'I Fell, Ergo I Slipped': FACT OR FANTASY?

A variety of factors can lead to falls. Blaming a slippery walking surface is not always the answer.

by David G. Curry, Steven Zebich, and Kami Kirk-Braland

According to the National Safety Council (2000), falls represent one of the most common causes of unintentional injury deaths in the United States annually (approximately 14,200 in that year). Only motor vehicle accidents and poisonings ranked higher, with 42,900 and 14,500, respectively. Of fatal falls, some 9,000 of them occurred in the home, and four out of five fatality victims were older than 65. Falls are estimated to cause at least 17 percent of occupational injuries and more than 18 percent of public sector injuries.

In our litigious society, falls resulting in injuries often result in legal proceedings, with many plaintiffs contending their fall resulted from the slipperiness of the walking surface. In reality, most common walking surfaces are inherently slip resistant. A variety of factors can lead to falls, of which the occasional slippery surface is only one. Goetsch (1993) identifies four primary contributing factors to slips, trips, and falls: 1) a foreign object on the walking surface, 2) a design flaw in the walking surface, 3) a slippery surface, or 4) an individual's impaired physical or mental condition.

Judging from personal experience, it is apparent many purported "experts" testifying in slip-and-fall cases do not have a good grasp of the mechanics of human locomotion, the meaning of the term "slip resistant," or the requirements for walking surfaces put forth by the various building and safety codes which apply around the United States. This article attempts to address each of these issues and show how they apply in cases involving slips and falls.

Standards, Requirements, and Recommendations

Several terms must be defined to proceed with this discussion. According to Gronqvist (1995), *slipping* is defined as "a sudden loss of grip, resulting in sliding of the foot on a surface due to a lower coefficient of friction than that required for the momentary activity." *Slip resistance* refers to "static, transitional, and kinetic properties of underfoot surfaces and foot/footwear during relative motion in actual conditions of wear" (Gronqvist, 1997) or "the relative force that resists the tendency of the shoe or foot to slide along the walkway surface" (ASTM F1637-02). *Slip resistant* means "the provision of adequate slip resistance to reduce the likelihood of slip for pedestrians using reasonable care on the walking surface under expected use conditions" (ASTM F1637-02).

Friction is the resistance to motion of one body across another. *Coefficient of friction* is "the ratio of maximum force acting parallel to a contact surface that resists motion of one body on the other, divided by the normal force acting on the contact surface" (Chaffin and Andersson, 1984). Coefficient of friction is a dimensionless quantity, independent of both the area of contact and the velocity between the two surfaces.

A slip-resistance value of 0.50 has long been recognized by the safety profession as being the minimum criterion for a "slip-resistant surface" in the United States. Underwriters Laboratories' UL 410, *Slip-resistance of Floor Surface Materials*, requires that the average static coefficient of friction for floor treatment materials, floor covering materials, and walkway construction materials shall be at least 0.50. OSHA's 29 CFR 1926.754 specifies a minimum average slip resistance of 0.50 for structural steel assembly tasks. ANSI's A1264.2-2001 also recommends this value under dry conditions but cautions that "Floors, which do not meet the 0.5 guideline for dry conditions, should not be considered to be inherently dangerous."

The Americans with Disabilities Act (in a non-mandatory appendix) notes that, "People who have difficulty walking or maintaining balance or who use crutches, canes, or walkers, and those with restricted gaits are particularly sensitive to slipping and tripping hazards" and cites a study sponsored by the Transportation Barriers Compliance Board, which conducted tests with persons with disabilities. The board concluded that "a higher coefficient of friction was needed by such persons" and recommends a static coefficient of friction of 0.60 for accessible routes and 0.8 for ramps. It should be noted the study cited in this guideline utilized an extremely small sample size (five subjects) and contains a considerable safety margin.

