SLIP AND FALL: FALL PROTECTION IN CONSTRUCTION SAFETY

PROBLEM STATEMENT

In 1995, there were approximately 343,000 injuries attributable to work-related falls involving days away from work in private industry. According to the National Safety Council, falls are one of the highest causes of death in the construction industry and other workplaces. During 1996, nearly 22% of days-away-from-work injuries resulted from slips and falls in the construction industry. In addition to the lost lives and injuries caused by falls, businesses lose millions of dollars each year due to the loss of work days of the injured workers, significant increases in insurance premiums, workers' compensation claims, and product liability costs.

Construction workers have high risks for occupational injuries and fatalities in the workplace. Data from the Bureau of Labor Statistics (BLS) indicated that the construction industry had the highest injury-incidence rate -- 9.7 per 100 full-time workers -- among all industries in 1996. The lost-workday injury-incidence rate (4.4 per 100 full-time workers) of the construction industry was the second highest in the United States in 1996; only that of the transportation industry (5.0 per 100 full-time workers) was higher. Falls are the third leading cause of non-fatal occupational injuries in the construction industry. Only overexertion and being struck by an object rank higher than fall-induced events. Falls have been found to be a significant contributor to lumbar spine injury, fracture of bones, and disability. The injury from a slip or fall may also result in a musculoskeletal strain injury, usually to the low back, ankle, or knee.

According to BLS, the number of workplace fatalities among all industries decreased to a five-year low in 1996. However, deaths caused by falls continued to increase in 1996 with the construction industry accounting for more than half of those fatalities. Falls are the leading cause of occupational fatality among construction workers. Falls accounted for approximately 32% of fatal occupational injuries in the construction industry for 1995, 98% of them were falls from elevation.

DEFINITION OF SLIP AND FALL

A fall is an event which results in a person unintentionally coming to rest on the ground or a lower level. Before a fall incident occurs, a person first experiences postural imbalance or increased propensity for loss of balance. The duration between the first experience of loss of balance and the event of fall is usually very short. In the event that a person cannot recover his or her balance, a fall incident will occur. A slip is a type of fall caused by a sudden decrease in the base of support. Slips are often caused by environmental factors such as icy, wet, or oily floors.

CLASSIFICATION OF FALLS

There are several ways to classify falls -- by environmental factors, medical factors, locations in which falls occurred, or kinesiologic factors. The most common classification is based on the place or location where the fall incident takes place. Falls can be categorized into

three groups: falls on the same level, falls from elevation, and stair falls. Slips and trips are the main contributors to falls on the same level. Stair falls may include slips or trips leading to falls, such as stumbling while ascending. Common examples of falls from elevations in the construction industry are falls from ladders or scaffolds, which often result in serious injury or even death.

Sliding is the motion that precedes a slip-type of fall. Some researchers use a sliding distance to determine a slipping performance level. Slips are classified into 3 groups: micro-slips, slips, and slides with respect to the sliding distance. The micro-slip is defined as a sliding movement which is brought under control within a distance of approximately three centimeters. These slips are often undetected. When a slip becomes an uncontrolled movement with a sliding distance greater than 10 centimeters, it is treated as a slide, and between the sliding distance of 3 and 10 centimeters, it is called a slip.

HOW DO FALLS OCCUR?

From the standpoint of biomechanics, a free-standing person is stable when the center of gravity (CG) of the body is located vertically above the ground-contact area of the feet, which is also called the base of support area. If a person's CG is within the base of support area, it is safe, since he or she is able to resist the de-stabilizing influence of gravity, and can continue to perform tasks. If that person's CG moves outside the perimeter of the base of support, the body exceeds the in-place limits of stability; therefore, the situation is unstable. To prevent a fall, a rapid step or stumble to re-establish the base of support beneath the CG or additional external support is needed. The base of support is the area contained within the perimeter of contact between the floor and the feet. In many cases, the base of support is reduced and confined if the standing surface is not firm and flat, or not big enough to support the entire area of the feet, such as standing on a ladder or rooftop. When the body's CG approaches the outer edge of the base of support, the probability of falling increases.

HOW DO SLIPS OCCUR?

A slip incident is related to forces generated at the feet and frictional properties of the shoe-floor interface. Slip is initiated when the ratio of horizontal force to vertical force at the feet exceeds the friction properties of the shoe-floor interface (Figure 1) . This ratio, also known as required coefficient of friction (COF), is the demand of friction to perform a task safely without any slips. In daily activities, the demand of friction changes continuously due to changes in task and environmental conditions. In a previous study of slips, comparisons were made between a required COF value for performing a particular task, with the COF value that can be provided by the shoe/floor combination. Slips were predicted when the required COF exceeded the specific COF provided by the shoe/floor interface. Results of high speed photography of a foot while contacting an oily surface showed that a slip could be predicted from comparisons of required COF and shoe/floor COF. Low friction may cause a slip but, on the other hand, high friction presents a potential risk of tripping. Slipping and tripping incidents often occur unexpectedly when COF changes rapidly.

