Slips, Trips & Falls in Construction & Mining: Causes & Controls

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Incidences of workplace slips, trips and falls (STFs) should be rare, as both the hazards that cause them and the severity of associated injuries are well-known. Furthermore, in light of advances in engineering, equipment, training, housekeeping and regulations, it is not unreasonable to expect that STFs would have been effectively controlled—if not eliminated. In reality, however, the statistics prove otherwise. The primary purpose of this article is to describe and discuss physical dynamics and common causes of STFs, and to explore and recommend a comprehensive strategy to reduce them. The primary focus of the article is two industries—construction and mining—that are particularly vulnerable to these incidents.

Slips, trips and falls are a serious topic (despite the overuse of STF as sight gags by the entertainment industry). STF incidents occur in every sector of the economy and cause a large number of deaths and injuries, as well as much pain and suffering.

Between 1994 and 1998, an average of 14,784 persons per year were killed by falls (NSC). As Table 1 shows, between 1996 and 1999, the average number of work-related deaths per year was 6,095 (BLS). The average number of occupational fatalities due to falls during this period was 705 per year—about 12 percent of the total.

Construction industry workers are particularly vulnerable to loss of life as the result of STFs. About 50 percent of all the work-related fall deaths involve construction workers. In addition, one in every three construction fatalities is due to a fall (Table 1). Falls to a lower level are the most-common type of fatal fall, accounting for nearly 90 percent of work-related deaths (Table 2).

These falls are further broken down into falls from ladders, roofs and scaffolds, and falls to the same level, with the first three categories accounting for most deaths. From 1993 to 1997, 23 percent of construction injuries/illnesses involving days away from work was attributed to STFs (NSC).

STFs also account for a significant proportion of non-fatal occupational injuries. On average in 1996 and 1997, STFs accounted for 20 percent of the injuries/illnesses involving days away from work (NSC).

Workers in certain segments of the mining industry are also at risk of STFs. As Table 3 shows, between 1996 and 1999, 28 miners died from slips or falls (MSHA). Some 86 percent of these fatalities occurred in operations other than coal mining (e.g., metal, non-metal, stone, sand and gravel). The greatest proportion (40 percent) of fall fatalities has occurred in stone mining (Figure 1), an industry that acounts for about 24 percent of the average total employment in mining. From 1996 to 1999, more contractors died from falls in the stone mining sector than contractors in all other sectors combined (Figure 2). Contractor workers account for more than half of the fatalities (53 percent) recorded.

STFs also account for a significant proportion (22 percent) of non-fatal lost-time (NFDL) injuries (Table 4). However, 92 percent of these injuries occurred in nearly equal proportions across mining sectors. The greatest proportion (43 percent) has occurred in coal mining (Figure 3). In every sector, the number of miners experiencing NFDL fall injuries is far greater than the number of contractors who experience such injuries (Figure 4).

HAZARDOUS ENVIRONMENTS

In addition to being exposed to the elements, construction worksites often feature many trip hazards (e.g., tools, materials, debris). Furthermore, steel erectors, roofers and carpenters often work above ground level and therefore are exposed to fall hazards. Construction workers are also mobile, often performing tasks in environments that change daily.

Mining environments (both surface and underground) pose a variety of STF hazards. For example, at surface mines, the grounds are often uneven and may feature depressions, broken rock, highwall edges, sloped banks, ponds, voids and cracks near walking/working edges. In addition, these sites are exposed to the elements of rain, ice, sleet and snow.

In underground mines, walking/working travelways may be poorly lit and may contain water-filled dips; in addition, they are frequently uneven and may be cluttered with debris. Some travelways include shafts or vertical and sloping tunnels while others contain rail tracks or belt haulage. Mining equipment, machinery and plant structures introduce additional hazards. Equipment operators and mechanics who service these machines are especially vulnerable to STFs.

Significant progress remains to be achieved in both construction and mining. Regulations are the first step in prevention efforts. The continued occurrence of these incidents underscores the vital role of management and the need for effective controls.

FALL PROTECTION/PREVENTION REGULATIONS

In the U.S., OSHA and MSHA have promulgated regulations to control STF hazards within the industries they oversee. The scope of these standards is broad and includes equipment, structures, training, management and work procedures.

OSHA Regulations

OSHA's standards regarding STF prevention can be found in 29 CFR Part 1910 (general industry) and 29 CFR Part 1926 (construction). Several provisions of 29 CFR 1926 address, either directly or indirectly, STF prevention. Topics covered include personal protective and lifesaving equipment (Subpart E); scaffolds (Subpart L); fall protection (Subpart M); cranes, derricks, hoists, elevators and conveyors (Subpart N); steel erection (Subpart R); underground construction (Subpart S); demolition (Subpart T); power transmission and distribution (Subpart V); stairways and ladders (Subpart X); and specific rules for fall protection and fall prevention (Subpart M). In particular, Subpart M includes five appendices that contain guidelines to enhance regulatory compliance.