Building codes are notoriously reticent about providing any guidance with regard to this issue. The Building Officials & Code Administrators (BOCA) National Building Code only specifies that "All walking surfaces, including the floors of corridors, stairways, and other components of the means of egress, shall have a slip-resistant surface," without providing any guidance as to exactly what they consider to be "slip-resistant." The *Commentary* to this document points out that "Field testing and uniform enforcement of the concept of slip resistance is not practical" but goes on to state, "One method used to establish slip resistance is that the static coefficient of friction between leather ...and the floor surface is greater than 0.5." One is forced to wonder about the rationale for establishing a requirement to builders while stating that there is no "practical" way of seeing whether it is met.

Both the Standard Building Code and the International Building Code are almost equally absent of any hard and fast requirements. The *2003 International Building Code* states in Section 1003.4, "Walking surfaces of the means of egress shall have a slip-resistant surface and be securely attached," and in Section 1010.7.1 that "The surface of ramps shall be of slip-resistant materials that are securely attached." In the *1999 Standard Building Code*, Section 1013.9 cautions that "Ramps shall have a slip resistant surface," but it contains no other requirements regarding slip resistance on walkways. It is possible some local codes (e.g., the Chicago Building Code, the New York City Building Code, etc.) may contain numerical values in requirements regarding what constitutes an acceptably slip-resistant surface, but to date, the authors have seen no such requirements in the codes we have examined.

Human Locomotion and Friction

While the recommended value of 0.50 is accepted as representing a "slip-resistant" surface within the safety community (at least in the United States), it does not represent the coefficient of friction that is required for human locomotion under normal conditions. According to Templer (1992), "A COF of 0.5 includes, by all accounts, a safety factor and therefore has some merit as a cautious recommendation (particularly as a precaution against slippery shoes)." A short discussion of the mechanics of walking will illustrate why this is true.

The gait cycle in normal human locomotion on a level surface begins with the heel strike (the point where the heel touches a surface) of one leg and includes the stance and swing phases of both legs. The stance phase is the period when the foot is in contact with the ground, while the swing phase is the period when the foot is off the ground. The stance phase takes up approximately 60 percent of the full gait cycle; thus, at least one part of each foot is in contact with the floor for almost two-thirds of the cycle.

There are three main subphases that make up the stance phase: contact, midstance, and propulsive. The contact subphase begins with heel strike and continues as the front of the foot rotates downwards and becomes fully weight bearing. During this subphase, the foot both adapts to uneven surfaces and absorbs the shock of impact with the walking surface. During the midstance subphase, the foot changes from a mobile adaptor into a rigid lever. During this subphase, the foot begins to lift from the rear, preparing the foot for the propulsive subphase. The propulsive subphase begins as the heel lifts and continues through toe-off.

The swing phase is the period when the foot is not in contact with the ground and accounts for approximately 38 percent of the gait cycle when walking. This phase allows the foot to recover from toe-off and then change its position to ready it for the next heel strike. The swing phase can be broken down into two subphases: early swing and late swing. The early swing begins at the start of toe-off. At this time, both feet are simultaneously in contact with the ground in a double support phase, which makes up about 10 percent of the gait cycle. This duration of this subphase decreases as the speed of locomotion increases, until the individual reaches running speed at which time there may be periods when either only one foot is on the ground or both feet may be simultaneously off the ground. The late swing subphase occurs as the foot recovers from toe-off and the forefoot and rearfoot lock into a rigid position in preparation for the contact subphase of the stance phase.

The initial portion of the contact subphase is the two points at which maximum friction is required in normal walking. As the heel strikes the ground at an angle, the forces generated can be decomposed into two components. The first is directed vertically downward, while the second is directed forward in the direction of travel. Friction force between the shoe and the walking surface is required whenever the shoe is in contact with the ground, but it reaches a peak level at the time of the initial heel strike (to prevent it from continuing its forward motion). A second, smaller peak is reached during the propulsive phase, where friction is required to resist the rearward thrust of the foot prior to toe-off. It is important to note the forces at these points are directed in opposite horizontal directions.

