A REVIEW OF RECENT DATA CONCERNING ACCIDENTS CAUSED BY FALLS OF UNSUPPORTED ROOF

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INTRODUCTION

Virtually everyone who works in a coal mine has been told that it is very dangerous to go under unsupported roof and knows that mine safety regulations prohibit this behavior. Nevertheless, information obtained through accident investigations and interviews with coal miners indicates that there are individuals in the coal mining work force who, in certain circumstances, do not hesitate to go under unsupported roof. During the past 8 years, 53 coal miners lost their lives because they travelled inby roof supports and the roof fell on them. How were these miners different from other miners? How were their mines different from mines where people have not been killed by falls of unsupported roof? This paper addresses these and other questions by showing how these 53 miners compare to other groups of miners in terms of their experience, age, and certain characteristics of the mines where they were employed.

FINDINGS

Characteristics of the Employee

Table 1 shows the median, mean, minimum and maximum values for the age and experience levels of three categories of miners.[1]

The first category consists of the 53 miners killed by a roof fall while under unsupported roof during the period 1986-1993. The second category consists of the 189 people who were killed by some type of underground mining accident other than a fall of unsupported roof during the period 1986-91.[2] The third category of miners is the underground coal mining workforce. Estimates of workforce characteristics are based on survey data obtained from 622 coal mining operations during 1986 (Butani and Bartholomew, 1988). Estimates are based only on underground employees. Employees who work at the surface of underground operations were excluded.

Age. Both the mean and median of the ages of miners killed by falls of unsupported roof are a little lower than the corresponding values for miners killed by some other type of accident.[3]

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[1]The median is the middle value in a set of numbers arranged in order of magnitude, i.e., the 50th percentile value.

[2]1991 was the most recent year for which complete data was available.

[3]It is important to remember that the groups being compared are complete populations rather than samples from a population. Therefore, it is not appropriate to perform t-tests on the data.

Table 1. Comparison of miner characteristics

Miner characteristic		GROUP 1. Miners killed by roof falls while under unsupported roof (N= 53)	GROUP 2. Fatalities **not** due to falls of unsupported roof (N = 189)	GROUP 3. Estimates of coal mining workforce from 1986 survey
Age (years)	Median	35.0	37.0	NA[1]
	Mean	35.3	38.5	38
	Min-Max	20-60	19-62	NA
Experience in job (years)	Median	4.0	4.0	3
	Mean	5.7	5.9	NA
	Min-Max	0.01-24	0.02-30	NA
Total mining experience (years)	Median	12.0	13.9	11
	Mean	12.8	14.3	NA
	Min-Max	0.3-28	0.12-44	NA
Experience at this mine (years)	Median	0.6	2.5	9
	Mean	2.1	5.5	NA
	Min-Max	0.02-19	0.02-38	NA

[1]Not available.

Likewise, the estimated average age of the entire workforce is a little higher than the average age of miners killed by falls of unsupported roof (38 versus 35.3 years).

Experience in job. The median number of years experience that Group 1 miners had in the job that they were performing when they were killed was 4 years. The corresponding values for Groups 2 and 3 are, respectively, 4 years and 3 years. The mean values for Groups 1 and 2 are nearly identical.

Total mining experience. Both the mean and median number of years of total mining experience for miners killed by falls of unsupported roof are a little lower than the corresponding values for miners killed by some other type of accident. The estimated median years of total mining experience of the entire workforce is a little lower than the corresponding value for miners killed by falls of unsupported roof (11 versus 12 years). Thus, it does not appear that miners who have been killed by falls of unsupported roof differ very much from other miners in terms of their total mining experience or their job experience.

Experience at this mine. There are very sizeable differences between the groups in terms of the amount of experience the individuals had working at the mine where they were employed. The median number of years experience miners had working at their mine before they were killed by a fall of unsupported roof was only 0.6 years. This means that about half of these victims had been working at the mine for less than 8 months when they were

killed. This value (0.6) is about one fourth of that for miners killed in other types of accidents (2.5) and less than one tenth of the corresponding value for the remainder of the underground workforce (9 years)! Similarly, the mean value for Group 1 is substantially lower than the mean for Group 2.