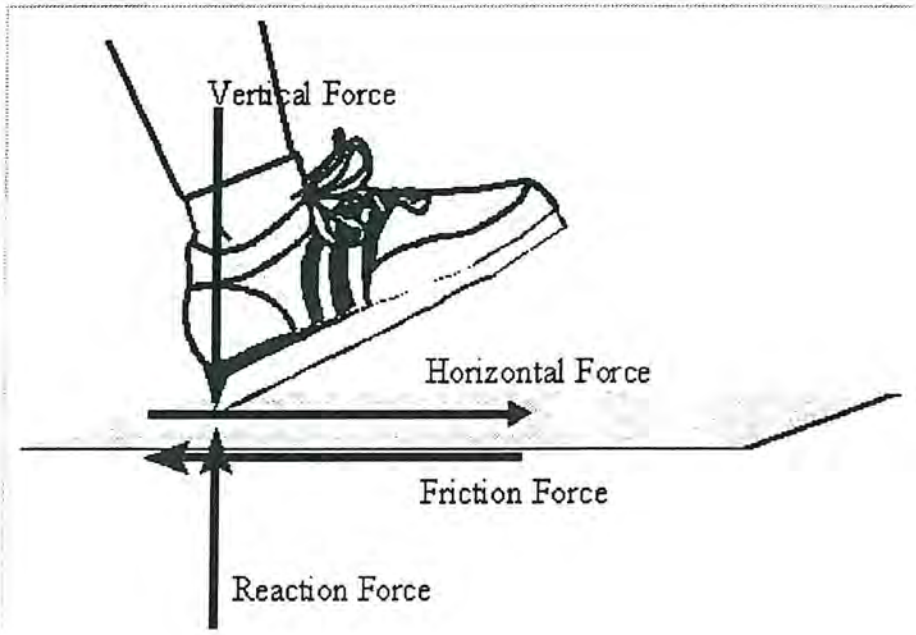

Figure 1 The required COF is the ratio of horizontal force to vertical force. If the required COF exceeds the COF between the shoe and the floor, a slip will occur.

CAUSES OF SLIPS AND FALLS

Epidemiological, tribological, biomechanical, and psychological approaches have been studied to reduce slip and fall accidents. It has been found that causes of slips and falls in the workplace are complex. Many factors contribute to the mechanism of a slip or fall, such as the type of task being performed, environmental factors, required friction between footwear and the floor, and health status. An accident-profile analysis of 3000 cases in the workplace by Cohen et al., found that environmental lighting, work surface, job-task, and footwear properties were significant factors in slip-induced incidents. The following describes the causes of slips and falls as multi-dimensional events involving physical, chemical, and personal factors:

Physical Factors

Physical factors contributing to slips and falls include the type of task being performed and environmental factors. In the construction industry, many tasks require workers to maintain awkward postures, often resulting in a localized muscle fatigue and a propensity for loss of balance which may give rise to a slip/fall incident. Construction tasks which have to be conducted at elevated surfaces are also main sources of fall injuries. In a study conducted by the National Institute for Occupational Safety and Health (NIOSH), 180,876 construction workers' compensation cases in 21 states were studied for the year 1987. Among 30 construction occupations studied, roofers and drywall installers were found to have the most fall-from-elevation injuries. The high incidence rate for falls for these two occupations can be attributed to the nature of the roofing and drywall installation tasks. Roofers often have to transport materials while ascending and descending ladders, work at the edge of the roof to perform tasks, or work on roofs that contain openings. For drywall installers to perform ceiling installation, they first have to lift a heavy and bulky drywall sheet to elevated surfaces and then constantly extend their heads/necks, upper extremities, and upper trunks to handle the weight of the sheets. Both roofing and drywall installation activities are physically demanding and are likely to cause workers' CG to extend closer to the outer edges of the base of support, thereby increasing the probability of falling. In addition, roofers and drywall installers may not be able to change their base of support efficiently and accurately in response to any possible momentary loss of balance, since the workers are handling bulky and heavy materials within confined and elevated spaces (e.g. on ladders).

