Slips, Trips & Falls in the Occupational Environment

Countering the Growing Human & Economic Cost

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What is the problem?

Slips and falls are an increasingly serious cause of injury and death in both the occupational and non-occupational environments. They are second only to injuries and deaths from motor vehicle accidents.

Falls are the number one cause of accidental injury, resulting in around 20 percent of all emergency room visits in the USA.

Similar rates occur in Australia when the population difference is taken into account. Indeed, in economic terms, falls cost Australia more than any other cause of injury. Reference [1]. And many slip and fall initiated injuries tend to be hidden in statistics, for example as scald injuries, when the act of falling has caused hot liquids to be spilt. These statistics indicate to an annual per capita cost greater than A$100, where the direct morbidity costs are very high compared with most other types of accidents.

Falls occur in virtually all manufacturing and service sectors, but, in Australia, fatal falls are concentrated in construction, mining, and certain maintenance activities.

It has also been estimated that falls account for 16% of all insurance claims and 26% of all costs.

Note that falls are generally classified into one of two categories, falls from elevation (approximately 40% of compensable fall cases, approximately 10% of occupational fatalities) and falls on the same level (approximately 60% of compensable fall cases)

In the non-occupational environment, victims are typically the very young and the very old.

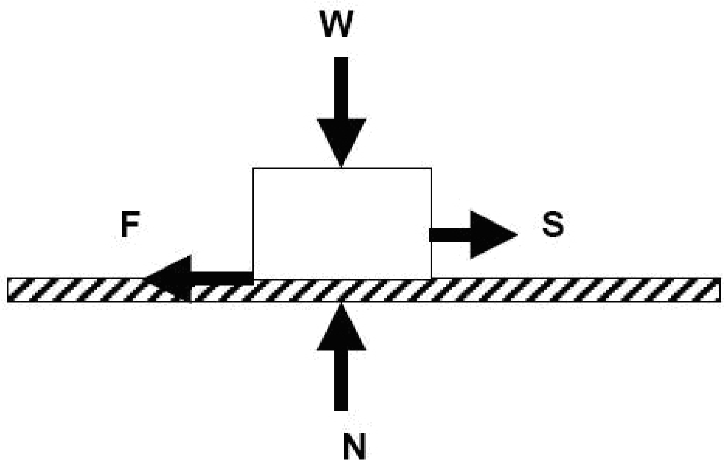
What is a slip?

Slips result from relative motion (i.e., sliding) between the shoe sole and the floor surface. Sliding occurs if friction is insufficient to overcome forces acting parallel to the shoe-floor interface.

What is a trip?

Trips happen in a different way. The foot is suddenly stopped from moving forward when it meets an unexpected object in its path. Generally most trips are caused by obstructions, with less by uneven surfaces.

Traction Mechanics



In the above figure, we have an object (e.g. a shoe) at rest on the floor. (Note that this condition occurs while the shoe is in contact with the floor during a stride.) The following terms are defined:

W is the weight of the object (in this case the portion of body weight and clothing borne by the shoe). **N** is the normal force exerted by the floor against the shoe. **N** is a reactive force because it acts in opposition to **W**. On a level surface such as illustrated above, **N** and **W** are equal but act in opposite directions. (Note: There is a maximum level of **N**, determined by the structural strength of the floor.) Under these conditions, **N** and **W** act perpendicular to the floor surface. Note, on an inclined surface **N** is less than **W** and can be computed as $\mathbf{N = W \times \cos \Theta}$ where **Θ** is the angle of inclination.

F is the **frictional force** that resists sliding. Friction is a "reaction" force that acts against any "disturbing" shear force (**S**) that would cause the shoe to slide across the floor. **F** and **S** act in opposite directions. In terms of magnitude, **F** can never exceed **S** (because it is a reactive force). However, under certain circumstances **S** can exceed **F** because the maximum value of **F** is limited by the coefficient of friction. Since the example above represents a static situation, we can use the symbol $\mathbf{F_s}$ to represent static friction.