The differences between Groups 2 and 3 may reflect the victim's lack of familiarity with the new mine--the physical characteristics of the mine, the equipment, the habits of coworkers, or various factors associated with management. Prior research strongly suggests that lack of familiarity is a significant contributor to injuries among underground coal miners (Goodman & Garber, 1988). Perhaps the new employee tries to win the approval of supervisors by showing them that he is willing to take shortcuts or risks in order to appear more productive. Or, perhaps he tries to gain the respect of his co-workers by showing them that he is not afraid to perform risky behaviors.

The factors mentioned above also might explain some of the differences between Group 1 and Group 3. The differences between Group 1 and Group 3 may also reflect the fact that there can be substantial differences in the stability of the roof from one mine to another. Miners who are used to working where falls of unsupported roof happen very rarely may develop the habit of doing certain things under unsupported roof. If these miners should go to work at a different mine where falls of unsupported roof are more common, it may take some time for them to change their old habits. Once they are firmly established, habits can be very difficult to change. Unfortunately, miners may be killed by a roof fall before they even have a chance to realize that their old habits are much more dangerous in their new work environment. Therefore, it is very important that all newly employed experienced mine workers be reminded of the importance of never going under unsupported roof. This is especially important for miners who have recently worked at mines where roof conditions were stable. Such individuals may have developed a complacent attitude about going under unsupported roof.

When newly employed people are first assigned to work near face areas, they should be closely monitored to ensure that they are not exposing themselves to unsupported roof during the course of performing certain activities associated with their job. If they are, corrective actions need to be taken immediately (see Peters (1991) for a discussion of several strategies for changing unsafe employee behaviors). If the individual persists in the behavior, reassignment may be necessary to a job where working in close proximity to areas of unsupported roof is not required.

Distance beyond the last row of bolts. The Mine Safety and Health Administration's (MSHA) reports on fatal accidents involving miners killed while under unsupported roof were reviewed to determine how far beyond the last row of supports the victim was at the time they were killed. Most of the victims were found within 4 feet of the last row of supports. Thus, it is important that miners realize that it is NOT safe to go even a short distance beyond the last row of roof supports.

Characteristics of the Mine

Table 2 shows characteristics of underground coal mines that fall into three categories. These categories correspond to the ones in Table 1. The 52 mines in Group 1 are operations where one or more miners were killed by a roof fall while under unsupported roof during the period 1986-1993. All of the 155 mines in Group 2 are operations where one or more miners were killed by some type of underground mining accident other than a fall of unsupported roof during the period 1986-91. Group 3 consists of all mines operating in 1988. The statistics for Group 3 mines are based on data from 1988 because that year is near the middle of the time period 1986-91. Many of the mines in Groups 1 and 2 were not in operation during the entire period for 1986-91. The average of the annual figures that each

Table 2. Comparison of mine characteristics

Mine characteristic		GROUP 1. Mines with roof fall fatalities under unsupported roof (N= 52)	GROUP 2. Mines with fatalities **not** due to falls of unsupported roof (N = 155)	GROUP 3. All mines operating in 1988 (N = 1,841)
Annual production (tons)	Median	72,896	335,151	63,279
	Mean	230,146	687,028	221,298
	Min-Max	3,362-1,980,072	2,245-3,296,794	NA[1]
Annual employee hours	Median	26,867	121,071	20,666
	Mean	78,338	234,785	72,186
	Min-Max	1,200-780,926	1,783-1,485,845	NA
Seam height (inches)	Median	42	54	42
	Mean	50.7	58.6	49.3
	Min-Max	26-120	24-144	NA
Lost-time injury rate (per 200,000 hours)	Median	15.3	14.0	14.0
	Mean	17.5	17.8	21.4
	Min-Max	0-90.4	0-46.3	NA
Productivity (tons per employee hour)	Median	2.4	2.7	2.6
	Mean	3.0	3.0	2.9
	Min-Max	0.8-6.9	0.7-7.8	NA

[1]Not applicable.

mine reported for its production, employment, and lost-time injuries, for each of the years during 1986-91 that it was in operation, was used to estimate the "typical" levels of production, employment, and lost-time injuries for each of these mines. The figures for employment, and lost-time injuries reflect underground units only. Surface workers at underground mines are excluded from the analyses.

