HUMAN FACTORS CONTRIBUTING TO GROUNDFALL ACCIDENTS IN UNDERGROUND COAL MINES: WORKERS' VIEWS

Robert H. Peters and William J. Wiehagen

U. S. Department of the Interior
Bureau of Mines
Pittsburgh Research Center

ABSTRACT

The paper presents findings from a Bureau of Mines study on barriers that may prevent miners from correcting, and avoiding, groundfall hazards. Such barriers stem from four basic types of problems: (1) inability to recognize groundfall hazards; (2) inability to correct groundfall hazards; (3) lack of motivation to search for groundfall hazards; and (4) lack of motivation to correct groundfall hazards. Data are presented that summarize the views of miners, section supervisors, and mine inspectors about the contribution of these barriers to groundfall accidents, and what they think should be done to reduce the frequency of injuries sustained by falls of roof and rib. The paper also includes a summary of miners' responses concerning their recent experiences with groundfall accidents.

INTRODUCTION

In many underground coal mines, the economic costs associated with falls of roof and rib are a substantial proportion of the total costs of operating the mine. During the 5-year period, 1980-84, 16,352 groundfall accidents were reported to the Mine Safety and Health Administration (MSHA).

These accidents often require that labor, supplies, and equipment be diverted from coal production and used for cleanup, recovery and repair of mine equipment, and resupport of the mine roof. The costs of these activities are quite substantial. But of even greater significance are the financial and intangible losses, and the emotional anguish, suffered by the families of miners who have been killed or seriously disabled by groundfalls. During 1980-84, groundfall accidents claimed the lives of 181 coal miners and caused 5,323 nonfatal injuries. According to the Accident Cost Indicator Model, the direct cost of these fatalities and injuries alone exceeds $200 million (1). Clearly, the need to further reduce the number of miners being injured and killed by groundfall accidents is great.

The Bureau of Mines performed the research described in this report in order to (1) better define the types of barriers preventing miners from correcting or avoiding groundfall hazards; 2) provide direction for future research; and 3) identify promising approaches for preventing this type of accident. Interviews were conducted with (1) various personnel from three underground coal companies (nine states), and (2) MSHA coal mine roof and rib inspectors. Interviewers used a structured interview guide.

BARRIERS TO MINERS' PREVENTION OF GROUNDFALL ACCIDENTS

Geological factors relevant to the inherent stability of the roof and rib influence the likelihood of a groundfall accident. Although geological history cannot be changed, there are several other factors that influence the probability of groundfall accidents over which people potentially have some control. This study focuses primarily on (1) assessing the measures miners can potentially take to avoid groundfall accidents, and (2) gaining a better understanding of the types of barriers that prevent them from performing these activities.

Figure 1 presents a conceptual framework for addressing these barriers.

FIGURE 1. - Barriers to miners' prevention of groundfall accidents

Source of barrier	Stage of occurrence: Recognition	Correction
Ability	Inability to recognize groundfall hazards	Inability to correct groundfall hazards
Motivation	Lack of motivation to search for groundfall hazards	Lack of motivation to correct groundfall hazards

The model assumes that, in order for miners to do an effective job of preventing groundfall injuries, they must not only recognize the existence of the hazard but also be willing and able to take corrective action. Barriers can be differentiated on the basis of whether they occur at the stage of hazard recognition or hazard correction, and on the basis of whether they are due to miners' lack of ability or lack of motivation (See Peters and Wiehagen (2) for a more detailed discussion of this model). Data was collected to determine whether the people who work underground consider the barriers identified in Figure 1 to be important contributors to groundfall accidents.

METHODS OF DATA COLLECTION

A sample of miners, section supervisors, and MSHA inspectors was asked to respond to a variety of questions in one-on-one interviews. Most of the questions were intended to determine if the people who work in underground coal mines consider the factors identified in the previous section to be important contributors to groundfall accidents. Other questions dealt with strategies for reducing the frequency of roof and rib fall accidents.

Sample

Data were collected from February 1984 to April 1985. A total of 143 employees from three underground coal mining companies, located at nine sites throughout Pennsylvania, Virginia, and Kentucky, participated in the study. All mines in this study were using the room-and-pillar method of extraction and continuous mining machinery. Table I breaks down the total sample of mine employees by job title. The average length of time spent working as an underground coal miner was 10.5 years. Of the 143 employees in the sample, 85 pct. had some.

experience working as a bolter or bolter helper. All 143 employees were working underground on a daily basis. Data were also collected from nine MSHA coal mine roof and rib inspectors.