Two of the primary gait-related factors influencing the amount of friction required are the speed at which the individual is traveling (a major determinant of the force generated as the foot strikes the ground) and the angle at which the heel strikes (which directly influences the amount of force directed in the forward versus downward direction). The higher the speed or the more acute the angle at which the heel strikes the ground, the more friction is needed between the foot and the walking surface to overcome the forward-directed force component. Burnfield and Powers (2001) conducted a study to examine the coefficient of friction required by a variety of subjects of both genders and a range of ages at a variety of walking speeds. Results of their study are summarized in Table 1 on right and correspond well with data from other researchers.

TABLE 1: PEAK COEFFICIENTS OF FRICTION REQUIRED IN NORMAL WALKING

Age Group	Gender	Slow	Medium	Fast
Young (age 20-39)	Female	.24	.24	.25
	Male	.19	.21	.27
Middle (age 40-59)	Female	.24	.27	.26
	Male	.22	.26	.32
Senior (age 60-79)	Female	.23	.22	.22
	Male	.19	.22	.24
Average by Gender	Female	.24	.24	.24
	Male	.20	.23	.28
Overall Average		.22	.24	.27

Even these comparatively low values, however, would not necessarily result in a slip and fall. During walking, one is often unaware of slight slips that may occur between the shoe and the walking surface at the beginning of the heel strike (*microslips*). In a study performed by Leamon and Li (1990), "microslips" of less than 3 centimeters had only a 50 percent chance of being detected by the walker.

Work by Standberg and Lanshammar (1981) has indicated a slip is unlikely to result in a fall unless the foot slips at least 10 centimeters; with shorter distances, the walker normally either compensates unconsciously or recovers from the slip without falling. This work also indicated a peak coefficient of friction value at which a fall was sure to occur of 0.07. Lockhart et al. (2002) calculated a "fall recovery threshold" distance for three age groups that must be exceeded in normal walking before a fall would occur of 3.9 centimeters for younger walkers, 3.8 centimeters for middle-aged walkers, and 3.12 for older walkers.

Pye (1994) performed an analysis of required coefficient of friction data obtained by the Building Research Establishment and developed a statistical model for assessing the likelihood of slipping at several coefficients of friction during three walking maneuvers conducted at normal speed. These data are summarized in Table 2 below.

TABLE 2: RELATIVE RISK ASSOCIATED WITH COEFFICIENTS OF FRICTION BETWEEN FOOT AND FLOOR

Risk	Walking straight	Turning on left foot	Turning on right foot
1 in 20	0.24	0.27	0.29
1 in 200	0.27	0.31	0.32
1 in 10,000	0.29	0.34	0.33
1 in 100,000	0.34	0.38	0.34
1 in 1,000,000	0.36	0.40	0.36

All of the preceding discussion and the aforementioned standards are predicated on normal walking behavior. There are several circumstances under which required coefficients of friction (though not the standards) differ from these conditions.

When stride mechanics differ, the required coefficient of friction changes accordingly. One example of this is running, during which the heel strike phase of the stride requires a slightly higher friction force to avoid slipping (approximately 0.30). Greater increases also are observed at the toe-off portion of the stride, where peak requirements are about 0.45 (Vaughan, 1984). Under conditions where the stride is shortened, the foot strikes the ground at a less oblique angle than under normal walking, and required levels of friction are reduced. One example of this is stair descent. According to Templar, referring to studies conducted by Klopsteg and Wilson, "Force plate studies have shown that the horizontal component of foot force, in stair descent, is not great. It reaches two apogees: at first contact and at toe-off. At these moments, the force is only about 6 percent of body weight, compared to apogees of 15 and 20 percent for walking on the level, where the horizontal speeds are greater." This suggests the coefficient of friction required for stair descent would be between 30 percent and 40 percent of that required for normal walking. This supposition agrees well with the work of Harper et al. (1967), which showed the average coefficient of friction required for ascending or descending stairs was approximately 0.09. Because the potential for injury is higher in a fall from stairs, however, a lower standard for coefficient of friction on stairs is generally not recommended.

