

## **Contributing factors to slip, trip, and fall fatalities at surface coal and metal/nonmetal mines**

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Previous work has been done in the mining industry to identify contributing factors for injuries based on MSHA reports of fatalities and non-fatal injuries. Although slips, trips, and falls account for a large proportion of fatalities and non-fatal injuries, the contributing factors associated with these incidents have not been adequately documented in the mining industry. To this end, publically available MSHA reports describing fatalities were coded to identify job categories, activities, causal factors, and contributing factors for slip, trip, and fall fatalities at surface mining facilities. Laborer, equipment operator, mechanic/maintenance man, and supervisor/management/trainer were the job categories associated with a large proportion of fatalities. Maintenance and repair has been shown to be a hazardous task, and it was also found to result in slips, trips, and falls fatalities. In addition, installation, construction, and dismantling were common tasks at the time of the incidents. The cause of most fatalities involved a fall from height for both the coal and metal/nonmetal sectors, with falling through an opening, failure of the ground/equipment, or being ejected from/thrown off of equipment being secondary causes. The most common contributing factor was the lack of fall protection or inappropriate use of fall protection. Inadequate barriers, equipment-related factors, and a lack of adequate operating procedure were also identified as contributing factors. To prevent slip, trip, and fall fatalities, it is recommended that (1) special attention be placed on maintenance, repair, construction, and dismantling activities, (2) appropriate and adequate barriers are installed when needed to prevent inadvertent access, (3) equipment is regularly inspected and maintained, and (4) employees are provided appropriate safety equipment, safe working procedures are established and followed, and adequate training is provided.

### **INTRODUCTION**

Mining is a hazardous occupation leading to approximately 10,500 non-fatal injuries a year (Mine Safety and Health Administration, 2003-2012). Approximately 21% of these non-fatal injuries can be attributed to slips and falls. The large proportion of injuries associated with slips and falls also plague other industries such as construction, healthcare, and food services (Bell, Collins, Dalsey, & Virginia, 2010; Courtney, Sorock, Manning, Collins, & Holbein-Jenny, 2001; Lipscomb, Glazner, Bondy, Guarini, & Lezotte, 2006).

The Mine Safety and Health Administration (MSHA) provides a detailed description of all fatalities that occur at mine sites in a public fatal accident investigation report (referred to as fatal report from now on) (<http://www.msha.gov/data-reports/fatality-reports>). These fatal reports provide detailed information and are often used to identify common citations and as case examples in training. Importantly, the reports also provide additional information including remedial actions that could prevent further incidents.

In 2005, Chi, Chang, & Ting (2005) systematically evaluated fall fatalities in the construction industry and identified a number of contributing factors and preventative measures including barriers and restraint systems that could help improve health and safety in the construction industry. Similarly, work has been done in the mining industry to identify contributing factors for injuries based on MSHA reports of the fatality (Drury, Porter, & Dempsey, 2012; Reardon, Heberger, & Dempsey, 2014). However, slips, trips,

and falls were not the primary focus of those investigations. The aim of this study was to identify the causes of slip, trip, and fall fatalities in the mining industry, and document contributing factors that if eliminated may have prevented the fatalities.

### **METHODS**

#### **Case selection**

The detailed fatal reports published by MSHA were used for this analysis. The fatal reports can be categorized based on general incident type and provide a description of the incident, any investigation that was carried out, the root cause of the incident, and citations served.

A preliminary review of both coal and metal/nonmetal fatal reports for a 10-year period from 2003-2012 was conducted by two reviewers independently to identify if the event entailed a slip, trip, or fall and occurred at a surface operation (i.e., a non-underground mining operation). A list of potential fatal reports was compiled for further classification and coding after discrepancies in the potential list were resolved through discussion. Forty-seven of 242 fatal reports from the metal/nonmetal sector and 20 out of 299 from the coal sector over the 10-year period of interest entailed a slip, trip, or fall event.

#### **Classification and coding**

Preliminary coding was carried out on 20 fatal reports by two coders to develop and refine the coding scheme. The

categories of interest included the job category of the individual involved, activity at the time of the incident, the cause of injury, and the contributing factors.

Job categories were coded based on what was specified in the fatal report, and terms commonly used by MSHA for coding fatalities and non-fatal injuries were used as descriptors. A list of activities at the time of the incident was created based on the preliminary coding and included categories such as routine maintenance and repair, installation/construction/dismantling of new/old equipment or structures, daily operations (activities performed as part of regular operation of a mine, such as operating equipment), housekeeping, inspection, and supervising.