Slips and falls can also arise from various environmental hazards. The three major environmental factors associated with slips and falls are lighting, weather, and floor conditions. Poor lighting, along with obstruction of peripheral vision, which can be due to poor workplace layout or carrying oversized material, can place the worker at risk of a fall incident. The Illuminating Engineering Society suggested that 30 foot-candles of general lighting be used for all areas where regular visual tasks are done. In some construction work sites, supplementary lighting should be obtained with a combination of general lighting. In a study conducted by a British hospital emergency department, inadequate illumination has been found to account for 42% of slips and falls. A clear view of the walkway and of any potential hazard is a necessity. Any lack of visual acuity (poor lighting, or in a poor contrast environment) can lead to slips, because the visual feedback necessary for maintaining postural balance is considerably inhibited.

Many slip and fall incidents are the results of an unsafe floor. Floors with temporary obstructions cluttering the area, level changes, or low friction may cause trips, falls to a lower level, or slips. Flooring materials are also important for preventing slips. Floors with roughened surfaces tend to be more slip resistant than smooth surface floors. However, an absolute non-slip floor does not exist, there are only varying degrees of slip resistance. The friction change of the floor surface due to contaminants such as oil or water can cause a loss of traction resulting in a fall or slip. Although there are a variety of devices for testing the slip resistance of floors, the Occupation Safety and Health Administration (OSHA) does not recommend any standard testing method or device due to the complex factors involving in measuring COF. In 1989, a Finnish researcher developed a COF classification using an artificial leg in the laboratory. He suggested a minimum dynamic COF value of 0.2 to be slip resistant. For COF values of 0.15 to 0.19, a slip is

possible but the loss of balance is often recoverable.

Chemical Factors

Exposure to neurotoxic chemicals may contribute to postural imbalance. Chemicals such as lead, organic solvents, and pesticides can affect the neuromotor function of the human body which is crucial in maintaining balance. When postural balance cannot be maintained, the propensity for loss of balance is increased; thus, workers become more susceptible to slips and falls.

Personal Factors

Age, postural stability adjustment capability -- which can be indicated by the level of fitness and muscle strength -- and the perception of an impending slip or fall are all important personal factors related to slips and falls. Postural stability undergoes maturation from birth to about 10 years of age. After 25 to 30 years of age, body balance begins to deteriorate gradually. Previous studies have documented that if a person moves a body segment while standing upright, there exists a postural adjustment preceding this movement. Therefore, workers ability to correctly perceive their balance demands during task performance is critical to triggering the body movement strategy needed to maintain balance without slipping.

FALL RELATED REGULATIONS IN THE UNITED STATES

The Federal Government administers workplace safety and health through OSHA with a series of mandatory standards to provide safe employment and workplaces. Fall-related standards issued by the American National Standards Institute (ANSI) are voluntary, representing the consensus of participating members substantially concerned with the standards' scope and provisions. A summary of current regulations and standards pertaining to fall protection is shown in Table 1.

Table 1

The application of regulatory requirements depends on the specific location, industry, and the type of operations in the workplace. To address the high incidence rate of fall injuries in the construction industry, OSHA published the final fall-protection regulations for the construction industry in August, 1994, which took effect in February 1995. The fall protection standard details when an employer must provide fall protection to workers. Fall protection is required whenever employees are potentially exposed to falls from a height of six feet or greater. To comply with the standards, OSHA requires the implementation of at least one fall protection system (e.g., safety

nets, guardrails, personal fall arrest system) when a potential fall hazard exists. If conventional fall protection is not feasible, the locations must be identified and classified as controlled access zones with warning lines and monitoring systems.

SOLUTIONS TO THE PROBLEM

Construction workers face enormous safety hazards due to the nature of their work. Construction tasks are highly dynamic and complex, and often require workers to handle heavy materials, perform jobs at elevated surfaces and in varying environmental conditions. Additionally, construction projects often involve different contractors or sub-contractors working in the field. Unique characteristics of the work environment — constantly changing tasks, materials, worksite layout, and environmental conditions such as exposure to the weather — contribute to the safety hazards of the construction worksite.

To prevent fall injuries, the use of engineering methods to eliminate all fall-related hazards is necessary. Engineering designs that eliminate hazards are most preferred over any other methods such as the use of personal protective devices; however, this is not always possible. If safeguards by design are not feasible, then protective devices should be used. Additionally, adequate procedures and worker training should be used whether or not protective devices or engineering methods are in use or available.