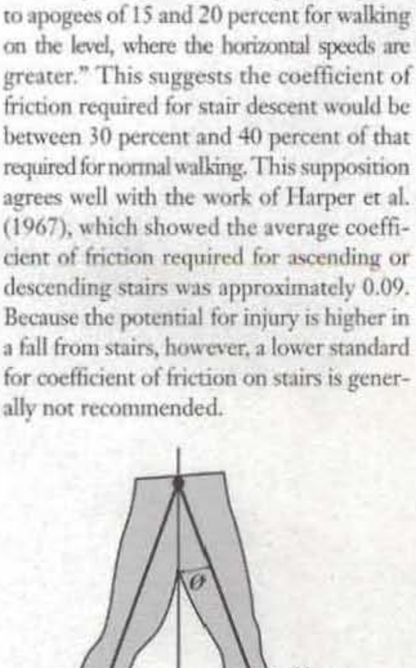

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Figure 1: Walking on Level Surface

Ramps provide a somewhat different situation because the slope itself serves to increase the angle of incidence of the foot striking the walking surface, and thus increases the level of friction required to counter the increased horizontal component of the decomposed foot strike on the walking surface. Harper et al. (1967) analyzed the required levels of friction required by normal subjects while walking down a 1:6 slope. Examination of the maximum reactive forces involved led to an average value of 0.32 across subjects.

Under known low-friction conditions, walkers usually adapt their gait within a one step cycle after recognizing the slippery condition (Andres et al., 1992). According to Llewellyn and Nevola (1992), this protective strategy usually involves adjustments to the posture and the amount of force employed in the early stance. Shorter steps are taken and knee flexion is increased, which combine to result in lower vertical acceleration and forward velocity of the body, as well as shorter stride length.

Walking is regarded as safe when the coefficient of friction (:) is larger than the ratio of horizontal (F_H) and vertical (F_V) force components that are applied the ground (: > F_H/F_V). Friction force itself (F.) is directly proportional to the normal force (the force resisting the vertical force) and can be expressed as F. = :F_N. When these two equations are combined, the F./F_N > F_H/F_V. It follows then that if the horizontal and vertical forces applied to the walking surface as well as the coefficient of friction are all known, it is possible to evaluate mathematically whether the surface will potentially be slippery. Referring to Figure 1, when the system is in equilibrium (no sliding) the limiting friction on a level walking surface (:) can be approximated using the equation below:

$$\mu = \frac{F}{N} = \frac{R\sin\theta}{R\cos\theta} = \tan\theta$$

where F is the forward directed force, N is the normal force, R is the force applied by the heel of the forward leg and θ is the angle between the forward leg and the vertical (Templer, 1992). For a 50th percentile male, the average distance from the hip joint to the heel is 92.5 centimeters (36.4 inches), and the average stride during full-speed walking is 71.6 centimeters (28.2 inches) from the rear foot heel to lead foot heel, leading to a half pace of 35.8 centimeters (14.2 inches). The angle θ then, would be 21.3 degrees. Trigonometric calculations then lead to a coefficient of friction under this condition of 0.39 if no slipping is to occur (remember from earlier discussion that, in normal walking, slips of less than 3 centimeters are normally not detected and that force plate analysis values for normal walking usually result in required coefficients of friction of much less than this). To reach a required COF of 0.50, stride length would have to be increased by approximately 25 percent, an extremely awkward stride. While such a stride length is *possible*, it is extremely unlikely to occur during normal walking. Leg length variation within sexes normally affects the stride length, but not the angle of incidence between the heel and the walking surface, so the ratio between leg length and stride length is more or less constant within a small range.