TABLE I. - Breakdown of mine employees interviewed, by job title

	Number
Belt worker	2
Bridge worker	2
Continuous miner operator	16
Continuous miner operator helper	10
General inside laborer	10
Mechanic	11
Roof bolter	27
Roof bolter helper	10
Scoop operator	2
Section supervisor	14
Shuttle car operator	25
Supply worker	2
Timber worker	5
Utility worker	5
Total	143

Interviews

Data were collected using a structured interview guide. (See Peters and Wiehagen (2) for a copy of this interview guide.) Interviewers asked questions concerning the following issues: (1) nonresponse to possible roof hazards; 2) walking beneath unsupported roof; 3) the effect of various changes on preventing groundfall accidents; and 4) recent experiences with roof falls. Participants were asked to respond to both open-ended and forced-choice questions. All interviews with miners were conducted in private, usually at the miner's work site. Interviews with MSHA inspectors were conducted at their offices. All participants were assured that their responses would be held in confidence and were told that their participation was completely voluntary. Interviews required approximately 30 minutes to complete.

FINDINGS

This section presents participants' responses to the four sets of issues cited above. Responses to both open-ended and forced-choice questions are presented. For the forced-choice questions, simple frequencies of the response categories chosen to answer each question are given in tabular form.

Nonresponse to possible roof hazards

Each participant was initially asked to respond to an open-ended question on why miners sometimes do not take action to correct roof hazards. This question was followed by eight forced-choice questions.

Open-ended questions. Participants were asked for their opinions about why miners sometimes neglect the correction of hazardous roof conditions. This question was asked as follows:

> At one time or another, most miners have seen areas of the roof that look like they may not be entirely safe, but for some reason, do not do anything about it. What are the major reasons why miners sometimes fail to do anything about potential roof hazards?

Miners' most common replies are listed below. (Numbers in parentheses indicate the number of persons who replied as indicated.)

- in a hurry (22)
- laziness (15)
- the area is traveled infrequently (11)
- too busy doing other work (10)
- don't want to delay production (10)

careless or don't care (8)
don't believe it's hazardous (7)
it's not their job (7)
complacency (6)

Inspectors gave several different types of responses to this question. The most common response was that miners do not think it is worth the time and effort required, i.e., they are insufficiently motivated to correct roof hazards.

Another reason frequently mentioned by mine inspectors was that miners do not realize how dangerous the hazard really is. Several inspectors also said that, because nothing usually happens to miners who occasionally decide to risk working beneath hazardous roof, many tend to become complacent. Apparently, the failure to experience negative consequences for deviating from a safe work practice may promote continued deviation. Other factors believed by mine inspectors to contribute to miners' failure to correct roof hazards were (1) miners' inattentiveness, caused by their preoccupation with off-the-job problems (e.g., family, medical); and (2) the temptation to let the next shift deal with the hazards when it is close to quitting time.

Forced-choice questions. Miners were asked to indicate the extent to which they agreed or disagreed with various reasons (listed in Table II) given by the interviewer to explain why miners might sometimes decide not to do anything about potentially hazardous roof conditions. A six-point rating scale ranging from "strongly agree" to "strongly disagree" was used. The rating scale contained the following options: strongly agree, agree, slightly agree, slightly disagree, disagree, and strongly disagree.

The percent of miners who chose each of these points on the rating scale to respond to each of the questions is presented in Table II. The first column of numbers (labeled Total "agree") shows the total percentage of miners who chose either "slightly agree," "agree," or "strongly agree" (to allow quick understanding of the general results without additional calculations). The eight reasons are rank-ordered in terms of the highest to the lowest percentage of persons expressing agreement with the statement.

With the exception of reason A.5, a significant number of miners agreed that each of the factors listed in this section is an important deterrent to the prevention of groundfall accidents. This suggests that further attention should be given to devising better ways to lessen the influence of these seven barriers.

Why miners sometimes walk under unsupported roof

The victims of roof falls are often found in areas of unsupported roof. MSHA fatality reports indicate that more than half of the 97 deaths due to groundfalls in coal mines during 1979 and 1980 occurred in areas of unsupported roof. The questions in this section were directed toward better defining the reasons why miners fail to avoid unsupported roof, how many miners go under unsupported roof, and how often.

