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The Safety of Floor Mats on Flexible Foundations

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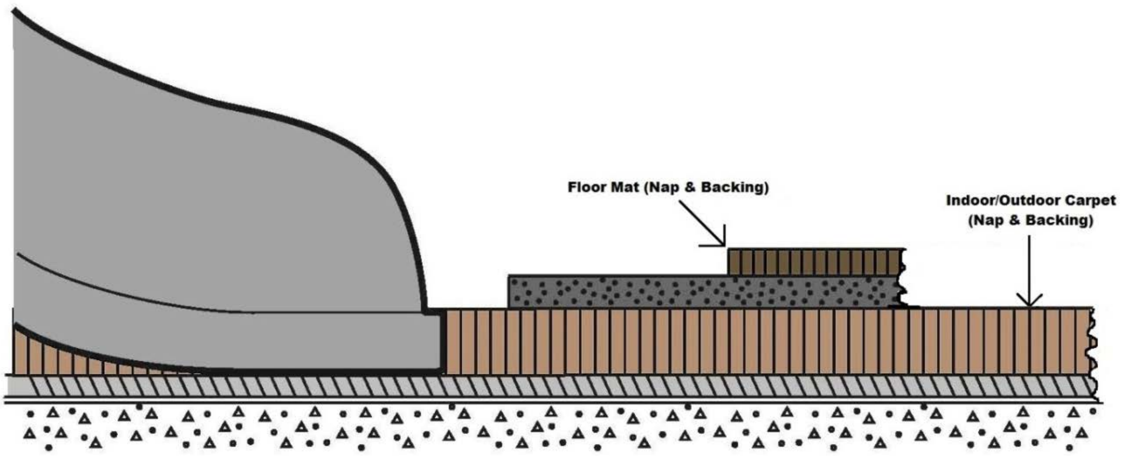
Abstract The ordinary floor mat is a ubiquitous Type V safety device; i.e. it sometimes protects you, sometimes hurts you, and sometimes makes no contribution. Its hazardous nature has been embraced by technical codes and standards and the courts have declared that an unremarkable ordinary floor mat is not unreasonably dangerous because reasonable lookout on the part of a pedestrian will abate its downside. As it turns out, these endorsements are all predicated on the notion that floor mats are supported on "rigid" surfaces such as concrete, tile, or wood. If the mat is placed on a flexible surface, such as a carpet, an unreasonably dangerous trip hazard may be formed by the carpet/mat combination. Furthermore, the hazard is open but not obvious.



Floor Mat on Carpet

Keywords: *slip and fall, trip and fall, change-in-level, open and obvious, risk utility, easily avoidable*

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1. Introduction

A heavy set senior citizen with diabetic neuropathy was visiting an orthotic clinic to pickup special boots. After fitting and training she was directed to a reception counter in the center of a fully carpeted facility to check out. In front of the counter, a perfect floor mat with an embroidered logo was placed on the indoor/outdoor carpeting. She testified that her approach to the counter was impeded when her foot encountered the edge of the mat and she tripped and fell with her wheeled walker. She and her husband noted that her boot was entangled in the mat. Her injury required brain surgery. It followed as the night the day, a negligence claim was brought against the clinic.

Before addressing the differences in the legal and technological approaches to the negligence action, a few background matters are worth presenting in this introduction.

A. Major Advantages of Floor Mats

1. Mats provide high friction resistance that can improve slippery surfaces such as polished wood floors. [National Safety Council, Data Sheet 595] [1]
2. Mats absorb water from footwear to ensure that building entrances and interior walkways are kept dry during inclement weather. [ANSI/ASSE A1264.2-2001] [2]
3. Mats help remove foreign particles and other contaminants from the bottom of pedestrian footwear that may become dangerous when tracked on floors. [ASTM 1637-95] [3]
4. Mats may reduce fatigue (ergonomics). [National Safety Council, Data Sheet 1-595-81] [1]
5. Mats reduce noise. [National Safety Council, Data Sheet 595] [1]
6. Mats reduce breakage of dropped frangible objects such as glass bottles. [National Safety Council, Data Sheet 595] [1]

All of the above cited advantages are also provided by conventional carpeting.