Group 1 versus Group 3 mines. Mines where a fatality occurred due to a fall of unsupported roof produced an average of 8,848 more tons of coal per year than mines where there were no fatalities. Similarly, the median of the annual tons of coal produced for Group 1 mines is 72,896, which is 9,617 tons more than the median for Group 3 mines. There is a similar difference with respect to the mean and median values for annual number of hours worked by underground employees. In comparison to Group 3, the workforce at mines in Group 1 appears to be a little larger. There is no difference in terms of the median seam heights for Group 1 and 3 mines. The median for both groups is 42 inches. The median of the rates of lost-time injuries per 200,000 hours worked by underground employees is a little higher for Group 1 mines than for Group 3 mines (15.3 versus 14.0). The median number of tons produced per hour of underground labor is slightly lower for Group 1 mines than for Group 3 mines (2.4 versus 2.6). In terms of the parameters listed in Table 2, it appears that mines where fatalities occurred under unsupported roof are fairly similar to mines that did not have any fatal accidents.

Group 2 mines versus Groups 1 and 3. The group of mines that experienced fatalities caused by accidents *other than* falls of unsupported roof (Group 2) appear to be different from the mines in Groups 1 and 3 in two respects. Group 2 mines are larger, and operate in higher seams. The injury rate and productivity rate for Group 2 mines is about the same as for the other two groups.

A More In-Depth Look at Seam Height

The seam height in many mines is so low that workers crawl most of the time when they need to move around. For various reasons, low seam height may influence miners' propensity to go under unsupported. In comparison to walking, it takes considerably more time and effort for mine workers to move from place to place when they must crawl. Therefore, in low-seam mines, it may be more tempting for employees to take shortcuts through areas that have not yet been bolted e.g., an unbolted crosscut. Low seam height also makes it more difficult for miners to get a good view of the roof in front of them. Bureau researchers recently asked miners from a low seam mine to describe recent incidents in which they had unintentionally gone under unsupported roof (Peters and Randolph, 1992). Some of them noted that it is easier to go under unsupported roof unintentionally in a low seam mine because (1) it is more difficult to look at the roof from a crawling position than from a standing position, and (2) when operating equipment, such as a scoop, it is sometimes difficult to see whether the roof ahead is bolted or not without getting off the equipment to get a better view. A comparison of interview data collected from miners at both low seam and high seam mines suggests that people unintentionally go under unsupported roof more frequently in low seam mines than in high seam mines (Peters and Randolph, 1992).

Is the rate of fatal accidents from falls of unsupported roof actually higher at low seam mines? The data in table 3 was compiled to address this question. The second column of table 3 breaks down employee hours worked in underground coal mines during 1988 into 6 categories based on seam height (column 2). Of the total hours employees spent working in underground coal mines, 5.6% was in mines with seams less than 36 inches high, 9.7% was in mines with seams of between 36 and 41 inches, etc. The third column in table 3 shows the percent of all the accidents in which miners have been killed by falls of unsupported roof during 1986-93 that occurred at mines within each of the same 6 categories of seam height. Of the total fatal accidents from falls of unsupported roof, 21.2% occurred at mines with seams less than 36 inches high, 26.9% occurred at mines with seams between 36 and 41 inches, etc. The fourth column in table 3 shows the ratio of the numbers in the third column to the numbers in the second column. These ratios show that, relative to the percentage of employee hours, a

disproportionate number of fatal accidents from falls of unsupported roof occur in seam heights less than 48" and particularly in seam heights less than 42".