MSHA Regulations

MSHA promulgates standards for both metal and nonmetal mining and coal mining, covering both surface and underground operations. Standards relevant to STF prevention are found in 30 CFR Parts 56, 57, 75 and 77. Parts 56 and 57 for surface metal/nonmetal mining (e.g., crushed stone, dimension stone, sand and gravel) and underground mining (e.g., limestone, metals, clay), respectively, include mandates relevant to STF prevention (Subparts J and N). Most of these standards are applicable to both surface and underground operations and cover safe access, handrails/toeboards, ladders, walkways and openings.

These standards encompass design and placement requirements, warnings and housekeeping. Those applicable only to surface operations address fixed ladder requirements and scaffolds, while those applicable only to underground mines cover ladderways and escape routes. Except for the standard regarding escape routes, these regulations can be classified as equipment-related. MSHA regulations (Subpart N) do not prohibit (as OSHA's do) use of safety belts for fall protection in areas where miners are exposed to fall hazards and when areas such as bins and tanks are entered.

30 CFR Part 77 (Subpart C) contains requirements for facilities, openings, travelways, ladders and illumination. Related to STF control, these mandates are applicable to surface coal mining, and surface areas of underground coal mining. The standards address general conditions of structures and travelways (e.g., in good repair, free of snow and ice) protection of openings and design considerations of ladders.

From a safety standpoint, these regulations appear to be extensive. OSHA's rules governing construction activities, occupations, equipment and training appear to be more comprehensive than those for mining environments. This difference is likely due to the fact that construction worksites may contain more STF hazards and are more subject to change.

As the injury statistics indicate, significant progress remains to be achieved in both construction and mining. Regulations are the first step in STF prevention and fall protection efforts. The continued occurrence of these incidents underscores the vital role of management and the need for effective hazard controls as part of the effort to reduce unsafe conditions

TABLE 1 Comparison of Total Occupational and Construction Fatalities and Construction Fall Fatalities (1996-1999)

Year	Total Fatalities	Fall Fatalities	% of Total Fatalities	Construction Fatalities	Construction Fall Fatalities		
					Number	% of Construction Fatalities	% of Total Fall Fatalities
1996	6112	684	11.2	1039	337	32.4	49.3
1997	6218	715	11.5	1107	377	34.1	53.0
1998	6026	702	11.6	1171	383	32.7	54.6
1999	6023	717	11.9	1190	378	31.8	52.7
Average	**6095**	**705**	**11.6**	**1127**	**369**	**32.6**	**52.3**

Source: Bureau of Labor Statistics (www.bls.gov).

TABLE 2
Number of Fatal Occupational Falls by Event (1996-1999)

Event	1996-1999 Average	1996	1997	1998	1999
Falls to lower level	629	607	652	623	634
•from ladder	105	95	116	111	96
•from roof	152	148	154	156	153
•from scaffold	91	88	87	97	92
Falls on same level	53	49	44	51	66
All other falls	304	304	314	287	310
Total	**705**	**684**	**715**	**702**	**717**

Source: Bureau of Labor Statistics (www.bls.gov).

and at-risk behaviors involved in injury-producing incidents.

UNDERSTANDING SLIPS, TRIPS & FALLS

STF events share similar characteristics. They involve unintended human movement—the loss of one's balance or footing—and are linked by a common force—gravity. Trips and slips may lead to a fall, but a fall need not be preceded by a slip or trip. Sometimes, all three events are part of one mishap involving a chain-reaction sequence. However, the cause of each event is unique.

These events can result in injuries of varying degrees. Some slips result in strained muscles. Some trips cause a person to fall into another object, producing blunt-trauma injuries. Falls can produce a variety of injuries—ranging from strains and sprains to fractures (Leclercq). An understanding of the physics involved and of the direct and indirect causes related to each incident type is essential to effective prevention strategies.

Slips

In most cases, a person slips due to a sudden decrease of friction between the footwear sole and the contact surface. Technically, slips occur only when the slip resistance between the foot sole and the surface with which it is in contact is insufficient to prevent the two surfaces from moving against one another (Anon. 10). Just as an automobile slips and slides on an icy road due to the loss of traction between the tires and the road surface, humans can experience the same feeling of loss of control when traversing a slippery surface. During a slip, the body's center of support rapidly moves out from under the body's center of gravity.