The maximum value of $\mathbf{F_s(max)}$ is:

$$\mathbf{F_s(max) = \mu_s \times N}$$

where $\mathbf{\mu_s}$ is the coefficient of static friction. This coefficient is a function of the surface characteristics of the object, the surface characteristics of the floor and other conditions (e.g., wetness, floor treatments, etc.). Note that $\mathbf{F_s}$ acts parallel to the object/floor interface **S** is a disturbing force that acts parallel to the object/floor interface. If $\mathbf{S > F_s}$, then sliding will occur. Note that on ramps, a fraction of the object's weight creates a disturbing force $\mathbf{S = W \times \sin \Theta}$ where $\mathbf{\Theta}$ is the angle of inclination

To prevent slipping, it is essential that the available frictional forces exceed any disturbing force.

What are the issues for employers?

Broadly, the issues for commercial and industrial employers involves the reality of occupational health and safety expectations today.

Today, state based Occupational Health and Safety acts are often built around the duty of care principle.

Implementing the ***duty of care principle*** means planning for the prevention of workplace accidents, injuries and illnesses. How is this done?

- There is a general duty of care on all employers to ensure the health, safety and welfare at work of all employees and ***others who come on to the workplace.***
- It is the employer's responsibility to ensure that all reasonably practicable measures have been taken to control risks against all possible injuries arising from the workplace.
- The employer's duty of care applies to all people in the workplace, including visitors, contractors etc.
- There is a general obligation on designers, manufacturers and suppliers of plant and substances for use by people at work to ensure that their products are not a risk to health and safety when properly used, and to provide information on the correct use and potential hazards associated with the use of the products in the workplace.
- There is a general obligation on employees to take care of others and cooperate with employers in matters of health and safety

Since employers are in control of the workplace and workplaces can have significant risks to health and safety, employers are required to manage and organise their workplace and their work systems to ensure people at work are not put in harm's way.

Significant penalties apply to both individuals and corporations for failing to meet duty of care requirements.

For example, in the State of NSW, the penalties range from A$55,000 to A$825,000 and include potential imprisonment.

In occupational health and safety terms, ***risk management*** is the process of recognising situations that have the potential to cause harm to people or property, and doing something to prevent a harmful situation occurring or a person being harmed.

Risk management is a process of well-defined steps that, when taken in sequence, allow management to make informed decisions about how best to avoid or control the impact of risks. Overall, risk management involves:

hazard identification identifying the problem
risk assessment determining how serious the problem is
risk elimination or **control** deciding what needs to be done to solve the problem
reviewing risk assessments if, for instance, new information becomes available about the hazardous nature of a process.

The Occupational Health and Safety Regulation 2001 (NSW) imposes obligations on all employers to implement risk management processes in all workplaces. Employers must take reasonable care to identify any foreseeable hazard that has the potential to harm the health and safety of workers or anyone else in the workplace.

Moreover, every employer must take out and keep up to date a **workers' compensation insurance policy** covering all their employees and certain other persons brought within workers compensation benefits by the legislation.

A collision of forces

Today then, industrial and commercial workplaces must adjust to the changing reality. Society is demanding safer working environments and practices. Unions are seeking safer working environments. And insurance premiums rise with increasing safety related claims.

Employers, managers, directors and corporations all have a responsibility to work intelligently and conscientiously to provide safe working environments, and prevent these accidents from occurring.

Surface texture parameters

Historically, industrial polymer flooring systems were characterized solely by their bulk properties including compressive strength, elongation, chemical resistance, permeability, impact and modulus. Because those bulk polymers were essentially homogeneous, characterization of substructure was not important. However recent advances in formulating approaches, application engineering and testing have allowed advanced methods for polymer surface structure characterization.

Every surface has some form of texture which varies according to its structure and the way it has been prepared, manufactured or used. These surfaces can be broken down into three main categories: Surface Roughness, Waviness and Form. In order to predict the surface behaviour of a walking-working surface, it is necessary to quantify these surface characteristics. This is done by using surface texture parameters.