In the lowest three categories of seam height, rates of roof falls increase as seam height increases to a high of 1.43 roof falls per 100,000 tons for mines with seam heights of 42" - 47". Rates then decline to about 0.90 for mines with seam heights between 48" - 71". Finally, seams heights of 6 feet (72") or higher have the lowest rate (0.64). Thus, a trend of decreasing roof fall rates with increasing seam height is not evident. On the contrary, up to a

Table 3. Percent of employee hours and fatal accidents under unsupported roof, by seam height

Seam height (inches)	Employee hours worked throughout all mines operating in 1988 (%)	Mines with fatal accidents under unsupported roof (%) N=52	Ratio of column 3 to column 2
35 and lower	5.6	21.2	3.8
36 - 41	9.7	26.9	2.8
42 - 47	5.9	11.5	1.9
48 - 59	23.3	11.5	0.5
60 - 71	19.2	7.7	0.4
72 and higher	36.3	21.2	0.6

This data appears to fit with the assertion that miners are more likely to go under unsupported roof in low seam mines. However, these variations in fatality rate by seam height might also reflect non-behavioral factors, such as differences in the stability of the roof. Another scenario that could explain the pattern of data in table 3 would be: Miners are spending the same proportion of time under unsupported roof in both low seam and high seam mines, but roof falls occur more frequently in low seam mines. The data in table 4 was compiled to examine this issue. Table 4 shows the rate of roof falls reported to MSHA by mines in each of the six categories of seam height.[4] The rate of roof falls (both injury and non-injury) per 100,000 tons of coal produced was computed for mines operating within each seam height category to see whether a disproportionate number of roof falls occur in lower seam height mines.[5]

[4]Mine operators are required to report to MSHA any of the following types of roof or rib falls: (1) falls that cause death or injury, (2) falls that cause entrapment of an individual for more than thirty minutes, (3) any unplanned roof falls at or above the anchorage zone in active workings where roof bolts are in use, (4) any unplanned roof or rib fall in active workings that impairs ventilation or impedes passage. Of the 15,983 groundfall accidents reported to MSHA in 1991, 72% were non--injury incidents.

[5]A roof fall rate based on the amount of exposed roof and rib (some surface area measurement) might be the most appropriate measure to use. However, because such information is not available, the amount of production probably more closely approximates this area than any other measure readily available.

Table 4. Rate of roof falls[1] reported to MSHA for all mines operating during 1988 and for mines with a fatality under unsupported roof, by seam height

Seam height (inches)	Roof fall rates throughout all mines operating in 1988	Roof fall rates for mines with a fatality under unsupported roof[2]
35 and lower	0.85 n=390	2.76 n=8
36 - 41	0.96 n=447	0.0 n=11
42 - 47	1.43 n=185	0.92 n=3
48 - 59	0.89 n=348	1.54 n=4
60 - 71	0.91 n=189	2.10 n=4
72 and higher	0.64 n=282	0.98 n=11
Overall	0.83 N=1,841	1.11 n=41

[1]Roof fall rates were computed as the number of roof falls per 100,000 short tons of coal produced.

[2]Roof fall rates reflect what the mine reported to MSHA during the year preceding the fatality.

height of 48" the rate of roof falls steadily increases. Thus, using rates of roof falls reported to MSHA as a measure of roof stability, it does not appear that roof falls happen more frequently in low seam mines. This suggests that the substantially higher fatality rates in lower seam mines cannot be adequately explained by differences in the frequency of roof falls, but rather, reflects differences in worker behavior.[6]

Perceived Roof Stability

In interviews about the causes of roof fall fatalities, miners and mine inspectors have occasionally remarked, "It's not the 'bad' roof that kills people, it's the 'good' roof" (Peters and Randolph, 1992). In other words, people who work in mines with very stable roof

[6]It is important to remember that the comparisons that have been made are based on the assumption that mines are accurately reporting roof fall accidents to MSHA. Unfortunately, there is currently no way to determine how often mines fail to report roof falls that MSHA defines as "reportable" accidents. If there were a tendency for low seam mines to be significantly more likely to fail to report roof fall accidents than high seam mines, then the conclusion that worker behavior is a more important contributor to fatal roof fall accidents in low seam mines than in high seam mines might not be accurate.

conditions may eventually stop worrying about avoiding unsupported roof because roof falls happen so infrequently. When a fall of unsupported roof eventually happens, it is more likely that someone will be beneath it in mines where people perceive the roof as 'good' than in mines where people perceive it as 'bad'. Is there empirical support for this proposition?