The physics of "people slips" are more complex than vehicle tire slips. In a human locomotion sequence (a series of alternate push-offs and touchdowns performed by the feet), the most-frequent slip occurs in the touchdown, when the person's heel slides forward.

Such a slip usually results in a backward fall, as the forward momentum of the slipping foot shifts the center of gravity backward. A slip resulting in the body falling forward may occur when the push-off foot slips backwards. Lateral slips are also possible; these can occur when a person changes direction or turns a corner (Lin, et al 1995).

Slippery surfaces, such as icy sidewalks, wet linoleum, tile or smooth concrete can cause slips. Worn out shoe soles or certain types of sole material can increase the risk of slips as well. At times, at-risk behavior such as abrupt starts and stops or quick direction changes can cause slips. A person's gait is also a factor; failure to adjust one's gait or walking speed when moving from one surface to another (e.g., from a carpeted floor to a smooth, hard-surface floor) can produce a slip.

Construction and mine sites are prime locations for slips. Parking lots on these sites are often uneven, contain smooth stones and are exposed to precipitation. Most walking and climbing areas in surface mining and construction are subject to weather elements as well. In effect, every surface becomes a hazard at one time or another.

Mud, grease and oil are also present in many cases. Mud can cling to shoes, ladder rungs and equipment. In addition, walking and working surfaces on large machines (e.g., draglines, cranes, excavators) may be partially covered with oil, grease and other petroleum-based fluids. The presence of such contaminants compromises traction. Underground mines also contain several slip hazards, such as sloping ground, muddy bottom and moisture-covered surfaces (e.g., rails, ties).

Trips

A person trips when the forward movement of the feet is suddenly interrupted but the body continues to move forward (Figura 30); the body's center of gravity has moved forward from its center of support (the feet), creating a loss of balance. While balance may be regained in some cases, in others the body may continue moving forward until it collides with the walking surface (fall to same level) falls to a lower level or crashes into another object.

Trips may caused by irregularities in the floor. For example, one may encounter a step in an otherwise flat walking surface. The human gait is such that the average clearance is around eight millimeters, but can be as small as one millimeter; in some cases, seemingly insignificant height differences—as small as six millimeters—can cause a trip (Figura 30).

Obstacles in a walkway or travel path can also cause a trip. A person's foot can snag a hose, wire, debris or tool; these items can also block the movement of the feet and produce a trip. Obstacles in the travel path (snag points) above the level of the ankle can catch clothing or tools and cause a trip as well.

Trip hazards abound in the mining environment. Walking/working areas around surface mills and plants, and those in and around the pit area may contain loose rocks (various sizes and dimensions). Surface mine workers involved in clearing the land of trees may trip over tree limbs, logs and stumps. Blasting sites present tripping hazards related to tubing, wires, and blast-related tools, materials and equipment. In some cases, one may also find belting, steel bundles, tires and other materials stacked or stored around mills, plants and buildings, which exposes workers to additional tripping hazards. Parts, hoses, electrical wires, pipes and storage buckets left in pathways, stairwells and travelways further increase the risk of trips. Underground mining travelways, storage areas and working faces demand attention as

TABLE 3
Fall Fatalities in the Mining Industry (1996-1999)

Mining Industry Sectors	Total Fatalities in Mining Sectors	Fall Fatalities			Proportions Within a Sector		Proportion of Fall Fatalities to Total Fall Fatalities by Sector
		Mine Worker	Contractor Employees	Total	Total Fall/ Total Fatalities	Contract Worker Fall/Total Fall	
Coal	129	3	1	4	0.03	0.25	0.14
Metal	45	3	2	5	0.11	0.40	0.18
Non-Metal	13	0	2	2	0.15	1.00	0.07
Stone	101	3	8	11	0.11	0.73	0.39
Sand & Gravel	53	4	2	6	0.11	0.50	0.21
Total	**341**	**13**	**15**	**28**	**0.08**	**0.53**	**100%**

Raw data compiled from U.S. Dept. of Labor, MSHA (Mine Injury and Worktime, Quarterly); 1999 data is preliminary; total may not equal 100 because of rounding.