To code the cause of the fatality, Chi et al. (2005) used the US Department of Labor event categories similar to those used by MSHA. One shortcoming of this approach was that it is not clear if a fall was from a height (i.e., if the surface from which the fall occurred was above the surface on which the victim landed). To help alleviate this issue, if the location from which the individual fell was known, it was specified in the coding or the incident was coded as a fall from height or a fall to same level. The primary cause of the fatality was often stated in the fatal reports; however, the exact surface of origin and events leading to the fatality or secondary causes were often unclear. For example, although the fatal reports may indicate that the individual fell from a height, it was unclear where exactly the individual was standing or what caused the fall (e.g., a slip or unexpected movement).

For each incident, it was assumed that there was at least one contributing factor that if eliminated/rectified would have prevented the fatality (Drury & Brill, 1983). We identified up to five such contributing factors for each fatal report. Table 1 shows the list of contributing factors and their definitions.

After the preliminary coding and coding scheme development, two coders independently coded all 67 identified fatal reports. After coding, any discrepancies were resolved through discussion. If it was not possible to resolve discrepancies, a third independent coder was consulted. As part of the coding, it was identified that some fatal reports (four for metal/nonmetal and one for coal) that were initially identified as associated with a slip, trip, or fall were in fact due to other causes and were eliminated from further analysis. The fatalities eliminated were associated with individuals getting engulfed or drowning without a slip, trip, or fall event. The resultant data set accounted for 62 fatal reports (43 for metal/nonmetal and 19 for coal).

## RESULTS

### Job categories and activities

Eighty-two percent of all identified fatalities could be attributed to four primary job categories: laborer, equipment operator, mechanic/maintenance man, and supervisor/management/trainer (Table 2). For the coal sector, a larger proportion of fatalities were attributed to laborers and supervisor/management/trainer as compared to the metal/nonmetal sector. In contrast, the metal/nonmetal sector had a larger proportion of fatalities attributed to equipment

operators and truck drivers as compared to the coal sector. The proportion of fatalities was the same for the mechanic/maintenance man for both sectors.

Table 1: Contributing factors and their definitions

Contributing Factor	Definition
Barriers	Barriers not present, not properly installed or inadequate
Equipment-related	Any equipment-related issues, including use of broken or damaged equipment, unintended/improper use of equipment, modifications to equipment not recommended by manufacturer, failure of equipment, improper design of equipment
Fall protection	Fall protection not used or not used appropriately
Housekeeping	Contaminants on working surface
Illumination	Lack of adequate illumination
Lockout/tagout & blocking	Failure to properly de-energize, lockout/tagout and/or block equipment to resist movement
Medical complications	Victim had a medical complication after initial injury that led to fatality
Operating procedure	No safe working procedures provided (either from management or manufacturer) including no training on procedures
Personal protective equipment	Personal protective equipment (PPE) not available or not used (other than fall protection), PPE not used appropriately, incorrect type of PPE used
Structural/ground failure	Failure of building, walking surface, unstable ground (at time of incident)
Substance abuse	Person under the influence of a controlled substance at time of incident

Table 2: Job categories for individuals who were fatally injured

Job categories	Coal		Metal/nonmetal		Total	
	n	(%)	n	(%)	n	(%)
Laborer	8	(42.1)	10	(23.3)	18	(29.0)
Equipment operator	2	(10.5)	12	(27.9)	14	(22.6)
Mechanic/maintenance man	3	(15.8)	7	(16.3)	10	(16.1)
Supervisor/management/trainer	6	(31.6)	3	(7.0)	9	(14.5)
Truck driver	-	(0.0)	6	(14.0)	6	(9.7)
Contractor	-	(0.0)	3	(7.0)	3	(4.8)
Owner	-	(0.0)	2	(4.7)	2	(3.2)

The largest proportion of fatalities (37%) occurred when performing maintenance and repair activities (Table 3). Installation/construction/dismantling accounted for 18% and daily operations also accounted for 18% of the identified fatalities. On occasion, job categories did not correspond directly to the work activities—for example, at the time of the fatality, a laborer may have been inspecting equipment or a

truck driver may have been conducting routine maintenance. For the coal sector, a larger proportion of fatalities were attributed to installation/construction/dismantling and inspection as compared to the metal/nonmetal sector. In contrast, the metal/nonmetal sector had a larger proportion of fatalities attributed to maintenance and repair and daily operations as compared to the coal sector.

**Event or cause of fatality**

The primary cause (approximately 60%) of all fatalities identified was a fall from height for both sectors (Table 4). Although in 10 (27%) of the cases it was not clear what led to the fall from height (secondary cause), based on the fatal reports 50% of the fall from height fatalities were due to falling through an opening, failure of the ground/equipment, or being ejected from/thrown off of equipment (Figure 1).