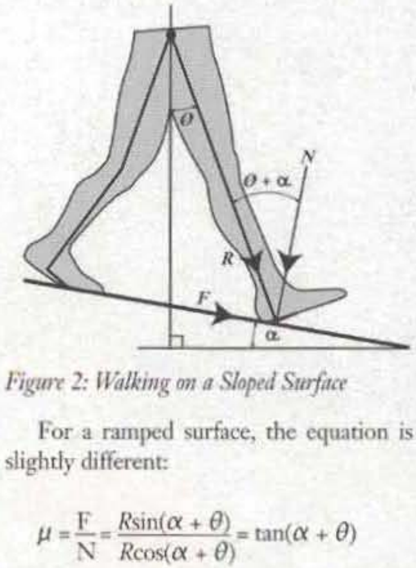

Figure 2: Walking on a Sloped Surface

For a ramped surface, the equation is slightly different:

$$\mu = \frac{F}{N} = \frac{R\sin(\alpha + \theta)}{R\cos(\alpha + \theta)} = \tan(\alpha + \theta)$$

where α is the angle of inclination of the ramp itself (see Figure 2). Using the values for a 50th percentile male from our previous example to perform a biomechanical analysis, when walking down a 1:12 (7.5 degrees) sloped surface, a coefficient of friction of 0.584 would be the limiting friction. It should, however, also be noted stride length is usually shortened when descending ramps, which would lead to a lower limiting friction level. Table 3 shows a similar analysis of the friction values that would be equivalent to a 0.50 COF on a horizontal surface for various ramp inclinations. In force plate analysis performed by Harper et al. (1967), tested measurements of friction forces actually utilized when walking on slopes ranged between 0.40 and 0.60 for slopes of less than 1:3 (33.3 degrees).

From the above discussion, it is clear that while 0.50 may be the consensus standard in the United States for a "slip-resistant" walkway, a value of less than 0.50 is not by definition something that can be characterized as "slippery" (a term that has no precise technical definition). Merriam-Webster's online dictionary defines the word *slippery* as "a causing or tending to cause something to slide or fall." Using Pye's data as shown above, it is difficult to consider odds in excess of 1,000,000:1 for a coefficient of friction of 0.40 as "tending to cause something to fall."

About the most that can be said about a surface with a coefficient of friction of less than 0.50 is that it does not meet the criteria for a slip-resistant surface. The 0.50 criterion is acknowledged by the overwhelming majority of researchers in the field as having a large inherent safety margin built into it. To say that a walking surface with a COF of 0.51 is "slip-resistant" and that one with a COF of 0.49 is "slippery" is akin to saying that just because there is a general consensus that basketball player Shaquille O'Neal at 7'1' is "tall," then it must follow that fellow Lakers player Kobe Bryant at "only" 6'6" is "short." This is obviously absurd—there is a range between "slip-resistant" and "slippery," just as there is between "tall" and "short."

TABLE 3: SCOF VALUES EQUIVALENT TO SCOF OF 0.50 ON HORIZONTAL SURFACE

Slope	Static coefficient of friction equivalent to 0.50 on Horizontal Surface
1:20 (4.50)	0.56
1:18 (50)	0.57
1:16 (5.60)	0.58
1:14 (6.40)	0.59
1:12 (7.50)	0.61
1:10 (9.00)	0.63
1:8 (11.30)	0.67
1:6 (150)	0.73
1:4 (22.50)	0.86

Measuring COF

While numerous building codes and other guidance documents specify "slip resistant" surfaces are required for means of egress or other walking surfaces, they rarely (if ever) specify how a determination of this is to be made. This lack has resulted in many building inspectors, code compliance officials, and testifying "experts" employing a variety of completely subjective criteria to the task (ranging from visual inspection to running fingers or shoes across the surfaces of interest) and making almost completely arbitrary decisions based on them.

It appears to be a more or less common misperception that in order to be "slip resistant" (and thus meet the appropriate codes), a surface must have a visually or tactually rough surface. This is incorrect. While it is true such a surface is almost undoubtedly slip resistant, it does not follow that one that does not meet that expectation is not. Common linoleum flooring, for example, is often quite smooth to the touch and commonly results in a coefficient of friction on the order of 0.60 or greater when tested with appropriate apparatus.