TABLE 4
Non-Fatal Days Lost (NFDL) Fall Injuries in the Mining Industry (1996-1999)

Mining Industry Sectors	Total NFDL in Mining Sectors NFDL	Fall NFDL Incidents			Proportions Within a Sector		Proportion of Fall NFDL Incidents to Total Fall NFDL by Sector
		Mine Worker	Contractor Employees	Total	Total Fall/ Total NFDL Incidents	Contract Worker Fall/Total Fall	
Coal	22,954	3,965	432	4,397	0.19	0.10	0.42
Metal	6,115	1,137	202	1,339	0.22	0.15	0.13
Non-Metal	3,133	690	69	759	0.24	0.19	0.07
Stone	11,159	2,617	152	2,769	0.25	0.05	0.27
Sand & Gravel	4,130	1,048	16	1,064	0.26	0.01	0.10
Total	**47,491**	**9,457**	**871**	**10,328**	**0.22**	**0.08**	**100%**

Raw data compiled from U.S. Dept. of Labor, MSHA (Mine Injury and Worktime, Quarterly); 1999 data is preliminary; total may not equal 100 because of rounding.

well. These areas may be cluttered with product, rock, discarded supplies, parts and tools; some travelways also contain railroad ties and rails. Depending on the mining methods used, working face areas can be confining (e.g., longwall panel). In such tight quarters, workers must bend over while walking, which brings them close to many snag points. Continuous mine face areas contain many trip hazards as well, such as cables, curtains, posts, roof bolts and protruding nails. In other areas of the mine, workers often share space—in relatively tight quarters—with pipes, cables, steel, blocks, belting, rollers, posts, hoses and roof bolts, each of which presents a potential tripping hazard.

Falls

A fall occurs when a person's center of gravity either gets ahead or behind the center of support. Unless balance is regained, the force of gravity pulls the person down to rest on a lower surface.

Falls can be divided into two main categories: 1) falls to the same level and 2) falls to a lower level. In most cases, falls to a lower level are more serious since the length of the fall determines the acceleration the body reaches during its downward motion, which in turn determines the force of impact. The force the body experiences as it collides with an object in its path is greater at higher velocities than at lower velocities. As noted, falls may be precipitated by a slip or trip. However, falls may also be caused by secondary causes, such as missteps (Figure 3), loss of support and overextending.

Construction and maintenance workers often work above ground level and are particularly vulnerable to falls as a result of these secondary causes. For example, roofers are regularly exposed to the danger of falling off ladders or off the edge of a roof. Maintenance workers are also exposed to hazards posed by floor or wall openings, as well as elevated walkways, scaffolds, ramps and other structures. Miners (especially drillers) who work around highwalls could fall off the top of the highwall edge. Such incidents occur when workers get too close to the edge and lose their footing, or when the edge of the highwall breaks lose underfoot. Workers may also be exposed to unmarked drill holes that may pose a falling hazard.

Miners who work as mechanics or equipment operators face fall risks as well. For example, mechanics typically use ladders to gain access to work areas that may be slippery. In other cases, a hand railing may give way. A miner may also encounter an uncovered—and unbarricaded—floor opening. Equipment operators climb on and off equipment (loaders, dozers, shovels, excavators, trucks) several times each day, which increases the risk of a slip and fall. Dozer operators are especially vulnerable to STF hazards since this equipment rarely is equipped with steps or stairs (Stanevich 703+). As a result, operators often use the tracks as "steps"; these surfaces are typically smooth metal, which may be wet and slippery.

CONTRIBUTING FACTORS

Factors that contribute to STF hazards are associated with four areas: 1) workers; 2) machine/equipment; 3) work environment; and 4) management. Walking, climbing, carrying materials and working in locations that are elevated and slippery require caution. Personal factors that contribute to STF hazards include failure to follow prescribed work practices, improper use of equipment, inadequate training, inadequate supervision, fatigue, motor-skill impairment and risk-taking behavior. Around equipment and machinery, personal factors can include poor traction; not using three points of contact while ascending/descending equipment; and failure to use protective gear.

Machinery and equipment factors include improper design (e.g. ladders, stairs, scaffolds, handholds), missing components (e.g., open-sided or unguarded walking or working elevated surfaces), inadequate maintenance, poor housekeeping and defective equipment (e.g., worn, damaged PPE). Environmental conditions such as wind, snow, dust, steam and poor lighting can increase fall risks as well.

Management must strive to control the sources of these hazards and work to eliminate or mitigate their adverse effects. STF hazards are exacerbated when no controls are implemented—or when controls are ineffective. Management can control personal, equipment and environmental factors through proper planning, monitoring and corrective action.

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STRATEGIES TO REDUCE STFS

STFs demand a systematic problem-solving approach. The Shewhart Cycle, which consists of a plan-do-check-act sequence, is especially relevant considering the consistent losses incurred as a result of STFs (Deming). The "plan" step consists of devising a strategy to improve results. Most programs will have a similar overarching goal such as, "Eliminate loss-producing STF incidents." This goal would then be supported by a site-specific objective, such as, "Reduce the number of STFs by 50 percent in the next 12 months."

The "do," "check" and "act" aspects are concerned with implementing the plan, measuring results, and initiating control actions on the basis of the measurement and progress toward objectives. In traditional process management school terminology, the strategy should consider the following aspects: 1) planning; 2) designing and engineering; 3) organizing and staffing (including training); and 4) monitoring and controlling.