B. Major Disadvantages of Floor Mats

1. Tripping Hazard

"*Mats, especially lightweight types, can be torn by handling or excessive wear. The resulting loose or raised areas can catch footwear, creating tripping hazards. Mats that have been moved and not properly relaid may develop curled or raised edges, which also creates tripping hazards. Mats that are not laid flat or fastened securely may pucker, causing toes or heels to catch, leading to falls*." [NSC, Data Sheet 595] [1]

2. Slipping Hazard

"*Grease or water can make mat surfaces slippery. Also, when mats are not suited to the surfaces they cover or are laid with the wrong side down, they may slip, creating greater hazards than the surfaces they cover*." [NSC, Data Sheet 1-595-81] [1]

C. "Change in Level" - Codes and Standards

Any convex elements that protrudes from a flat surface can arrest or delay the tangential motion of footwear moving across the surface. Walking can only be achieved by falling forward. To stabilize this dynamic process, the fall must be continually interrupted by the timely positioning of the walker's trailing leg. Falling will occur if the action of the trailing leg is arrested or unduly delayed by an asperity in the surface.

Generally, taller trip elements increase the frequency of trip and falls. The safety profession treats the trip problem under the heading "change in level." Identical standards are promulgated by the following prestigious safety organizations:

ANSI...American National Standards Institute, Inc.

ICC...International Code Council

ASTM...ASTM International

NFPA...National Fire Protection Association

ADA...Department of Justice

A typical presentation of the "change in level" rules may be taken from ICC/ANSI A117.1-1998,

303 Changes in Level

303.1 General. Changes in level in floor or ground surfaces shall comply with Section 303.

303.2 Vertical. Changes in level of 1/4 inch (6 mm) high maximum shall be permitted to be vertical.

Fig. 303.2
Vertical Changes in Level

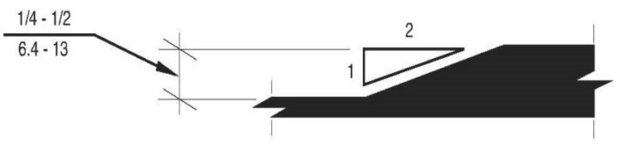

Fig. 303.3
Beveled Changes in Level

303.3. Beveled. Changes in level between 1/4 inch (6 mm) high minimum and ½ inch (13 mm) high maximum shall be beveled with a slope not steeper than 1:2.

Violations of these rules have been judged to create an unreasonably dangerous trip hazard. Note the use of the important "shall" language which makes code compliance mandatory.

D. Dangerous Safeguard Consensus

Perhaps the most unequivocal and widespread position taken in the safety literature is the admonition against the use of safeguards which introduce hazards of their own. Typical excerpts from this literature, which date from 1916, provide some insight into this philosophy. For example:

1994: "General Requirements for All Machines," 29 CFR 1910.212 (a)(2). Washington, DC, OSHA, effective August 27, 1971. [4]

"*General requirements for machine guards: Guards shall be affixed to the machine where possible and secured elsewhere if for any reason attachment to the machine is not possible. The guard shall be such that it does not offer an accident hazard in itself*."

1982: American National Standard for Machine Tools - Power Press Brakes - Safety Requirements for Construction, Care and Use, ANSI B11.3-1982. [5]

"*6.1.4.1 Point of Operation Guards. Every point-of-operation guard shall meet the following design, construction, application, and adjustment requirements*:

1) *It shall prevent entry of hands or fingers into the point of operation by their reaching through, over, under, or around the guard.*
2) *It shall, of itself, create no pinch point between itself and moving machine parts*."

1975: "Handbook of Occupational Safety and Health," Chicago, National Safety Council, 1975. [6]

"*It is a cardinal rule that safeguarding one hazard should not create an additional hazard*." p. 138.

1943: C.M. Macmillan, "Foremanship and Safety," New York, John Wiley, 1943. [7]

"*In considering a machine guard we must realize that it has to give 'tops' in protection and it must not interfere with operation. Also, care must be taken that in guarding against one hazard we do not create another*." p. 46.

The admonition not to adopt safeguards that have a safety downside applies to individual designers and manufacturers. This prohibition is specifically stated in most of the standards, codes, or statutes yet these very standards, codes, and statutes, regularly demand, recommend, or permit safety features with dangerous side effects such as automotive seat belts or "falling object protective structures" on forklifts. There is no contradiction; engineers, designers, and manufacturers are not allowed to make judgements that hurt people even when the benefits are substantial, but value systems are.

