include oversized plates, header boards, wood planks, steel straps, mesh, and in rare instances, spray coatings. These control methods can control skin failures. Unfortunately, they are implemented reactively to control problems that are occurring, rather than proactively to prevent future skin failure occurrences. The success of these controls can be enhanced by matching the characteristics of the support to the expected strata reactions to mining and modes of failure. However, the key to preventing injuries will be the amount of surface coverage developed by the surface control systems.

Equipment safety enhancements, especially to the roof bolting machine, have been directed at removing the worker from the dangerous areas and/or increasing the area of protective canopies. The modifications can provide additional measures of safety to the roof bolting machine operators, thereby reducing the potential for injuries from falling roof and rib. Unfortunately, it is difficult to get some of the equipment modifications adopted by the mining industry. Only those changes that either maintain the status quo or that speed up the bolting cycle are readily accepted, whereas other safety modifications are more difficult to implement.

NIOSH research is continuing to address the causes and control of skin failure in underground coal mines. Emphasis will be placed on determining the geologic and stress conditions associated with roof and rib skin failure and the best surface control practices being used by the coal industry to minimize the hazard of skin failure injuries.

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