Planning

Implementation of any incident reduction program requires strong management support and direction. The first step is to conduct a comprehensive needs assessment to better understand the problem and to define goals; such an assessment will help identify and document the problem (Kaufman 1987). Although this can be a time-consuming process, it is essential for all subsequent activities.

In the context of STF reduction efforts, some needs are dictated by regulations; however, compliance is only the starting point. A site must also gather data related to workers, machinery, the work environment and management. This can be achieved via surveys and interviews, inspections, observations and analysis of injury/incident reports.

Pertinent administrative factors that must be considered during a needs assessment include policies on training, inspections, audits, supervision, planning practices, maintenance, availability and allocation of resources. Developing policies that require daily inspections and regular audits, as well as timely follow-up with corrective actions, are a basic administrative responsibility. Aggressive production goals or unrealistic maintenance deadlines can tempt employees and supervisors to take shortcuts, which may lead to STF incidents.

Policies on personnel selection, training and job assignments are essential as well. For example, some workers are afraid of heights; where possible, they should not be assigned to perform work above ground level (Kuhar 69+). Specific policies and work rules that identify critical safe behaviors are also needed. In other words, a comprehensive assessment of management control factors in terms of both "paper" and "practice" must be conducted.

Environmental conditions must also be assessed. This will encompass factors such as lighting, dust, spills, water accumulation, equipment/tool design and condition, walking/working surfaces and obstacles. Engineering input is needed during the planning stages to ensure that an effective personal fall protection system is devised. Here, the safety department must work closely with supervisors, employees and purchasing staff to determine what tasks require fall protection; what type of fall protection system is most appropriate for each task; the type and quality of equipment available; and the availability and design of tie-off points.

Employee knowledge, skills and attitudes also play an important role in STF incidents. These personal factors can be difficult to assess, but they must be addressed since training is an important element in reducing STF incidents. Any assessment would be incomplete without data that document current work practices (i.e., evaluate at-risk and safe behaviors in the context of potential movement-related injuries). This evaluation could focus on activities such as working from scaffolds, climbing ladders, roof work and getting on/off equipment.

At this stage, site management should explore programs that can reinforce positive behavior. For example, behavior-based safety (BBS) programs aim to enhance safe behaviors and eliminate unsafe behaviors. Essentially, through

FIGURE 1 Proportion of Fall Fatalities to Total Fall Fatalities by Sector

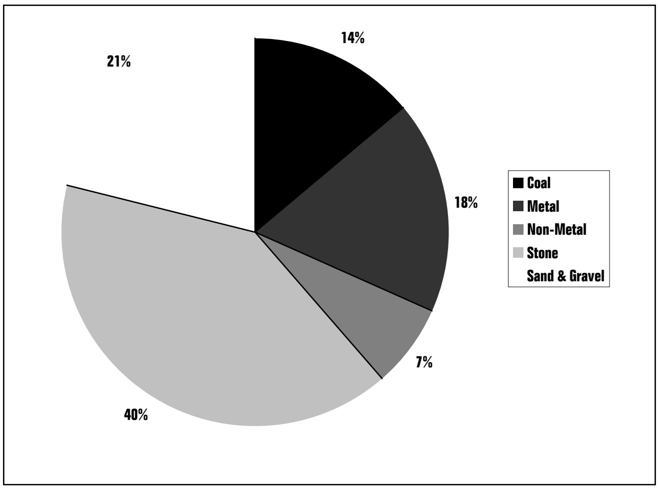
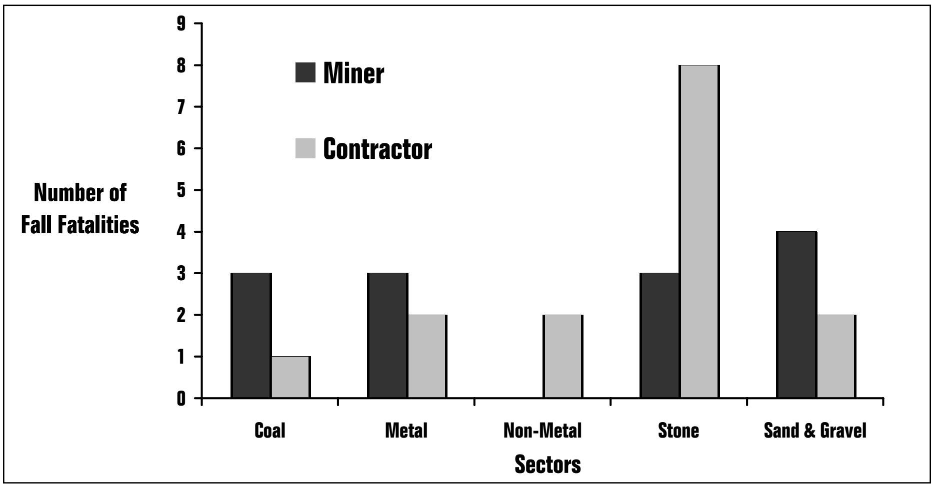