A comprehensive fall protection program is very important to prevent fall-related incidents. It can eliminate or significantly reduce on-the-job injuries and fatalities, and substantially reduce business losses. Effective fall protection programs are those where employers take an active role to work closely with workers to identify fall hazards and then jointly develop a comprehensive plan that either eliminates fall hazards or provides appropriate protection against them. A comprehensive fall protection program has five components: (1) fall hazard identification; (2) written fall protection plan; (3) fall protection equipment; (4) worker training; and (5) audit and maintenance. All fall-related incidents should be monitored and investigated. Implementing any necessary changes to the fall protection plan is crucial. Each of the fall protection program components are described below:

Fall Hazard Identification

A well conceived fall protection program begins with the identification of all potential fall hazards in the workplace. Most environmental and task-risk factors that are related to falls can often be identified from an inspection of the work site by experienced safety professionals. OSHA requires employers to evaluate potential hazards and control measures before workers begin work at heights. Major environmental risk factors that are related to falls include the lighting condition of the workplace, slip resistance and contamination of the walking surface, falling objects, and tripping hazards. Tasks which involve handling heavy and bulky objects might expose the workers to a higher risk for falls. These tasks can shift the workers' whole body CG close to the edge of their base of support, and/or block the workers' peripheral vision, which is important for maintaining balance. Examination of elevated equipment is also important. The collapse of

unstable structures can result in serious fall injuries and fatalities. Where a fall hazard is identified, there are two acceptable options as described earlier: (1) eliminate the hazard by design, or (2) provide protective equipment.

Written Fall Protection Plan

Following hazard identification, a written program should be developed specifying how to deal with each hazard. If standardized safe-work practices and operating procedures can eliminate the hazard, then such procedures should be specified. If hazard elimination is not possible, the plan should indicate what fall protection measures are to be used, how they are to be used and who is responsible for overall supervision and training. This program should include essential elements, clearly conveyed and understood by all participants in the program. According to OSHA regulations (CFR 1926.502), a fall protection plan must be developed by a qualified person and put in writing. A copy of the plan should always be available at the work site.

Fall Protection Equipment

The majority of fall incidents can be prevented by planning and utilization of safety equipment. There are many types of fall protection equipment such as lifelines, lanyards, body belts, harnesses, netting, guard rails, and shock absorbers. The application of fall protection equipment is complicated since it deals with dynamic motion. In addition, there are a variety of styles to choose from and each style may have many pieces to inspect. Non-availability of safety equipment plays a role in fall incidents, and the improper selection of protective equipment for a given job may put workers in danger. For example, workers might use lanyards that are the incorrect length. Therefore, a qualified person with fall-protection knowledge and experience should make the selection or recommend proper equipment.

Worker Training

Worker training is an important complement to engineering controls and protective equipment. A complete fall protection training program should address the following six areas: (1) how to properly use and maintain fall protection devices; (2) explanation of the fall hazards, severity of injuries resulting from fall incidents, and the benefits of fall protection; (3) ensuring that engineering controls are not altered or removed in the interests of productivity; (4) workers' duties and rights under the OSHA regulations; (5) need for good housekeeping; and (6) how to perform rescue operations properly in case of a fall. Within OSHA regulations, the certification of training section mandates that employers have written certification records showing who was trained, dates of training, the signature of the person providing the training, and the date the employer determined that the training was adequate.

Audit and Maintenance

A comprehensive audit and maintenance system should be developed to regularly monitor the effectiveness of the fall protection program. This system should always allow feedback from

safety personnel and workers as well as allow them to suggest any possible and necessary corrective actions and plans. In order to circulate the feedback into the prevention and control strategies, safety personnel with a full understanding of fall protection programs should be assigned to take the lead in collecting and evaluating such information.

Table 1
List of current fall-related OSHA regulations and ANSI standards

Agency	Applied Industry	Title
OSHA	General	Floor and Wall Openings (1910.23)
		Ladder Safety Devices (1910.27 (d) (5))
		Powered Platforms and Building Maintenance (1910.66)
		Scaffold Structures (1910.23)
		Fall Arrest System (1910.66 Appendix C)
		Grain Storage & Handling (1910.272)
		Confined Space Entry (1910.146)
	Construction	Scaffold Structures (1926.451)
		Stairways & Ladders (1926.1050/3)
		Fall Protection (1926.500 Subpart M)
ANSI	General	Scaffolding (A10.8)
		Personnel and Debris Nets (A10.11)
		Safety Belts and Harness (A10.14)
		Portable Wood Ladders (A14.1)
		Portable Metal Ladders (A14.2)
		Fixed Ladders (A14.3)
		Job-Made Wooden Ladders (A14.4)
		Portable Reinforced Plastic Ladders (A14.5)
		Confined Spaces (Z117.1)
		Fall Arrest System (Z359.1)

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