A value system is defined as "the system of established values, norms or goals existing in a society." Some of the more important ones that deal with safety issues are:

a. American National Standards Institute - A consensus value system comprised of all parties substantially concerned with the safety of a particular machine.

b. Occupational Safety and Health Administration - A government regulatory value system.
c. State Building Codes - Legislative value systems.
d. Case Law - The judicial value system.
e. Industry Practice.

E. Falls Among Older Adults

It is widely known that in the general population automobile accidents are the leading cause of traumatic deaths and the most common cause of disabling injuries. For senior citizens the statistics are even more compelling. The following excerpts are taken from the Centers for Disease Control and Prevention [8]

"*More than one third of adults 65 and older fall each year in the United States (Hornbrook et al. 1994; Hausdorff et al. 2001*). [9]

Among older adults, falls are the leading cause of injury deaths. They are also the most common cause of nonfatal injuries and hospital admissions for trauma (CDC 2005). [10]

In 2005, 15,800 people 65 and older died from injuries related to unintentional falls; about 1.8 million people 65 and older were treated in emergency departments for nonfatal injuries from falls, and more than 433,000 of these patients were hospitalized (CDC 2005). [10]

The rates of fall-related deaths among older adults rose significantly over the past decade (Stevens 2006). [11]

Twenty percent to 30% of people who fall suffer moderate to severe injuries such as bruises, hip fractures, or head traumas. These injuries can make it hard to get around and limit independent living. They also can increase the risk of early death (Alexander et al. 1992; Sterling et al. 2001). [12]

Falls are the most common cause of traumatic brain injuries, or TBI (Jager et al. 2000). In 2000, TBI accounted for 46% of fatal falls among older adults (Stevens et al. 2006). [10]

Most fractures among older adults are caused by falls (Bell et al. 2000). [13]

The most common fractures are of the spine, hip, forearm, leg, ankle, pelvis, upper arm, and hand (Scott 1990). [14]

Many people who fall, even those who are not injured, develop a fear of falling. This fear may cause them to limit their activities, leading to reduced mobility and physical fitness, and increasing their actual risk of falling (Vellas et al. 1997). [15]

In 2000, direct medical costs totaled $0.2 billion ($179 million) for fatal falls and $19 billion for nonfatal fall injuries (Stevens et al. 2006)." [11]

2. MATS

A. Ordinary Floor Mat Applications

A typical floor mat consists of a rubber base with or without nubs on the bottom surface and a nap on the top surface. As shown in Figure 1 the outside edges of a mat present a vertical obstruction of about 0.110 inches (2.79 mm), when it is mounted on a hard surface such as wood, tile or concrete. The five codes and standards cited in Section I-C imply that a "change in level" no greater than 1/4 inches (6.4 mm) is not unreasonably dangerous even though it presents a trip hazard.

Without imperfections such as puckers, snags, or curled or raised edges, it is proclaimed by the courts that a regular floor mat is open and obvious and can be safely negotiated by pedestrians who are expected to keep a proper lookout and adopt an adequate gait. For the cited accident the defense filed a motion for summary judgment that was devoid of any reference to technology. Only legal arguments were advanced to establish that an "ordinary mat" is not unreasonably dangerous. This approach failed decisively because technology is required to distinguish between an "ordinary mat" and the carpet/mat system actually involved in the plaintiff's excursion.

B. The Mat/Carpet Trip Hazard

A typical indoor/outdoor office carpet is illustrated in Figure 2. Under transient loading this carpet behaves elastically; indeed, each fabric loop comprising the nap springs erect after compressing it underfoot. The uncompressed mat/ carpet combination is depicted in Figure 3 where the mat produces a de minimis compressive load on the carpet of 0.00351 psi (0.0000242 Mpa). On the other hand, a 250 lb (1,112.06 N) man supported on the ball of his foot during ambulation may apply a compressive carpet loading of 25 psi (0.1732 Mpa).

Figure 4 illustrates a walker approaching a mat/carpet combination; his trailing foot sinks down into the carpet's nap and presses down on the backing. The resulting maximum deflection of the shoe must be added to the thickness of the leading edge of the mat to establish a "change in level" corresponding to the codes and standards presented in Section C on page 2.