FIGURE 2 Number of Miner & Contractor Fatalities by Sector



positive feedback for correct behaviors and corrective feedback for at-risk behaviors, the proportion of safe behaviors can significantly increase. In this context, target behaviors might include: near-hit reporting, safety enhancement suggestions, participation in voluntary training, achieving a pre-determined percentage of safe behaviors and safety audits completed during a certain period of time.

In addition, all employers should adopt a policy that enables an employee to stop work if s/he believes a hazard exists; work should resume only after the hazard has been controlled or eliminated. Ideally, employee involvement should be the cornerstone of preventive efforts. In the authors' opinion, an organization that actively solicits employee input regarding STF reduction strategies will have greater success than one that proceeds in a top-down manner.

Since all worksites are unique, the resulting injury reduction plan should reflect that uniqueness. However, all plans will share several similar characteristics based on current knowledge of STF causes and effective countermeasures.

Designing & Engineering

Eliminating STF hazards or at least limiting exposure to these hazards through engineering and design should be a primary goal. Engineering-based controls, while potentially expensive, are an effective strategy because they enhance the safety of the work environment, which is often more controllable than personal or behavioral factors. Consequently, engineering and equipment selection should include a discussion of the benefit/cost of adopting a strategy that will reduce, for example, climbing or limit exposure to STF hazards.

For example, the traction and design characteristics of walkways, stairs, platforms, ramps, ladders, floors and boot/shoe soles are critical concerns. Engineering solutions to STF hazards must also be considered with regard to stairs, ladders, personal fall protection systems, lighting and drainage. Technological advances such as remote control and automation must be considered where applicable as well.

Enhancing Traction

Substantial research has been conducted on the slip resistance of both walking/standing surfaces and work shoe/boot soles (Gronqvist; Jones; Silver). While unrealistic to increase the slip resistance of all surfaces that may be traversed, many can be modified to improve traction. Sanding slippery surfaces or using anti-skid products can improve traction.

In addition, eliminating the buildup of contaminants is important, For example, water is often used in mining/milling processes to control dust, wash and separate materials, and circulate and move minerals. To prevent water accumulation on travelways, the site must control leaks from pipes, hoses, tanks and roofs, and eliminate overspray. Accumulations of ice or snow on travelways or in work areas must be cleared as well.

Slip-resistant footwear should also be considered. Spiked or studded soles can improve traction on ice, while soles surfaced with aluminum oxide have reportedly decreased slips as much as 50 percent (Figura 29+). The shape of the heel edge and degree of sole wear are key factors as well. Specifically, a slightly beveled or rounded heel edge (as opposed to sharp or square) helps prevent slips, as do slightly worn (as opposed to new) soles.

A comparative analysis of the slip-resistant qualities of nitrite rubber, styrene rubber and polyurethane soles found polyurethane soles to be the most slip-resistant (Gronqvist 224+); a similar study supported the superiority of polyurethane soles over other common sole materials (Jones 242+). Generally, the most-slip-resistant soles seem to be those with a rough finish and high elasticity (Silver 36+).

Climbing Aids

If ladders are a required element of a particular job, management should con-

FIGURE 3 Proportion of Non-Fatal Days Lost Fall Incidents to Total NFDL Fall Incidents by Sector