Reasons for walking under unsupported roof. MSHA roof and rib inspectors were asked what motivates miners to illegally go under unsupported roof (the only legally permissible reason for going under unsupported roof is to set temporary supports, before installing permanent

TABLE II. - Rank-ordering of reasons for neglect of roof fall hazards, according to percentage of persons expressing agreement

	Reason	Total "agree" responses	Strongly agree	Agree	Slightly agree	Slightly disagree	Disagree	Strongly disagree
A-8	They don't take enough time to look for roof problems.....	80.7	11.4	55.0	14.3	5.0	14.3	0.0
A-7	They don't realize how dangerous roof problems really are.....	68.4	13.7	43.2	11.5	2.9	20.9	7.9
A-4	They dislike doing the type of work necessary to correct the problem.....	57.7	8.1	31.1	18.5	5.2	33.3	3.7
A-2	They feel it is someone else's responsibility.....	51.5	9.2	32.4	9.9	10.6	31.7	6.3
A-1	They don't have the tools or materials to correct the problem...	51.0	7.1	32.6	11.3	7.8	32.6	8.5
A-3	They don't want to risk getting hurt.....	47.9	5.0	25.0	17.9	6.4	40.0	5.7
A-6	They don't know how to correct the roof problem.....	36.5	2.9	20.7	12.9	5.7	45.7	12.1
A-5	They believe that their foreman thinks that taking care of roof problems is unimportant.....	11.3	0.7	7.8	2.8	2.8	56.7	29.1

supports). The most common reply to this question was that miners do this to save time and/or effort, i.e., they want to take a shortcut.

Inspectors mentioned several factors that sometimes contribute to miners' willingness to risk working under unsupported roof. Among them were the following:

- they are in a hurry to get more coal out, especially if they think they are behind
- they want to cut down the walking distance to a place they need to go
- they think that the unsupported roof "looks good" (safe")
- they do it inadvertently
- they have done it before without getting hurt
- they are unwilling to set temporary supports
- in order to finish loading a shuttle car, continuous miner operators might go a little beyond the edge of properly supported roof

Proportion and frequency of miners walking under unsupported roof

In order to roughly estimate the proportion of miners who go under unsupported roof, miners were asked "During a typical month, what percent of miners who work at the face go under unsupported roof for reasons other than to set temporary supports?" Miners' responses to this question are given in Table III. The median of the estimates for the percentage of miners who go under unsupported roof during a typical month was 10 pct. (Half of the estimates were greater than 10 pct and half the estimates were less than 10 pct.) This suggests that the percent of miners going under unsupported roof is relatively low.

In order to estimate the frequency with which miners go under unsupported roof, miners were asked, "Considering a typical crew of miners who work at the face, how often does someone go under unsupported roof for reasons other than to set temporary supports?" Miners' responses to this question are listed in Table IV.

TABLE III. - Estimates of percentage of miners who go beneath unsupported roof during a typical month

Estimate (in pct.)	Miners in agreement with estimate	Miners in agreement with estimate (pct.)
0.....	34	27.2
1.....	9	7.2
2.....	8	6.4
5.....	9	7.2
9.....	1	.8
10.....	21	16.8
15.....	2	1.6
20.....	7	5.6
25.....	7	5.6
30.....	4	3.2
35.....	2	1.6
50.....	13	10.4
60.....	1	.8
75.....	2	1.6
80.....	2	1.6
90.....	2	1.6
100.....	1	.8
Total.....	125	100.0

Approximately 44 pct. indicated that they believed someone goes under unsupported roof at least once per shift.

Over 25 pct. indicated that they believed that someone goes under unsupported roof at least once per week, but not as often as once per shift.

These estimates suggest that going under unsupported roof is not an uncommon event in a typical mining crew, and that more attention should be given to preventing miners from engaging in this practice. In conjunction with the data from Table III, these estimates suggest that few miners go under unsupported roof, but that those who do so, do so rather often.

TABLE IV. - Estimates of frequency with which someone in a typical crew of miners goes beneath unsupported roof

Estimate	Miners in agreement with estimate	Miners in agreement with estimate (pct.)
At least once per shift..	48	43.6
At least once per week, but less often than once every shift..	28	25.4
At least once per month, but less often than once every week..	16	14.6
Less than once per month..	18	16.4
Total..	110	100.0

Opinions on various measures for preventing groundfall accidents

Each participant was initially asked to respond to an open-ended question concerning measures that could be taken to prevent groundfall accidents. This question was followed by nine forced-choice questions.