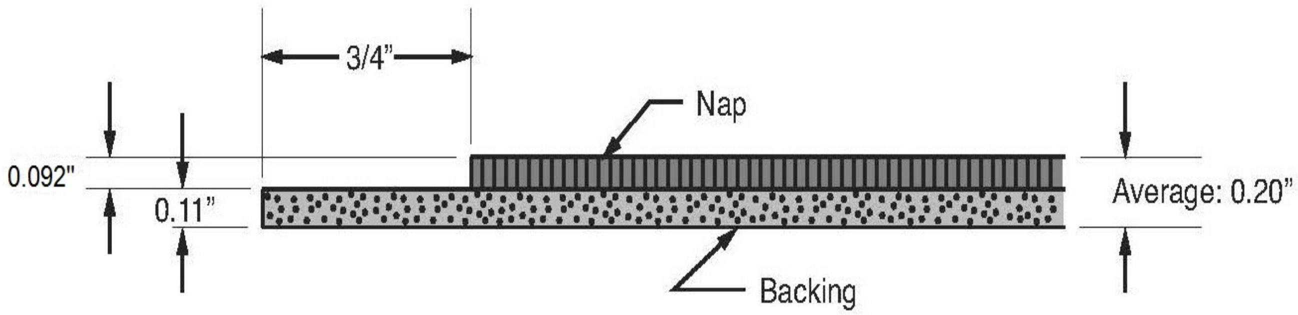

Figure 1. Typical Floor Mat

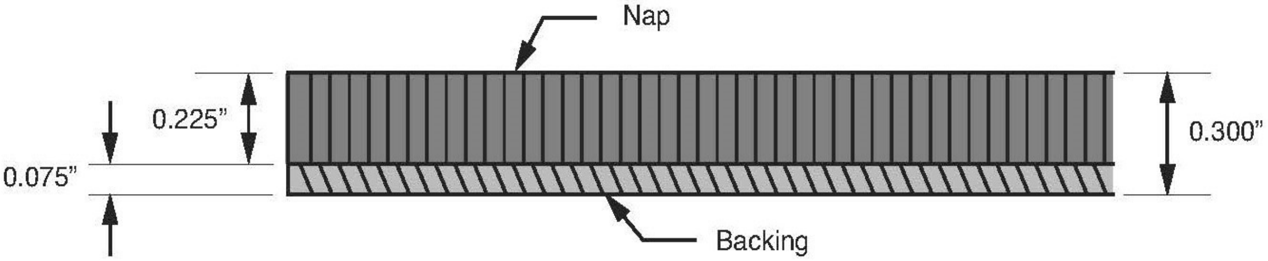

Figure 2. Typical Office Indoor/Outdoor Carpet

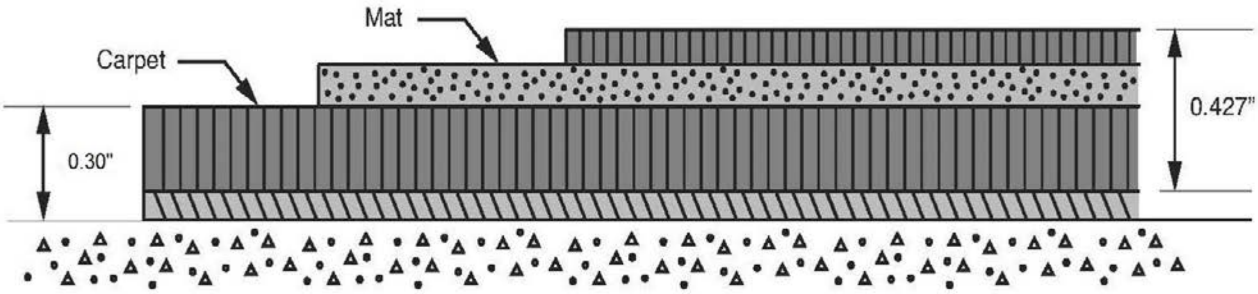

Figure 3. Uncompressed Mat/Carpet Combination

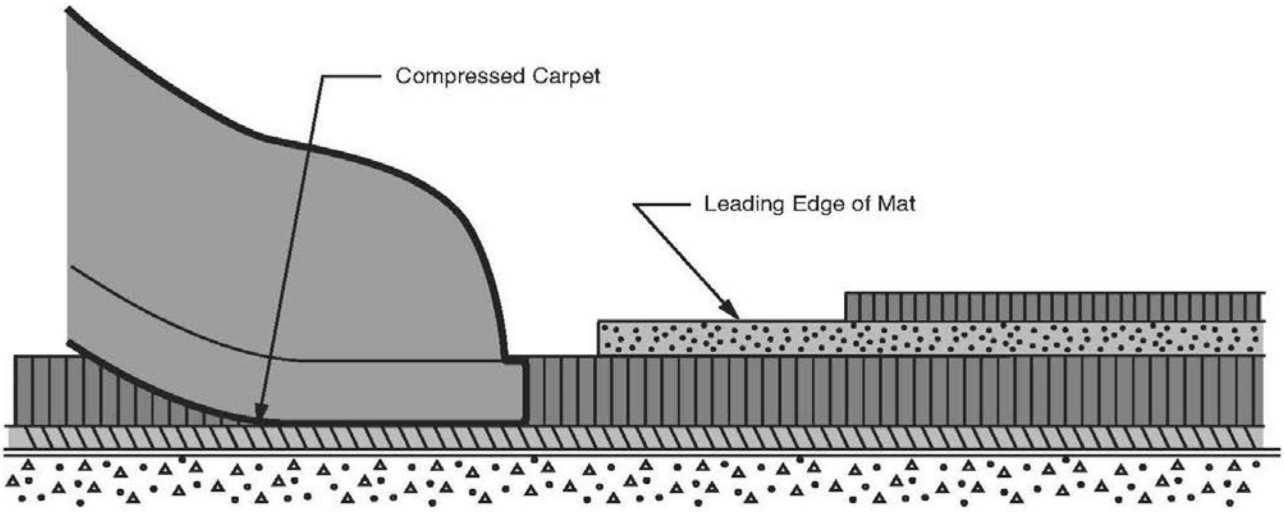

Figure 4. Compressed Mat/Carpet Combination

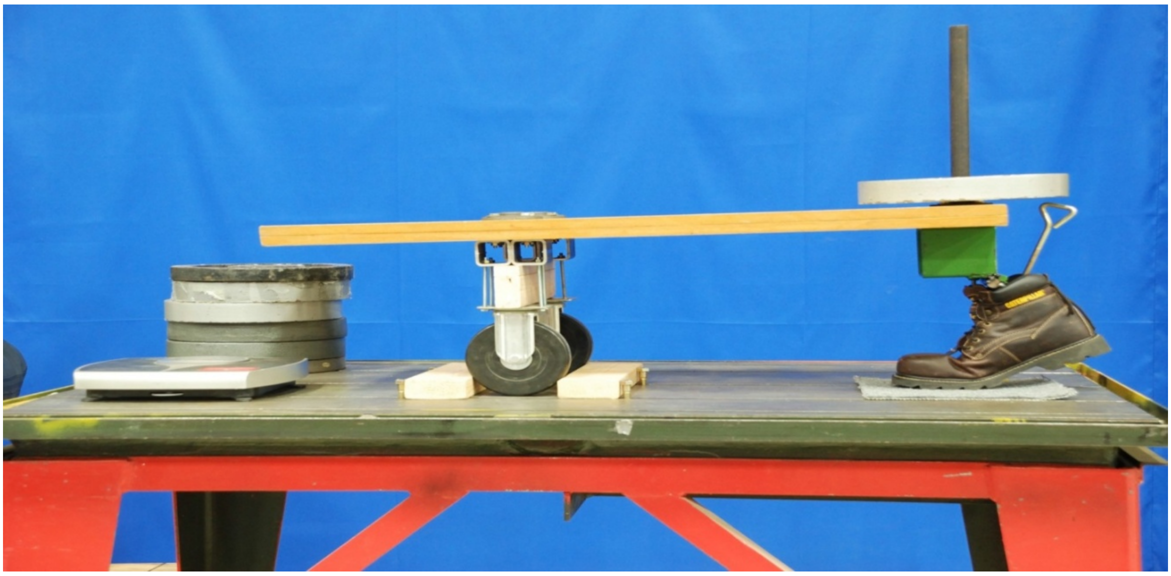

Figure 5. Shoe Jig with Lifting Weights

Table 1. "Change in Level"- 30 lb. Compression

Carpet Style	• Maximum Footwear Deflection (inches): "Defl:" • "Change In Level" (inches): "CIL"			
	Men's Work Boot	Men's Dress Shoe	Men's Gym Shoe	Women's Shoe Pointed Toe
Hot Shot II Nap 1/4 in. Backing 1/16 in (Woven)	Defl: 1/4 in CIL: 0.36 in	Defl: 1/8 in CIL: 0.235 in	Defl: 1/4 in CIL: 0.36 in	Defl: 1/4 in CIL: 0.36 in
Elevations Sky Gray Nap 3/16 in Backing: None	Defl: 3/16 in CIL: 0.2975 in	Defl: 1/8 in CIL: 0.235in	Defl: 5/32 in CIL: 0.2663 in	Defl: 1/8 in CIL: 0.235in
#362964 Nap 3/16 in Backing 1/16 in (Woven)	Defl: 3/16 in CIL: 0.2975 in	Defl: 1/8 in CIL: 0.235 in	Defl: 5/32 in CIL: 0.2663 in	Defl: 5/32 in CIL: 0.2663 in
#416855 Nap 1/8 in Backing 3/16 in (Foam)	Defl: 3/16 in CIL: 0.2975 in	Defl: 5/32 in CIL: 0.2663 in	Defl: 1/8 in CIL: 0.235 in	Defl: 1/8 in CIL: 0.235in
Smoke Haze Nap 3/8 in Backing 1/16 in (Woven)	Defl: 5/16 in CIL: 0.4225 in	Defl: 3/16 in CIL: 0.2975 in	Defl: 1/4 in CIL: 0.36 in	Defl: 5/16 in CIL: 0.4225 in

"Change in Level" = Footwear Deflection + Mat Backing Thickness (0.110 in).