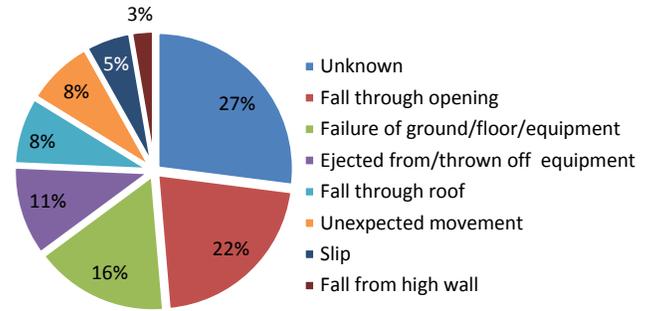


Figure 1: Secondary causes that led to fall from height fatalities

Approximately 10% of the identified fatalities (Table 4) were due to fall from stairs/ladders, half of which were due to a slip or unexpected movement of the stairs/ladder. Falling into water also accounted for approximately 10% of the fatalities. Additional causes of fatalities identified were engulfed by material, fall into equipment, fall from trailer/truck, and fall to same level. The one struck by incident was an unusual case where an individual fell off a piece of equipment and the equipment rolled onto the individual while the individual was still on the ground.

**Contributing factors**

Fall protection not being used when it should have been or not being used appropriately (incorrect type for situation or tying off incorrectly) contributed to 33% of the fatalities identified (Table 5). Equipment related issues including broken, damaged, modified, failed, improper use of, and design of equipment contributed to 14% of the fatalities. The lack of and inadequate barriers contributed to 13% of the fatalities and was most often due to an individual stepping into/onto an opening in the ground. In addition, safe operating procedure contributed to 12% of the fatalities. The other contributing factors associated with slip, trip, and fall fatalities are shown in Table 5. There were some differences between the coal and metal/nonmetal sectors. For the metal/nonmetal sector, three factors—fall protection, barriers, and operating procedure—accounted for approximately 67% of the identified contributing factors. In contrast, for coal, two factors—fall protection and equipment-related factors—accounted for approximately 50% of the identified contributing factors.

**DISCUSSION & RECOMMENDATIONS**

The objectives of this investigation were to identify job categories, activities, causal factors, and contributing factors for slip, trip, and fall fatalities at surface mining facilities. Laborer, equipment operator, mechanic/maintenance man, and supervisor/management/trainer were most often the victims of a fatal slip, trip, or fall incident at surface mining facilities. This is not surprising as there is evidence that maintenance and repair workers are exposed to slip, trip, and fall hazards; including working on debris and wet surfaces (Heberger, Nasarwanji, Paquet, Pollard, & Dempsey, 2012).

Table 3: Activities being performed at the time of the incident

Job categories	Coal		Metal/nonmetal		Total	
	n	(%)	n	(%)	n	(%)
Maintenance and repair	4	(21.1)	19	(44.2)	23	(37.1)
Installation/construction/dismantling	7	(36.8)	4	(9.3)	11	(17.7)
Daily operations	2	(10.5)	9	(20.9)	11	(17.7)
Housekeeping		(0.0)	5	(11.6)	5	(8.1)
Inspection	3	(15.8)	2	(4.7)	5	(8.1)
Supervising	1	(5.3)	2	(4.7)	3	(4.8)
Unknown	2	(10.5)	2	(4.7)	4	(6.5)

Table 4: Primary cause of fatalities and number of incidents associated with each cause

Primary cause	Coal		Metal/nonmetal		Total	
	n	(%)	n	(%)	n	(%)
Fall from height	11	(57.9)	26	(60.5)	37	(59.7)
Fall from stairs/ladder	4	(21.1)	2	(4.7)	6	(9.7)
Fall into water	2	(10.5)	4	(9.3)	6	(9.7)
Engulfed/fall into material	-	-	4	(9.3)	4	(6.5)
Fall into equipment	-	-	4	(9.3)	4	(6.5)
Fall from truck/trailer	-	-	3	(7.0)	3	(4.8)
Fall to same level	1	(5.3)	-	-	1	(1.6)
Struck by	1	(5.3)	-	-	1	(1.6)