Open-ended question. Miners were asked for their opinions about what should be done to reduce the number of rock fall accidents in the coal industry. Their most common replies are listed below. (Numbers in parentheses indicate the number of miners who replied as indicated.)

better training (19)
inspect the roof more often (14)
don't make entries too wide (7)
drill test holes more frequently/deeper (7)
always set temporary supports before walking beyond bolts (7)
put more emphasis on the dangerousness of groundfall accidents (7)
follow the roof control plan/ bolting pattern more closely (6)
use more of the ATRS type bolter (5)
recheck existing supports more often (5)
add more supports to bad areas (5)

MSHA inspectors were also asked what they thought needed to be done to prevent more roof fall accidents in the coal industry. The most common response was that the use of automated temporary roof support systems on bolters should be mandatory. Such systems are expected to significantly reduce the amount of time miners spend beneath unsupported roof. Other responses included:

use remote sensing devices to check for gas at the face

do not assign inexperienced crews to perform retreat mining
encourage continuous miner operators to report roof problems to bolters
avoid letting sections stand idle during pillar recovery
ensure closer compliance with the roof control plan and other safety rules
improve training

Forced-choice questions. Miners were asked to indicate the degree to which various changes would help them avoid rock fall injuries. A six point rating scale from "a very small degree" to "a very large degree" was used to respond to each statement. The rating scale contained the following options: a very small degree, a small degree, a somewhat small degree, a somewhat large degree, a large degree, a very large degree.

Nine different changes (listed in table V) were inserted into the blank in the following question: "To what degree would _____ help miners avoid rock fall injuries?" The percent of miners who chose each point on the rating scale is presented in Table V. The first column of numbers indicates the percent of miners who chose "a large degree" or "a very large degree" to answer the question.

Table V rank-orders the nine questions in this section in terms of the highest to lowest percent of persons who chose either the "large" or "very large" responses. In order of descending rank, the top three items are: adding more support to bad areas of the roof; better training in proper methods of supporting the roof; and better training in the identification of roof hazards. Except for better lighting, the majority of the miners indicated that all of the proposed changes would help miners avoid rock fall injuries to a large or very large degree. (The corresponding percentage for "better lighting" was 44 pct.) The perceived importance of the nine changes proposed in this section suggests that consideration should be given to the possibility of implementing all nine.

Miners' experience with rock falls

The miners interviewed for this study were asked to provide information about their recent experiences with rock falls which is not typically collected by MSHA. Miners were asked for detailed information about either (1) recent injuries they had suffered as a result of a rock fall, or (2) incidents in which they were startled due to their close proximity to large pieces of falling rock.

Miners' responses indicated that unplanned rock falls in underground coal mines are a somewhat common event. Of the 143 miners interviewed for this study, 88 reported that they had either been injured or startled by a rock fall at least one time during the preceding year. Of those who reported that they had been recently startled by large pieces of falling rock, 8]. pct. said that such an incident had happened more than once within the past year. The median number of such incidents reported by these persons was 3. Of the miners who reported that they had recently suffered an injury caused by a groundfall, 65 pct. said that they had been near the location of the rock fall for only a few minutes prior to the accident. This suggests that many rock fall accidents could be avoided if miners would always check the roof before beginning to work in a new area.

TABLE V. - Rank-ordering of questions about degree to which various changes would help miners to avoid rock fall injuries, according to percentage of persons who chose "large" or "very large" degree responses

	Reason	Large or very large	Very small	Small	Somewhat small	Somewhat large	Large	Very large
B-8	Adding more support to bad areas of the roof.....	78.9	3.0	5.3	3.8	9.0	39.8	39.1
B-5	Better training in proper methods of supporting the roof.....	69.2	2.3	11.3	3.0	14.3	43.6	25.6
B-4	Better training in the identification of roof hazards.....	68.4	3.0	6.0	6.8	15.8	45.1	23.3
B-6	Reprimanding or penalizing those who repeatedly go beneath unsupported roof.....	60.0	10.4	14.8	5.2	9.6	28.9	31.1
B-7	Better scaling of the roof.....	56.7	2.2	17.2	8.2	15.7	37.3	19.4
B-3	Foreman putting greater emphasis on correcting roof hazards.....	56.3	6.7	15.6	4.4	17.0	37.8	18.5
B-2	Less noise.....	56.0	7.5	19.4	6.0	11.2	38.1	17.9
B-9	Better installation of roof bolts.....	53.1	6.1	25.8	5.3	9.8	25.8	27.3
B-1	Better lighting.....	44.0	14.2	26.9	9.7	5.2	30.6	13.4

DISCUSSION

The data collected for this study suggests that most people who work underground agree that the factors listed in Figure 1 are significant barriers to coal miners' prevention of groundfall accidents. The evidence supporting this assertion is reviewed below.