Using the fixture shown in Figure 5, five different carpet samples were exposed to four shoe styles that were gravity loaded. The weight of the shoe sample, the shoe mounting fixture, and lifting weights were impressed on a scale and then on a small carpet sample. The maximum shoe deflection measured from the undisturbed nap surface was recorded in Table 1 using a total compressive force of 30 lb (13.608 kg). Fourteen of twenty tests produced a "change in level" of greater than 1/4 inch (6.35 mm) when the thickness of the leading edge of the mat, 0.110 inches (2.794 mm), was added to the maximum shoe deflection.

The remaining six deflection tests all produced a 1/8 inch (3.175 mm) deflection. These were all retested using a total compressive load of 130 lb (58.967 kg). The "change in level" of every sample exceeded the 1/4 inch (6.35 mm) threshold level. During ordinary ambulation a walker transfers his entire weight from left to right foot. The indoor/outdoor carpet samples were obtained from "box stores." The shoe samples are described in Table 1.

3. Legal Considerations

With respect to the accident scenario described in the Introduction, the defense attorneys approached the associated litigation using only legal principles; no expert witnesses were retained. The contrast between technology and jurisprudence is highlighted in this section.

A. Definition: Defect (Louisiana)

"A defect is a dangerous condition reasonably expected to cause injury to a prudent person using ordinary care under the circumstances..., a condition which presents an unreasonable risk of harm and renders the premises unreasonably dangerous in normal use. [La. Civil Code art. 2695]" [16]