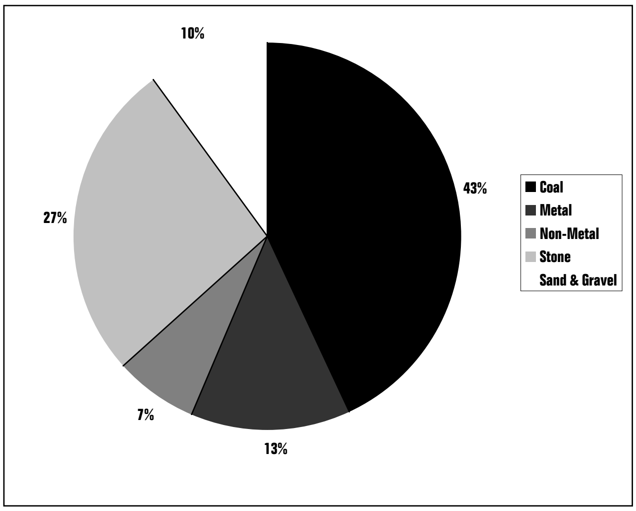
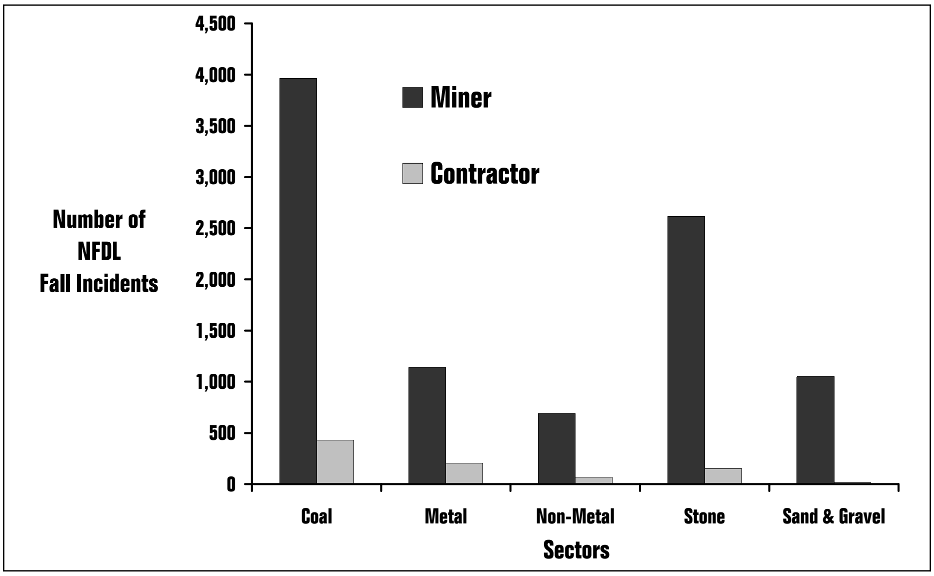


FIGURE 4 Number of Minor & Contractor Non-Fatal Days Lost Fall Incidents by Sector



sider installing appropriately designed stairs instead (e.g., evenly spaced risers, handrails that can be easily grasped). Existing stairs should be inspected regularly, as should all ladders. For tasks that require extensive climbing and long exposure to working at elevation, it may be best to install equipment designed for work above ground level.

Surface miners and construction workers have been observed working from the extended bucket of front-end loaders or the raised forks of lift trucks, both of which are dangerous practices. A mobile manlift, bucket truck or cage attached to a crane boom is a safer alternative for tasks that must be performed at heights (e.g., gutter work, changing lights, maintenance, manual scaling, roof bolting).

Lighting

Adequate lighting is crucial to injury prevention. Hazards that cannot be seen (wet spots, debris, uneven flooring) increase the risk of an incident. Fortunately, most outdoor construction work is conducted during daylight hours. However, basements, below-ground excavations and the interior of structures may be dimly lit.

Because underground mine environments lack natural light, miners must rely on cap lamps, lights from equipment and incandescent lighting (if available). As a result, many STF hazards go unnoticed or are noticed only after it is too late. During the day, surface mine sites have adequate lighting. However, since these sites may operate 24-hour shifts, certain hazards (e.g., those around highwalls) may be difficult to detect after sundown.

Wetness Control

Wetness of walking/working surfaces is another area that must be addressed. Many construction projects (roads, building construction, roofing) stop when it rains. However, workers in underground or surface mines are regularly exposed to water; in fact, a dry underground mine is rare. Aside from water accumulation in dips, many surfaces (such as ladders, rails, cables) can be wet and slippery. Around surface mine installations, it may be necessary to modify drainage in order to direct water away from walking surfaces. Surface water problems can be eliminated or controlled through the installation of swales, French drains and gutter systems, while indoor problems can be addressed with floor drain systems and pumps.

Regardless of the engineering solutions implemented, spills will occur and wet surfaces will develop. This is where regular housekeeping and maintenance step in. Although housekeeping policies start with administration, good housekeeping is the responsibility of every worker. It involves cleaning up a spill, marking the area until it can be cleaned or spreading an absorbent; it may also encompass activities such as removing debris, tools or other potential obstacles.

Proper maintenance is an effective STF control as well. Replacing oil seals, fixing fluid leaks and repairing ladders, stairs, walkways, scaffolds and personal fall system components all contribute to accident prevention. Workers must also be trained to identify STF hazards, especially those that can be controlled by housekeeping and maintenance, as well as in best practices designed to reduce the risk of STF.

Organizing & Staffing

To ensure the success of an STF reduction program, resources must be procured, coordinated, arranged and directed to achieve desired results. With respect to human resources, once hiring decisions are made, training is paramount.