Inability to recognize groundfall hazards

The reasons for an individual's inability to recognize groundfall hazards may be an attribute of the person or of the environment. Data supporting the importance of this set of factors comes from miners' responses to questions B.1, B.2 , and B.4. Forty-four pct. said that better lighting would help miners avoid rock fall injuries to a large or very large degree. This implies that miners may often fail to recognize hazardous roof conditions because the illumination is not good enough to be able to detect them. Fifty-six pct. said that less noise would help miners to a large or very large degree. This implies that there may often be too much noise for miners to hear sounds that could warn them that a hazardous roof condition exists. Sixty-eight pct. said that better training in the identification of roof hazards would help miners to a large or very large degree. This suggests that miners sometimes fail to recognize certain types of hazardous roof conditions because they are not aware that these roof conditions should be considered hazardous.

Inability to correct groundfall hazards

Data supporting the importance of this set of factors comes from miners' responses to questions A.1, A.6 and B.6. Fifty-one pct. agreed that one of the main reasons that miners sometimes neglect the correction of roof hazards is that they do not have the tools or materials with them that are needed to fix the roof problem. Thirty-seven pct. agreed that one of the main reasons that miners sometimes neglect the correction of roof hazards is that they do not know how to correct roof problems. This suggests that miners sometimes fail to correct certain types of hazardous roof problems because they have never learned how to correct them. ixty-nine pct. said that better training in proper methods of supporting the roof would help miners avoid rock fall injuries to a large or very large degree.

Lack of motivation to search for groundfall hazards

Data supporting the importance of this set of factors comes from miners' responses to questions A.8, A.7 and B.3. Eighty-one pct. agreed that one of the main reasons that miners sometimes neglect the correction of roof hazards is that they do not take enough time to look for roof problems. One reason that miners might not take enough time to look for roof problems is that they do not fully comprehend the dangers of roof problems. In response to questions A.7, 68.4 pct. agreed that one of the main reasons that miners sometimes neglect the correction of roof hazards is that they do not realize how dangerous roof problems really are. Another reason that miners might not take enough time to look for roof problems is that they do not think that their foreman wants them to devote much time to this activity. In response to question B.3, 56 pct. indicated that "foremen putting greater emphasis on correcting roof hazards" would help miners avoid rock fall injuries to a large or very large degree.

Lack of motivation to correct groundfall hazards

Data supporting the importance of five types of factors within this category come from miners' responses to questions A.2, A.3, A.4, A.7 and B.3. Fifty-one pct. agreed that one of the main reasons that miners sometimes neglect the correction of roof hazards is because they think that it is someone else's responbility to take care of roof problems. Forty-eight pct. agreed that one of the main reasons that miners sometimes neglect the correction of roof hazards is because they don't want to risk getting hurt while fixing the roof. Fifty-eight pct. agreed that one of the main reasons that miners sometimes neglect the correction of roof hazards is because they dislike doing the type of work necessary to correct the roof problem. Sixty-eight pct. agreed that one of the main reasons that miners sometimes neglect the correction of roof hazards is that they do not realize how dangerous roof problems really are. Fifty-six pct. indicated that "foremen putting greater emphasis on correcting roof hazards" would help miners avoid rock fall injuries to a large or very large degree.

Preventing groundfall accidents

When asked about what should be done to reduce the number of roof fall accidents in the coal industry, both miners and inspectors frequently cited the need for better training in this area. (See Peters and Wiehagen (2)) for a list of specific suggestions regarding training improvements.) A significant number of miners agreed that each of the changes proposed in statements B.1 to B.9 would significantly help miners to avoid rock fall injuries. The three highest ranked changes were: adding more support to bad areas of the roof; better training in proper methods of supporting the roof; and better training in the identification of roof hazards.

A major strength of the information presented in this paper is that it was obtained from people who regularly work underground. These people are in a unique position to explain why miners sometimes neglect the correction of potentially hazardous roof problems, why they expose themselves to hazardous areas of roof, and what might be done to overcome barriers to miners' prevention of accidents. However, there are a variety of cognitive limitations and motivational biases which shape the way people make sense of the world around them. In interpreting and understanding the data in this study, it is important to keep in mind that the miners and inspectors interviewed were subject to a variety of such limitations and biases. However, given that there are no obvious reasons why the participants in this study would have wanted to provide distorted answers to the questions they were asked, and given that they are the people whose decisions and actions most directly prevent or fail to prevent groundfall accidents, their assessment of the problem and potential solutions should most definitely be considered to be an informative and insightful source of information.

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EDITED BY:

Gavin Faulkner
Department of Mining and
Minerals Engineering
Virginia Polytechnic Institute
and State University

William H. Sutherland
Mine Safety and Health Administration
U.S. Department of Labor

David R. Forshey
Bureau of Mines
U.S. Department of the Interior

J. Richard Lucas
Department of Mining and
Minerals Engineering
Virginia Polytechnic Institute
and State University

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