This is the same historical definition of a defect taught to technologists before we were enlightened by the judicial value system. We designed for the "Expected Use" not the actual use. Today, on both a national and international level, we design for the "Reasonably Foreseeable Use" which includes reasonably foreseeable misuses (e.g. driving on under inflated tires) and reasonably foreseeable extended uses (e.g. using a screw driver as a crowbar to pry open a window). We do not design for a "prudent person."

Another safety engineering doctrine introduced by the legal system imposes a non-delegable duty on a manufacture to provide a safe design. Engineering does not forgive a trip hazard based on the notion that a proper lookout will mediate the defect.

B. Codes and Standards

Safety standards, codes, statutes, and regulations are formulated and promulgated at great expense to guide technologists in the safe design of works serving humankind. Such codifications are only developed for conditions that are reasonably foreseeable. With respect to the "change in level" problem, five sophisticated safety organizations have each endorsed the identical safety specifications in spite of fundamental differences in their scope and point of view. The NFPA is concerned with the rapid egress of personnel during a fire emergency. The ADA, which is administered by the U.S. Department of Justice, is focused on the rights of disabled citizens to accessible ambulatory facilities. Fundamental research on slip, trip, misstep, and fall technology is a principal preoccupation of ASTM. Practical safety solutions for the construction of accessible and usable buildings and facilities is the thrust of building code standards developed and administered by the International Code Council. Finally, the American National Standards is the largest developer of safety consensus standards in the U.S.