Surface texture parameters can be separated into three basic types: Amplitude, Spacing and Hybrid.

Amplitude parameters - Are measures of the vertical characteristics of the surface deviations

Spacing parameters - Are measures of the horizontal characteristics of the surface deviations

Hybrid parameters - Are combinations of spacing and amplitude parameters

Mean line - The mean line is a least squares line of nominal form fitted through the primary profile where the areas of the profile above and below this line are equal and kept to a minimum separation.

Cut-off - A cut-off is a filter that uses either electronic or mathematical means to remove or reduce unwanted data in order to look at wavelengths in the region of interest.

Bandwidth - Bandwidth is the ratio of the upper Cut-off (Lc) to the lower Cut-off (Ls)

Sample length - The profile is divided into sample lengths l, which are long enough to include a statistically reliable amount of data.
For roughness and waviness analysis, the sample length is equal to the selected cut-off (Lc) wavelength. The sample length is also known as the cut-off length.

Evaluation length - The length in the direction of the X axis used for assessing the profile under evaluation. The evaluation length may contain one or more sample lengths. For the primary profiles the evaluation length is equal to the sample length.

Max rule - If a parameter also displays max (eg Rz1 max) then the measured value shall not be greater than the specified tolerance value. If max is not displayed (eg Rp) then 16% of the measured values are allowed to be greater than the specified tolerance value.

For the first time, an assessment of the inherent traction of installed flooring system surface is possible with the presence of a great variety of industrial contaminants actually on the floor surface.

Typically this approach will find acceptance in a wide variety of flooring applications where safety under foot is critical in contaminated environments, including:

- Industrial / Manufacturing: assembly lines, traffic aisles, loading docks, machine shops, control rooms, battery rooms, packaging lines, locker & shower rooms, cafeterias & kitchens

- Food / Beverage: mixing / blending areas, bottling lines, bakeries, dairies, meat packing, cold storage

- Chemical Processing: sumps, pits, trenches, drum storage areas, double containment areas, wastewater treatment areas, processing areas, laboratories

- Pharmaceutical: packaging lines, laboratories, clean rooms, gowning rooms, blending rooms, processing areas

Slip resistance standards

A great many slip resistance standards have been proposed around the world. Intense debate has been generated over the applicability of particular standards.

Australian/New Zealand Standard AS/NZS 4586:2004, Slip Resistance Classification of New Pedestrian Surface Materials, provides means of classifying pedestrian surfacing materials according to their frictional characteristics. This standard enables characteristics of surface materials to be determined in either wet or dry conditions.

AS/NZS 4586 originated from AS/NZS 3661.1:1993, Slip resistance of pedestrian surfaces, Part 1: Requirements, which it partially supersedes. AS/NZS 3661.1 required slip resistant pedestrian surfaces to have a mean coefficient of not less than 0.4 when tested according to the specified wet pendulum and dry floor friction tester (FFT) test methods. At the time of publication, those parts of AS/NZS 3661.1 that deal with in situ testing of slip resistance were still in force and are intended to remain so until the draft document DR 99447 -Slip resistance measurement of existing pedestrian surfaces is published as a Standard.

AS/NZS 4586 establishes a new philosophy. The Standard rejects the concept of a universal minimum slip resistance threshold value that is both practical and safe. In equating safety with a coefficient of friction, one has to consider all the relevant variables, as well as whether the result has been unduly influenced by the method of slip resistance measurement. The slip potential is a function of footwear, activities, gait, contamination, environment and other factors.

Standards Australia Handbook HB 197:1999, An Introductory Guide to the Slip Resistance of Pedestrian Surface Materials, has been prepared to assist in the use of AS/NZS 4586:2004. It is an interim publication that will be withdrawn when Standards Australia publishes the more comprehensive Slip Resistance Handbook.