ANSI A1264.2-2001 and 29 CFR 1926.754 are notable exceptions to the practice of specifying slip resistance but not specifying a means of verification. The ANSI standard recommends five acceptable mechanisms for dry surface testing:

1) the Horizontal Pull Slipmeter;

2) the Portable Inclinable Articulated Strut Slip Tester (PIAST, *aka* the Brungraber

MkII);

3) the Portable Articulated Strut Slip Tester (PAST, *aka* the Brungraber MkI);

4) the Variable Incidence Tribometer (VIT, *aka* the English XL); and

5) the James Machine.

The first four of these test apparatus are usable for in-field testing, while the James Machine is a "laboratory only" unit. There are ASTM-certified test procedures for the use of each of these. OSHA's 1926.754 specifies the use of the Variable Incidence Tribometer (VIT) for testing and allows for the use of the Portable Inclinable Articulated Strut Slip Tester (PIAST) as an alternative.

When discussing slip resistance test mechanisms, it is important to differentiate what is being assessed. *Static friction* is the ratio of the horizontally applied force required to move a body from rest over the vertical force applied to the surface by the weight of the body. *Dynamic friction* involves the same ratio, but the horizontal force involved is one that is required to maintain constant speed of movement once the body has been moved from rest. More simply put, static friction is the friction force that must be overcome to start a body in motion across a surface, while dynamic friction is the friction force that must be overcome to keep that body in motion across the surface. In practice, static friction always exceeds dynamic friction in magnitude. There is a lack of consensus regarding whether static or dynamic friction is more appropriate to specify in the creation of standards (standards in the United States usually refer to static coefficient of friction where a differentiation is made, while most other nations focus on dynamic coefficient of friction).

Of the test mechanisms above, only the Variable Incidence Tribometer (VIT) and the Portable Inclinable Articulated Strut Slip Tester (PIAST) are certified by ASTM for the evaluation of wet surfaces. Testing of wet surfaces requires specialized apparatus due to a phenomenon known as *sticktion*. Sticktion is the result of water being squeezed out of the interface between the test surface and the walkway surface, creating a temporary bond between the two. It is a function of the residence time between the instant of surface contact and the application of horizontal force. Test results of devices subject to sticktion when used on wet surfaces can be artificially high, at times exceeding values derived for dry tests of the same surface. Both the PIAST and the VIT avoid this problem by applying both horizontal and normal forces simultaneously during testing.

Whatever testing apparatus is selected, there is often dispute as to whether leather or a synthetic material should be used for the surface of the test apparatus that is placed in contact with the walking surface. ANSI A1264.2-2001 recommends the use of Neolite (a synthetic material) for this purpose because of "its uniform and homogeneous properties, its availability as a specified material, and its resistance to contamination." Leather, being an organic material, exhibits none of these qualities and is rarely used as a shoe heel material (the part of the shoe which is most likely to slip in normal ambulation). Neolite, it has also been argued, is strictly a test material and has never been used in practice as a heel or sole material. This argument is spurious; Neolite's properties place it in the middle range of materials that are used for this purpose, and a cursory examination on the Internet shows a variety of manufacturers do use Neolite for shoe soles and heels.

Factors Affecting Walkway Surface Slip-Resistance

A variety of conditions affect the coefficient of friction on walking surfaces, one of the most common of which is the presence of contaminants (often liquid). Lubrication of the contact area between the shoe and the floor surface may in some cases substantially reduce its slip resistance.

According to Grandjean (1973), the decrease in COF between wet and dry surfaces may range from as little as 2 percent to as much as 81 percent, depending on the combination of shoe and walking surface materials. Almost all combinations of dry, clean shoes and walking surfaces exhibit COFs of greater than 0.50, while only selected combinations of wet shoes and surfaces result in COFs of greater than 0.40 (Miller, 1983). No estimate of the reduction in slip resistance can be made globally, but the following table excerpted from a report by the British Standards Institution (1984) is provided to provide some perspective. It must be remembered that for known slippery or wet conditions, walkers normally alter their gait by decreasing stride length (thus reducing the angle of incidence between the heel and the walking surface and reducing the required level of slip resistance).