Each of these safety institutions involve large numbers of participants in their deliberations; some reach out in "round robins" to solicit large numbers of stakeholders. Their committees are usually chosen to represent all the interest groups in an industry; e.g. manufactures, builders, users, insurance companies, independent experts, trade associations, and government agencies. It is often mandated that the committees reflect the geographic makeup of the country. Additionally, the adopted standards are regularly reviewed and updated (e.g. every five to seven years).

The standards development process seeks to provide guidelines that reflect the safety value system of our society. The proposed standards are vetted to establish their technical feasibility and their economic practicability. The "shall" language in the standards conveys the message that the standards are violated if the individual requirements are not met, exceeded, or satisfied by a logical equivalence. The sole purpose of the "change in level" requirement is to establish magnitudes that are unreasonably dangerous. This notion may be expressed as follows:

- A "change in level" of any magnitude is a trip hazard.
- "Change in level" heights not greater than 1/4 inches are not unreasonably dangerous.
- "Change in level" heights greater than 1/4 inches which are not beveled are unreasonably dangerous.

Above 1/4 inches the number of trips are unacceptably high.

Some insight into the legal point of view may be derived from the following observations:

1. The specific codes and standards cited in this paper have been characterized as "less-than-scientific standards." [Reed v. Wal-Mart Stores, Inc., 97-1174, p. 4, 708 So. 2d at 364.] To make this statement one must be unaware that a scientific safety standard does not exist, that any standard must ultimately rest on a value system, and that in contrast to scientific ethics engineers are required to hold "paramount the safety — of the public in the performance of their professional duties." [17]
2. "Thus, it is clear that even when the violation of a statute is proved, such is not a substitute for proving the existence of "an unreasonable risk of harm." [Smolinski v. Taulli, 276 So. 2d 288 (La. 1973)] [18]
   "Violation of a statute or ordinance constitutes negligence. To be actionable, however, the negligence must also be a legal cause of the accident. Actionable conduct is both a cause-in- fact of the injury and the legal cause of the harm incurred. To satisfy the cause-in-fact requirement, the finder of fact must determine that the injury would not have been sustained but for the conduct of the parties' alleged negligence. To be a legal cause of the harm, there must be a "substantial" relationship between the conduct and harm incurred." [Burns v. CKL Investments, 43 So. 3d 1152 (La. 2010)] [19]
   "In determining whether the risk of harm is unreasonable, you should consider, (1) the claim and interest of the parties, (2) the probability of the risk occurring, (3) the gravity of the consequences, (4) the burden of adequate precaution [.] (5) individuals and societal right and obligation, and the social utility involved..." [Reed v. Wal-Mart Stores, Inc., 97-1174 (La. 3/4/98)] [17]
3. In a classic decision, the Louisiana Supreme Court, dealing with these same kinds of building standards, held:
   While statutory violations are not in and of themselves, definitive of civil liability, they may be guidelines for the court in determining standards of negligence by which civil liability is determined.
4. "Testimony in the form of an opinion or inference otherwise admissible is not to be excluded solely because it embraces an ultimate issue to be decided by the trier of fact." La. C.E. art. 704. But the factfinder is not necessarily bound by such opinion evidence; the factfinder may disregard expert testimony altogether. See Madere. Madere. 93-610. p. 3 (La.App. 5 Cir. 2/9/94). 632 So.2d 1180. 1182. See also Lanasa v. Harrison. 02-0026. p. 4 (La. App. 4 Cir. 8/7/02). 828 So.2d 602. 604." [20]

C. Open and Obvious

One of the most jarring legal principles confronting safety professionals is the notion that a condition cannot be unreasonably dangerous if it is open and obvious. The Louisianan Supreme Court holds in Eisenhardt v. Snook:

"We have recognized that defendants generally have no duty to protect against an open and obvious hazard. If the facts of a particular case show that the complained-of condition should be obvious to all, the condition may not be unreasonably dangerous, and the defendant may owe no duty to the plaintiff. The degree to which the danger may be observed by a potential victim is one factor in the determination of whether the condition is unreasonably dangerous. A landowner is not liable for an injury which results from a condition which should have been observed by the individual in the exercise of reasonable care, or which was as obvious to a visitor as it was to the landowner." [21]

Eisenhardt v. Snook. 08-1287. p. 6 (La.3/17/09). 8 So.3d 541. 544-545 (emphasis supplied); Blank v. Capdeville. 94- 373. p. 4 (La.App. 5 Cir. 11/16/94). 646 So.2d 1146. 1149