To address this question, rates of roof fall accidents (both injury and non-injury) were computed for the year prior to the year of the fatality for 41 of the 52 mines in which miners were killed by falls of unsupported roof during 1986-93. Data for the remaining 11 of the 52 mines was not available because these mines were not in operation during the previous year. The overall rate of roof falls for these 41 mines was 1.11 per 100,000 short tons of coal produced. The overall rate of roof falls for all underground coal mines in 1988 was 0.83. The direction of this difference in rates is opposite that suggested by the proposition, "It's not the 'bad' roof that kills people, it's the 'good' roof".

Finally, the 41 mines in which miners have been killed by falls of unsupported roof during 1986-93 were partitioned into six categories on the basis of seam height, and rates of roof fall accidents (both injury and non-injury) were computed for each separate category (see column 3 of table 4). Overall, these rates are highly variable and show no obvious trend. One rather interesting finding is that only 3 of the 19 mines operating in seam heights of less than 42 inches reported any roof falls during the year prior to the fatality, i.e., only 15.8% of these 19 mines reported at least one roof fall.[7] Thus, if one looks only at the data on fatalities that have occurred in mines below 42 inches, it appears that there is some support for the argument, "It's the 'good' roof that kills people." However, one must be cautious in drawing any conclusions from the data in the last column of table 4 because the number of mines in some seam height categories is quite small (particularly in the 42" - 71" range). These rates may be unstable in that the addition of another mine (value) could significantly alter the rate for the category.

[7]As a basis of comparison, 24% of the 837 mines operating in seams of less than 42 inches in 1988 reported at least one roof fall.

CONCLUSIONS

Some of the more salient findings from this analysis of accidents caused by falls of unsupported roof include:

1. The rate of fatalities from falls of unsupported roof is higher at low seam mines than it is at high seam mines.
2. The overall rate of roof falls reported to MSHA is somewhat higher for mines where a fatality has occurred under unsupported roof than for mines that have not experienced such a tragedy.
3. Most miners killed by falls of unsupported roof are found within 4 feet of the last row of roof supports.
4. As a group, miners killed by falls of unsupported roof are similar to other miners in the workforce, except that the average length of time they had been employed at the mine was much shorter. This suggests that it is important to closely monitor newly employed people to make sure that they are avoiding unsupported roof at all times.
5. Miners have been killed by unsupported roof in a wide variety of mines since 1986, and what is "typical" (or the median) for this group of unfortunate mining operations looks very similar to what is typical at the many mines where fatalities did not occur.

In spite of this last finding, it may be tempting for mine workers to assume that mines where people are killed by falls of unsupported roof are somehow different from the mine where they work. This is part of how people rationalize that horrible events "could not happen to me." Miners may imagine that their mine is somehow different from mines in which people get killed. In some instances

there are valid reasons to hold such beliefs. However, in other instances this is an illusion. Trusting areas of unsupported roof not to fall is one of those instances.

The Bureau of Mines has been conducting research to learn more about why miners go under unsupported roof and what types of actions might help to eliminate this behavior. The strategies that have been suggested include: (1) ask miners for ideas about how to keep people from going under unsupported roof, (2) modify equipment and work procedures to eliminate situations which tempt miners to go under unsupported roof, (3) offer incentives for eliminating the precursors of going under unsupported roof, (4) increase fear of the harm that roof falls can cause, and (5) formulate and enforce a policy on how to handle individuals who persist in going under unsupported roof. For further information about why miners go under unsupported roof and how to stop them see Peters (1991), Peters and Randolph (1992), Peters (1993), and Mallett, Vaught and Peters (1992).

MSHA has a program devoted to preventing roof fall accidents called REAP (Roof Evaluation and Accident Prevention). Several very useful types of information are available through the REAP program including: safety posters, videotaped interviews with miners who have survived serious roof fall accidents, reports and videotapes that summarize each year's fatal roof fall accidents, and materials for conducting training exercises with miners.

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