Training entails the presentation of controlled information and practice that results in performance according to standards that can be measured. Implicit in this definition is the concept that training's primary purpose is to provide knowledge and skills to workers who will then apply what they have learned to complete tasks according to pre-established standards. As the cited statistics show, STF incidents are complex, the hazards many and progress toward improvement slow.

Therefore, in the case of STF incident reduction, training is not only appropriate, it is necessary to reduce gaps in knowledge and skills. To succeed, training content and duration must be based on site-specific needs. The program must be comprehensive in scope and should encompass both hourly workers and supervisors (Ramani, et al). For example, one track could focus on enhancing hazard awareness, another on supervisory responsibilities and yet another on fall protection.

Hazard Awareness Training

This training is recommended for all miners and construction workers. The goal is to enhance workers' ability to recognize and take appropriate actions in response to various STF hazards. Training should cover the nature and location of STF hazards in the workplace, and should review STF-related issues in the given industry along with a description of hazards, relevant regulations, preventive strategies and protection systems.

Training for Supervisors

Safety is a management function. While top and middle managers are responsible for planning, allocating and procuring resources for STF safety programs (including training), front-line supervisors are the key to effective implementation of these programs. Therefore, a comprehensive supervisory STF prevention program is recommended. It should focus on increasing hazard awareness and identification; provide strategies to effectively plan, implement and evaluate a hazard prevention program; and address principles for conducting accident investigations.

In addition, this program should address how key safety principles and practices can be adapted to STF prevention; this will include 1) establishing goals and objectives; 2) safe work practices and policies; 3) job and equipment design; 4) hazard assessment; 5) hazard controls; 6) workplace observations; 7) enforcement of policies and practices; 8) education and training; and 9) management and employee involvement.

Train-the-Trainer

Employers should also consider implementing a train-the-trainer course for STF control. Such a program would help refine the planning, teaching and organizational skills of those who provide STF-related training. Course content should include the basic principles of training, training needs assessment, job analysis, adult learning principles, designing and developing training lessons, presentation skills and course evaluation.

Specialty Training

The greatest need for specialty training is in the area of personal fall prevention and protection, particularly with respect to the many federal rules and wide array of specialized equipment. Fall prevention specialists recommend a curriculum that includes 1) common causes of falls; 2) physics of falling; 3) end result of falling; 4) different types of fall protec-

STFs demand a systematic problem-solving approach. The Shewhart Cycle, which consists of a plan-do-check-act sequence, is especially relevant considering the consistent losses incurred as a result of STFs.

tion available; 5) purpose and use of each component; 6) when and how to use them; 7) what happens when the fall protection equipment is deployed; and 8) inspection and maintenance recommendations, practices and procedures (Kuhar 69+; Willen 92+).

Other Training Issues

Instructional methods and materials are as important as training content because student interest and involvement are vital to learning. While delivering some material via lecture is unavoidable, a good training session will incorporate site-specific examples, demonstrations, case studies, illustrations, hands-on practice, video, slides and computer-aided instruction. Relevant instructional materials and resources can be obtained from various sources, such as OSHA, MSHA, NIOSH, state agencies, Construction Safety Council, Center to Protect Worker's Rights, land grant universities, insurance companies and various vendors; in most cases, these materials can be adapted to site-specific needs.

Monitoring & Control

Planning and control go hand in hand. Without planning, there can be no effective control; without control, planning is not very effective. To control, one must monitor and measure. Monitoring to ensure that STF hazards are controlled is essential. Unsafe conditions, unsafe acts and at-risk behaviors must be identified and eliminated. Frequent inspections by supervisors and workers should be standard practice. This process is aided by a checklist that covers all aspects of the job—workers, materials, environment and management.

Timely follow-up on reported hazards is essential as well. Here, affected workers and supervisors must be informed of inspection results and receive feedback on their performance and their accountability for workplace conditions. In addition, management must monitor industry-wide STF trends and investigate all STF incidents within its operations in order to update the STF database and identify emerging concerns.

CONCLUSION

Slip, trip and fall incidents continue to occur in U.S. workplaces despite advances in technology and accident prevention techniques. Some construction specialties (roofers, sheet-metal workers) and certain mining occupations (surface equipment operators and mechanics) appear to be particularly vulnerable to these incidents.

Understanding the physics and causal factors of these incidents, and developing effective control strategies is critical to their reduction. This should include development and enforcement of administrative measures and must account for OSHA and MSHA regulatory requirements. Wherever practicable, this process should focus on engineering solutions and should encompass training and behavior-based interventions. The final program should be based on a comprehensive needs assessment of the site and must detail planning, engineering, training, and monitoring and control aspects. To succeed, the program must have unconditional management support and widespread employee involvement. ■

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