1. When suddenly confronted with a lion, the risk is immediately open and obvious. The declaration that this condition is not unreasonably dangerous can be disproved by reductio ad absurdum.
2. The hazards associated with most machinery are open and obvious. Nevertheless, safeguards of every stripe are called for to render them reasonably safe.
3. Whereas the hazards of mechanical contrivances are usually obvious, the probability or likelihood of contacting the hazards is generally unknown and unappreciated.
4. The Louisiana Supreme Court had proceeded to clarify their position on "open and obvious." "This much needed clarification makes it clear that summary judgment is available in (defense) cases where a condition is open and obvious and could have been avoided by the patron." Notwithstanding the clarification, a dangerous condition is not obvious unless both the hazard and the likelihood of encountering the hazard is obvious.

The ability to avoid a hazard finds various forms of expression. For example,

- "If a condition is patently obvious and easily avoidable, it cannot be considered to present an unreasonable risk of harm."
- "A condition was plainly visible, open and obvious and could have been avoided through the exercise of reasonable care."

5. The danger associated with a mat/carpet combination is open but not obvious. The dangerous "change in level" does not manifest itself when a perfect mat is supported on a carpet.
6. Safe ambulation requires multitasking. Unfortunately, people process information serially and not in parallel. Watching a walking surface continually will not reveal all the hazards that arise in the environment; e.g. bicycles operating on a sidewalk, vehicles at an intersection, obstacles such as light poles and barber poles, low hanging obstructions that guide dogs are trained to observe, and pedestrians on cell phones.
7. The "obviousness" of an asperity is compromised by congested traffic, poor lighting, and non-contrasting obstacles.
8. Footwear styles have different propensities for clearing trip hazards; e.g. ski-nose designs.
9. Forward steps are easier to monitor than rearward steps that are out of sight. The rear foot can be delayed by defects that are not previewed by the front appendage.

10. Two modes of walking are considered normal. One is vision driven and involves cognition. The other is independent of vision and proceeds with kinesthetic receptors in the muscles.

4. Closing Remarks

A. The treatment of a shoe penetrating a carpet nap falls under the category Beams On Elastic Foundations.

The technology began with E. Winkler in 1867 and is usually covered in advanced strength of materials texts such as “Strength of Materials, Part II,” S. Timoshenko, Chapter 1 [22].

B. A conventional floor mat has always passed the risk/ utility test when its advantages and downsides were compared. When a mat is placed on a carpet all of its advantages are also supplied by the carpet. Here, the mat only presents a downside; it fails the risk/utility test.

C. The standard floor mat is a safety device. When combined with a carpet it introduces a trip hazard and in most cases an unreasonably dangerous trip hazard. This violates the Dangerous Safeguard Consensus.

D. There is a major disconnect between the technology of ambulation and the law of torts. Case law does not reflect reality; furthermore, its dogmatic. The legal principles are not amenable to Daulbert-like scrutiny because they cannot be formulated into a testable hypothesis. [23]

E. The body of laws governing slip/trip/misstep and falls minimizes the fault of tortfeasors. An incentive to be fault-free is responsible for most of the progress in the field of safety. Recall that slip and fall is a leading and growing cause of death and injury.

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[18] Smolinski v. Taulli Thomas Smolinski Sr Individually and As Administrator of the Estate of his minor son Thom as Smolinksi Jr Plaintiff Appellant-Relator v Saverio Taulli Defendant-Appellee-Respondent 276 So 2d 288 Supreme Court of Louisiana N d N p n d Web 2 Dec 2015 http://scholar.google.com/scholar_case?case=6532043909035308237&q=Smolinski+suppra&hl=en.

[19] Burns v CLK Investments V LLC 10-277 (L.A. App 4 Cir 2010) 45 So 3d 1152.

[20] Madere v Madere 93-610 (L.A. App 5 Cir 1994) 632 So 2d 1180 1182.

[21] Eisenhardt v Snook 08-1287 08-1287 (L.A. 2009) 8 So 3d541 544-545.

[22] Timoshenko, Stephen. Strength of Materials Part II Advanced Theory and Problems Princeton, NJ Van Nostrand 1956 pp 1-25.

[23] William Daubert ET UX. Individual and as Guardians Ad Litem for Jason Daubert ET AL Petitioners v Merrell Dow Pharmaceuticals Inc 469 N d Print