Table 5: Contributing factors associated with slip, trip, and fall fatalities

Contributing Factors	Coal		Metal/nonmetal		Total	
	n	(%)	n	(%)	n	(%)
Fall protection	11	(27.5)	27	(36.0)	38	(33.0)
Equipment-related	9	(22.5)	7	(9.3)	16	(13.9)
Barriers	2	(5.0)	13	(17.3)	15	(13.0)
Operating procedure	4	(10.0)	10	(13.3)	14	(12.2)
Lockout/tagout & blocking	3	(7.5)	7	(9.3)	10	(8.7)
Structural/ground failure	1	(2.5)	6	(8.0)	7	(6.1)
Medical complications	3	(7.5)	2	(2.7)	5	(4.3)
Personal protective equipment	1	(2.5)	3	(4.0)	4	(3.5)
Housekeeping	2	(5.0)	-	-	2	(1.7)
Illumination	2	(5.0)	-	-	2	(1.7)
Substance abuse	2	(5.0)	-	-	2	(1.7)

Fatalities associated with maintenance and repair were studied extensively by Reardon et al. (2014), as they are a significant contributor for fatalities in the mining industry. Our findings provide further support for the thesis that maintenance and repair, construction, and installing and dismantling equipment are hazardous activities. These activities pose a threat as equipment is often not designed for maintenance and repair, and during these activities the system is in flux. Because some of the hazards during maintenance and repair cannot be engineered out, care should be taken to limit access when possible and use appropriate PPE.

The leading cause of slip, trip, and fall fatalities at surface sites was a fall from height (approximately 60%). By comparison, the largest proportion of non-fatal fall injuries at surface sites is due to falls to walkway or walking surfaces (approximately 40%) (Mine Safety and Health Administration, 2003-2012). Although it is unclear if the falls to walkway or walking surface were from a height, there may be differences in the hazards that cause slip, trip, and fall fatalities and non-fatal injuries, and likewise in the strategies to identify and remediate them. A few contributing factors for fatalities are described here, but additional research is needed to identify the cause and contributing factors for non-fatal injuries to help remediate them.

All fatalities identified had at least one contributing factor that if mitigated could have potentially prevented the incident or lessened the severity of the injury. Guidelines suggest that preventing access or restricting work in hazardous areas is preferable (Occupational Safety Health Administration, 2003). As revealed by the fatal reports, the lack of barriers or inadequate barriers was a contributing factor to slip, trip, and fall fatalities. Chi et al. (2005) found a similar trend for fall fatalities in the construction industry, where unguarded openings was the leading contributing factor.

During maintenance, repair, or installing and dismantling equipment, areas of the walking surface are often removed to permit or improve access to the equipment. Special care should be taken in these situations to ensure that appropriate barriers are installed immediately around the opening to prevent inadvertent access. In addition, during regular operations, debris can cover surfaces that are not designed to support the weight of an individual such as skylights. These areas should also be kept free of debris and clearly marked or barricaded off to prevent inadvertent access. When housekeeping around these areas is undertaken, such as to remove debris, work should proceed with caution, so as to not tread on those surfaces. In addition, any temporary flooring, such as wooden panels, should be inspected regularly.

If barriers cannot be provided and access cannot be restricted, the use of fall protection is recommended when working at heights. The use of fall protection may have prevented a number of the fatalities identified; however, it is not clear why fall protection was not used. It would be beneficial to further evaluate the risk perception of individuals in these situations and identify why fall protection was not used. In some cases, such as fall through an opening or where barriers were inadequate, the individuals may not have felt that they were at risk and hence assumed they did not need the fall protection. In other instances, incorrect fall protection was used or the fall protection was not used appropriately (e.g., not tied off suitably). Providing adequate and appropriate fall arrest systems, including harnesses that are easily accessible, fitted to the individual, and designed for the specific task, and clearly marked and substantial tie off points, is essential for the safety of employees along with adequate training to ensure proper use.

Most equipment-related factors can be controlled, including broken, damaged, and modified or failed equipment. Regular inspection and maintenance of equipment is essential for not only the health and safety of employees but also for efficient operations. In addition, companies should be responsible for providing employees with safe working procedures and adequate training. Performing a hazard assessment before any task can help to identify hazards and ensure adequate safety precautions are taken to remediate them or prevent an incident.

## CONCLUSIONS

The objective of this paper was to identify the causes and contributing factors to slip, trip, and fall fatalities at surface mining operations. Most fatalities were associated with a few job categories and common activities. Maintenance and repair has been shown to be a hazardous task for other types of fatalities, and the same holds true for slips, trips, and falls. Fall from height was the primary cause of most fatalities. In addition, limiting access through the use of adequate and appropriate barriers and using appropriate fall protection is critical in preventing fatalities along with regular inspection and maintenance of equipment.

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