TABLE 4: SELECTED WET AND DRY COFS FOR VARIOUS SURFACE MATERIALS

Surface Material	COF (dry and unpolished)	COF (wet)
Clay tiles (Carborundum) finish)	>0.75	>0.75
Clay tiles (textured)	>0.75	0.40 to <0.75
Clay tiles (smooth)	0.40 to <0.75	0.2 to <0.40
Carpet	>0.75	0.40 to <0.75
PVC (with nonslip granules)	>0.75	0.40 to <0.75
PVC	>0.75	0.2 to <0.40
Mastic asphalt	0.40 to <0.75	0.40 to <0.75
Vinyl asbestos tiles	0.40 to <0.75	<0.40
Linoleum (untextured)	0.40 to <0.75	0.2 to <0.40
Concrete (untextured)	0.40 to <0.75	0.2 to <0.40
Terrazo	0.40 to <0.75	0.2 to <0.40
Rubber	>0.75	<0.2
Cast Iron	0.40 to <0.75	0.2 to <0.40

Slipping in the Real World

Thus far, a great deal of information has been presented relative to the mechanics of the human gait and the scientific methods available to characterize slip resistance of walking surfaces. However, it is important to depart from the laboratory for a moment and consider the nature of the interior and exterior man-made environment. One needs only to consider the wide variety of walking surfaces that exist around the world to understand that, in general, the overwhelming majority of common pavement and flooring materials are inherently slip resistant, and for centuries, man has successfully traversed roads, paths, floors, and stairs made from a variety of materials.

The most common outdoor slip-and-fall accidents reviewed by the authors typically involve a pedestrian slipping on an unsuspected patch of ice, water, or other slippery foreign substance, rather than a problem with the inherent slip-resistant characteristics of the walking surface itself. Common contaminants are:

- Ice patches formed by melting and refreezing of snow. Many states have laws that hold property owners liable for injuries resulting from an "unnatural" accumulation of ice.
- Ground surface icing (commonly referred to as "black ice"). Ground surface icing results when moist air, particularly ground fog, comes in contact with cooled surfaces, such

as road or sidewalk pavement whose temperature is below freezing.

- Oils, waxes, cleaning substances, and even water, which can significantly reduce the coefficient of friction of the walking surface material.

For interior floor surfaces, such as ceramic and vinyl tiles, concrete and stone, wood, and carpeting, slips rarely occur unless these materials are contaminated with a substance such as oil, wax, water, etc. It must be understood, however, that in some cases, surface treatments can markedly add to the coefficient of friction of the walking surfaces. Various waxes can raise the surface friction generated above that of the underlying substructure, and artificial texturing (such as is often used on marble walkway surfaces used outdoors) can have the same effect.

When a person walks on a continuous uneven or undulating surface, such as brick or cobblestone pavements, his gait will be both consciously and unconsciously adjusted to successfully traverse the surface. When an irregularity in the walking surface occurs (e.g., an unexpected change in the elevation of an otherwise level and smooth walkway), missteps and tripping (rather than slipping) can occur because the person's gait "rhythm" has been unexpectedly interrupted. Slips can normally occur when gait is not adjusted for changes in walking surface friction levels (e.g., from a normal walking surface to one covered with unseen ice or water).

Falls are the third-most-common cause of accidental death in the United States and represent almost one-fifth of both occupational and public sector injuries. Individuals who slip often pursue legal action, however, the safety profession has studied slips and falls in depth and demonstrated a floor surface may be smooth to the touch yet meet or even exceed industry standards for slip resistance.

Making a scientific assessment of the slip-resistant characteristics of walking surfaces and likelihood of an individual injuring himself on them can be a relatively straightforward task, assuming the individual attempting it has the required knowledge of human gait dynamics and the research that has been performed in the field, as well as the appropriate test equipment. There is little rationale or need for purely subjective evaluations based on erroneous assumptions, biases, or preconceptions. ■

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