This Guide establishes a basis for specifying pedestrian surface materials for various locations. Note that Standards Australia and CSIRO do not accept any liability arising from its use. Compliance with its recommendations will not necessarily alleviate all hazards. However, conformance will reduce certain pedestrian risks.

The guidance for commercial and industrial areas is based on German regulation (ZH/1/571, October 1993, *Floors in Workplaces and Areas with Increased Risk of Slipping),* with tests conducted according to Appendices D and E of AS/NZS 4586.

The recommendations in are confined to the floors of areas where contamination by friction-reducing materials might give rise to slip hazards. In connected work places with differing slip risks, where employees move from one place to the other, the floor covering of the higher classification group should be used for the entire area. If floor coverings of different slip resistance are used in connected work rooms or areas, only floor coverings of two consecutive classification groups should be used next to each other, e.g. classification groups R9 and R10 or R10 and R11 etc.

The mean angle of inclination, as determined by the ramp test procedure, is used to classify a floor surface into one of five classification groups. For most situations, class R13 floor surfaces provide the greatest amount of available slip resistance. For a given amount of contamination, floor surfaces with a low R9 classification would make the highest demands on the pedestrian in preventing a slip. The requirements that are given for specific work areas may need to be modified according to prevailing or expected operational conditions.

The Guide also covers work rooms and work areas where a displacement area is necessary below the walking surface, i.e. those that have a high quantity of expected slippery substances, are marked with a 'V' together with the figure of the minimum volume of displacement area. Some surfaces will provide better mechanical entrapment of solid substances; some offer excellent drainage, while others are well suited to wheeled traffic. The roughness and any structuring of the surface will influence the cleaning properties.

However, it should be pointed out that classification groups R9 and R10 or R10 and R11 etc are determined on a test ramp located off-site. Thus while the testing might be suitable for factory produced flooring systems (tiles, vinyl etc), it is not really entirely suitable for hand applied floor finishes where the surface finish of the installed system can vary from installer to installer.

Additionally, the test ramp cannot be used to test actual floor surface performance after a period of use.

New testing equipment

New developments in testing equipment enable traction assessments to be completed “on-the-floor” in real occupational environments with a great variety of contaminants present. It is not proposed that these will replace testing to any given standard. They have been to shown to provide a straightforward, reliable and very cost effective indication of traction levels being achieved during application. This “traction performance” can be cross referenced to off-site test ramp performance.

How much traction is needed?

Traction can vary from surface to surface, or even on the same surface, depending upon surface conditions and employee footwear. Flooring material such as textured, serrated, or punched surfaces and steel grating may offer additional slip-resistance. These types of floor surfaces should be installed in work areas that are generally slippery because of wet, oily, or dirty operations. High traction footwear will also be useful in reducing slipping hazards.

Although much discussion is made of the “traction” of a floor, it involves several factors. Slip and fall accidents can be associated with several major factors or conditions such as:

- floor surface characteristics
- footwear traction properties
- influence of slopes
- environmental factors (contaminants such as water, oil, etc.)
- human factors (gait, human activity, etc.)
- psychological and physiological conditions of the walker
- influence of cleaning regime

Generally environments requiring more physically intensive tasks generally require a higher level of traction for the safety of workers.

Conclusion - Practical Results

The use of a calibrated field instrument such as the Tractometer © has proven to be very useful in the Australian occupational environment.

HB 197:1999, An Introductory Guide to the Slip Resistance of Pedestrian Surface Materials, sets out the relevant standards for particular working environments.

The Tractometer © provides a fast field test analysis by being pre-correlated to ramp test results and ensuring, ultimately, that field performance is as expected.

The use of the Tractometer © also enables the performance of the floor surface to be measured in real life conditions (when contaminated) and also following periods of extended use.

The use of a computer based safety culture software system is also proving useful in the continuing quest for improving occupational safety.

References:

[1] Paradigm Shift – Injury: From Problem to Solution – New Research Directions, Strategic Research Development Committee of the National Health and Medical Research Council, AGPS, Canberra, 1999.

[2] Letter from OSHA dated March 21, 2003.